# RESPONSE TO SUBMISSIONS

## SPRINGVALE MINE
## Springvale Mine Extension Project

State Significant Development 5594

SEPTEMBER 2014

Centennial Coal

# Springvale Mine Extension Project

# Response to Submissions

Prepared By:

**Springvale Coal Pty Limited**

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# ABBREVIATIONS

| | |
|---|---|
| ACH | Aboriginal Cultural Heritage |
| AEMR | Annual Environmental Management Report |
| ANZECC | Australian and New Zealand Conservation Council |
| AP | Angus Place |
| APC-VS2 | Angus Place Colliery Ventilation Shaft 2 |
| APC-VS3 | Angus Place Colliery Ventilation Shaft 3 |
| AQ | Aquifer |
| ARMCANZ | Agriculture and Resources Management Council of Australia and New Zealand |
| BACI | Before After Control Impact |
| BMCC | Blue Mountains City Council |
| BMCS | Blue Mountains Conservation Society |
| CCC | Community Consultative Committee |
| CMRR | Coal Mine Roof Rating |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| dBA | Decibel Noise Level |
| DEWHA | Former Commonwealth Department Environment, Water Heritage and the Arts |
| DGRs | Director General’s Requirements |
| DgS | Ditton Geological Services Pty Ltd |
| DoE | Commonwealth Department of the Environment |
| DoP | NSW Department of Planning |
| DP&E | NSW Department of Planning and Environment |
| DPI NOW | NSW Department of Primary Industries - NSW Office of Water |
| DPI – OAS&FS | NSW Department of Primary Industries – Office of Agriculture Sustainability and Food Security |
| DRE | NSW Division of Resources and Energy |
| EECs | Endangered Ecology Community |

| | |
|---|---|
| EPBC Act | Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth) |
| EIA | Environmental Impact Assessment |
| EIS | Environmental Impact Statement |
| EPA | NSW Environment Protection Agency |
| EP&A Act | Environmental Planning and Assessment Act 1979 (NSW) |
| EPL | Environmental Protection License |
| FCNSW | Forestry Corporation of NSW |
| GBMA | Greater Blue Mountains Area |
| GDE | Groundwater Dependent Ecosystem |
| GHG | Greenhouse Gas |
| GIA | Groundwater Impact Assessment |
| GPS | Global Positioning System |
| GWIA | Groundwater Impact Assessment |
| ha | Hectare |
| HCPL | Helensburgh Coal Pty Ltd |
| IESC | Commonwealth Independent Expert Scientific Committee |
| KM | Kilometre |
| KTP | Key Threatening Process |
| KVAR | Kerosene Vale Fly-ash Repository |
| LDP | Licensed Discharge Point |
| LEG | Lithgow Environment Group |
| LGA | Local Government Area |
| LW | Longwall |
| MEP | Mine Extension Project |
| ML | Megalitre |
| MOP | Mining Operations Plan |
| MSEC | Mine Subsidence Engineering Consultants Pty Ltd |
| MU | Mapping Unit |

| | |
|---|---|
| NCC | Nature Conservation Council |
| NIA | Noise Impact Assessment |
| NGER Act | National Greenhouse and Energy Reporting Act 1997 (Cmwlth) |
| NGOs | Non-Governmental Organisation |
| NPHS | Newnes Plateau Hanging Swamp |
| NPSS | Newnes Plateau Shrub Swamp |
| NPWS | NSW National Parks and Wildlife Service |
| NSW | New South Wales |
| NSW Health - NBMLHD | NSW Health – Nepean Blue Mountains Local Health District |
| NTU | Nephelometric Turbidity Units |
| OASFS | Office of Agricultural Sustainability and Food Security |
| OEH | NSW Office of Environment and Heritage |
| PA | Project Approval |
| ROM | Run of mine coal |
| POEO Act | Protection of the Environment Operations Act 1997 (NSW) |
| PRP | Pollution Reduction Program |
| PUR | Polyurethane Resin |
| REA | Reject Emplacement Area |
| RMS | NSW Roads and Maritime Services |
| RO | Reserve Osmosis |
| RPS | RPS Australia East Pty Ltd |
| SCA | Sydney Catchment Authority |
| SCSGBM | Stop Coal Seam Gas Blue Mountains |
| SDWTS | Springvale Delta Water Transfer Scheme |
| SEPP | State Environmental Planning Policy |
| SSCAD | Sawyers Swamp Creek Ash Dam |
| SSD | State Significant Development |
| SV | Springvale |
| SWIA | Surface Water Impact Assessment |

| | |
|---|---|
| TAI | The Australia Institute |
| tCO2-e | Carbon Dioxide Tonnes Equivalent |
| TEOM | Tapered Element Oscillating Microbalance |
| THPSS | Temperate Highland Peat Swamps on Sandstone |
| TMP | Traffic Management Plan |
| TSC Act | Threatened Species Conservation Act 1995 (NSW) |
| TSP | Total Suspended Particulate |
| VPA | Voluntary Planning Agreement |
| WMA | Water Management Act 2000 (NSW) |
| WMP | Water Management Plan |

# 1.0 INTRODUCTION

Springvale Mine is an existing underground coal mine producing high quality thermal coal for both domestic and international markets. It is located 15 kilometres to the northwest of the regional city of Lithgow and 120 kilometres west-northwest of Sydney in New South Wales.

Underground coal mining commenced at Springvale Mine in 1995 following the granting of Springvale's development consent (DA 11/92) on 27 July 1992, pursuant to Section 101 under Part 4 of the Environmental Planning and Assessment Act 1979. DA 11/92 and its subsequent modifications remain current and authorises the extraction of up to 4.5 million tons of run-of-mine (ROM) coal per annum at Springvale Mine. The current development consent will expire on 28 September 2014. Development consent is required to ensure Springvale Mine continues to operate beyond this date.

An Environmental Impact Statement (EIS) was submitted to NSW Planning and Environment in April 2014 for the Springvale Mine Extension Project (MEP) (the Project). The exhibition period for the EIS commenced on 12 April 2014 and ended on 26 May 2014.

The Applicant for the Project is Springvale Coal Pty Limited (Springvale Coal). Springvale Mine is owned by Centennial Springvale Pty Limited (as to 50%) and Springvale SK Kores Pty Limited (as to 50%) as participants in the Springvale unincorporated joint venture. Springvale Mine is operated by Springvale Coal, for and on behalf of, the Springvale joint venture participants.

While there has been no change to the Project from that presented in the EIS additional assessments have however been completed to support the Project which have been included in this Response to Submissions (RTS). These additional assessments include:

- A Regional Water Quality Impact Assessment to assess the impacts of the proposed increase in mine water discharge to the Coxs River catchment as a result of the closing down of the Wallerawang Power Station (**Appendix 2**);
- The establishment of Site Specific Trigger Values for licenced discharge points LDP009 (**Appendix 3**);
- An interpretive report on the EPA's Direct Toxicity Assessment of LDP009 water discharge (**Appendix 9**);
- An ecotoxicology assessment on the Coxs river and mine water discharge (**Appendix 10**);
- An assessment of the height of fracturing above the Springvale and Angus Place longwalls (**Appendix 6**); and
- The revision of the Regional Biodiversity Offset Strategy (**Appendix 4**).

## 1.1 Scope

This RTS has been prepared in accordance with section 75H(6) of the EP&A Act and considers the matters raised in submissions received by NSW Planning and Environment during the public exhibition of the EIS. This report builds on information presented in the EIS and is to be read in conjunction with the EIS.

The electronic version of the EIS can be found on the NSW Department of Planning and Environment website (http://majorprojects.planning.nsw.gov.au/index.pl?action=view_job&job_id=5594) or the Centennial Coal website (www.centennialcoal.com.au).

## 1.2 Project Overview

The Project will:

- in general, include all currently approved operations, facilities and infrastructure of the Springvale Mine, except as otherwise indicated in this EIS;
- continue to extract up to 4.5 million tonnes per annum (Mtpa) of ROM coal from the Lithgow Seam underlying the Project Application Area;
- extend the life of the mine for an additional 13 years with rehabilitation to be undertaken after this period;
- develop underground access headings and roadways from the current mining area to the east to allow access to the proposed mining areas;
- undertake secondary extraction by retreat longwall mining technique for the proposed longwalls LW416 to LW432 and LW501 to LW503 (EIS Figure 4.2);
- continue to use the existing ancillary surface facilities at the Springvale pit top;
- continue to manage the handling of ROM coal through a crusher and screening plant at the Springvale pit top, and the subsequent loading of the coal onto the existing overland conveyor system for despatch to offsite locations (EIS Section 1.8);
- continue to operate and maintain the existing ancillary surface infrastructure for ventilation, electricity, water, materials supply, and communications at the Springvale pit top and on Newnes Plateau;
- install and operate two additional dewatering bore facilities (Bores 9 and 10) on Newnes Plateau and the associated power and pipeline infrastructure, and upgrade the existing and construct two new sections of access tracks to Bores 9 and 10 facilities;
- construct a downcast ventilation borehole at the Bore 10 facility location;
- establish a services borehole area;
- continue to use the existing Springvale Delta Water Transfer Scheme (SDWTS);
- upgrade the existing SDWTS comprising construction of new sections of the trenched pipelines to increase the water delivery capacity of SDWTS from the existing 30 ML/day to up to 50 ML/day;
- manage predicted increase in mine inflows using a combination of direct water transfer to the Wallerawang Power Station, via the SDWTS, and discharge through Angus Place Colliery's licensed discharge point LDP001 and Springvale Mine's LDP009;
- continue to undertake existing and initiate new environmental monitoring programmes;

- continue exploration activities, predominantly borehole drilling to further refine the existing geological model;
- continue to operate 24 hours per day seven days per week, 52 weeks per year;
- will provide employment to a full time workforce of up to 310 employees;
- progressively rehabilitate disturbed areas at infrastructure sites no longer required for mining operations;
- undertake life-of-mine rehabilitation at the Springvale pit top and the Newnes Plateau infrastructure disturbance areas to create final landforms commensurate with the surrounding areas and the relevant zonings of the respective areas; and
- transfer the operational management and physical infrastructure regarding coal processing and distribution infrastructure to the Western Coal Services Project (when approved). The exception to this is that it will be the development consent granted in respect of the Springvale MEP (and not the development consent granted in respect of the Western Coal Services Project) which will continue to authorise the transport of up to 50,000 tonnes per annum of coal to local domestic customers by road haulage.

## 1.3 Background

In 2011, Springvale Mine and Angus Place Colliery referred (separately) longwall extraction actions to the then Department of Sustainability, Environment, Water, Population and Communities (SEWPaC, now Department of the Environment, DotE) (referred to as EPBC 2011/5949 and EPBC 2011/5952 respectively). To support these applications, a significant body of work, referred to as the Preliminary Documentation, was submitted in 2011 to SEWPaC and placed on public exhibition during the assessment process. The Preliminary Documentation included discussion on:

- The area of THPSS within the proposed mining areas, including the angle of draw;
- The cumulative impacts to THPSS resulting from past and potential mining activities, including how these activities might impact THPSS in a regional context;
- The area of habitat for listed threatened fauna species within the proposed mining areas, including the angle of draw;
- Evidence as to why alternative mining methods including bord and pillar methods, cannot be used, in particular whilst mining under THPSS;
- Information and clarification on whether water is treated prior to discharge; and
- How each operation would ensure that ecosystem health of the THPSS would remain intact, and include ensure that mining would not result in the need to implement ecological community recovery measures. This report included:
    - Information on how the impacts of mining would be assessed, including the use of appropriately scaled statistical analysis (Before-After-Control-Impact, or BACI) with a minimum of 2 years of baseline data

- A description of the predicted impacts (direct and indirect) and management mechanisms designed to ensure that predicted impacts are avoided in the first instance, where impacts are unavoidable, mitigation and remediation measures were included in the report.

- Information on the indicators of change, established trigger levels and management responses, including mitigation and remediation measures to protect THPSS.

- An independent peer review by two experts with expertise in hydrology, water quality, ecology and geomorphology of THPSS (Dr Grant Hose and Dr Kirsty Fryirs) who were approved by the Department.

In 2012, based on the information provided to the Department, these actions were conditionally approved by the Minister. The key conditions of approval for the Springvale Mine[1], relevant to this RTS, were:

1. Unless otherwise agreed by the minister in writing, longwall mining is not to be undertaken in areas directly below known **high quality** sites of temperate highland peat swamps on sandstone or within approved buffer zones (as per condition 2) If at anytime the person taking the action seeks the **minister's** agreement to vary this condition the person taking the action must demonstrate in writing that a proven technology or engineering methodology will be used for the proposed longwall mining that prevents **severe impacts** of **subsidence** on temperate highland peat swamps on sandstone, or that would allow any **severe impacts** on temperate highland peat swamps on sandstone to be remediated[2].

2. Within three months of the date of this approval, the person taking the action must submit details of proposed buffer zones around **high quality** temperate highland peat swamps on sandstone for the **minister's** approval. The buffer zones must be approved by the **minister** before mining of longwalls 416 and 417 can commence.

Throughout 2012 and 2013, Centennial undertook investigations to satisfy these conditions and in 2013 and 2014, Centennial submitted a substantial body of work to the Department of the Environment, including:

- Justification for the selection of a 26.5 degree angle of draw buffer, including background information on the buffer zone selection.

- Application to Mine within Buffer Zones, supported by three volumes of supplementary information, including nine (9) swamp case studies, and various reports on swamp geology, results of ground penetrating radar (GPR) and resistivity studies on East Wolgan Swamp, critical analysis on the different mine geometries between longwall 411 (East Wolgan Swamp impacts) and longwalls 415 to 417, geotechnical investigation into East Wolgan Swamp, and others.

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[1] There were no similar conditions for Angus Place, as the referred action was not mining directly under THPSS.

[2] **High quality** is defined as those parts of Sunnyside East and Carne West swamps marked on the relevant Appendix to the approval. **Severe impact** is defined as impacts to THPSS that indicate a long term change in swamp hydrology, water quality of flora composition. This includes fracturing of the rock strata beneath the swamp, evident through an extended (longer than that recorded in reference sites during the same period) reduction in groundwater levels. **Subsidence** is defined as any and all ground movements that result from mining. **Minister** is defined as the Minister administering the Environment Protection and Biodiversity Conservation Act 1999 and includes a delegate of the Minister.

- Various case studies on remediation measures taken to remediate impacts to swamp communities.
- Springvale Mine Temperate Highland Peat Swamps on Sandstone Monitoring and Management Plan.
- Angus Place Colliery Temperate Highland Peat Swamps on Sandstone Monitoring and Management Plan.

This body of work is extensive, comprehensive and supported by various levels of peer review. For example, both the Springvale Mine Temperate Highland Peat Swamp on Sandstone Monitoring and Management Plan and the Angus Place Colliery Temperate Highland Peat Swamps on Sandstone Monitoring and Management Plan were peer reviewed by Dr David Goldney and Dr Grant Hose. Dr Hose was an expert who had previously been approved by the Department of the Environment to peer review previous swamp reports. Dr David Goldney was the expert who had undertaken an independent investigation into the impacts of mining on swamps at Angus Place Colliery for the then Department of Environment, Water, Heritage and Arts (DEWHA).

As a result of investigations into THPSS hydrogeology and interactions with mine subsidence, changes to the mine design were made, based on reduced mining void widths and increased chain pillar widths. The changes have been made in the context of cover depths in proposed future mining areas in the vicinity of THPSS and are designed to a criterion of sub-critical panel geometry. Subsidence modelling indicates that the design changes will result is very significant reductions to total subsidence and differential subsidence movements. These changes were made specifically to reduce the environmental impacts of longwall mining under the Newnes Plateau, and demonstrate Centennial's commitment to sustainable mining practices.

Since the Interim IESC advice was issued in February 2012, and as identified above, Centennial Coal has prepared, and submitted to the Department of the Environment, numerous documents to demonstrate compliance with the conditions of EPBC approvals for Springvale Mine and Angus Place Colliery, EPBC 2011/5949 and EPBC 2011/5952 respectively. These documents are available on the Centennial Coal website, www.centenniacoal.com.au.

Based on the reports provided to it, on 21 October 2013, the Department of the Environment approved mining beneath THPSS under the terms of EPBC 2011/5949 Condition 1. The mine design approach for all future longwall mining described in the Springvale MEP EIS and the Angus Place MEP EIS in the vicinity of THPSS is consistent with that approved for longwall mining beneath THPSS by DotE under EPBC2011/5949, and is summarised below.

This body of work has been relied upon, and supplemented with additional work, for the Springvale MEP EIS and the Angus Place MEP EIS.

In undertaking this work, Centennial Coal has recognised the conservation values that the Newnes Plateau and Ben Bullen State Forest currently holds and will hold in the future following cessation of forestry and mining activities. These conservation values have been identified through consultation with a number of stakeholders and a literature review of stakeholder documentation, including:

- The Greater Blue Mountains World Heritage Area Strategic Plan (2009 to 2019)[3];
- 'Save our Swamps' documentation (2010);

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[3] A full list of references is available in the Regional Biodiversity Strategy, at **Appendix 4.**

- Review of Piezometer Monitoring Data in Newnes Plateau Shrub Swamps and their Relationship with Underground Mining in the Western Coalfield, DECCW (2010);
- Coalpac Consolidation Project Planning Assessment Commission Report, (2013);
- The Geoheritage and Geomorphology of the Sandstone Pagodas of the North-western Blue Mountains region (NSW), Washington et al, (2011);
- The Gardens of Stone Park Proposal: Stage 2, the Western Escarpment, Airly-Genowlan Mesa, Newnes Plateau and related Crown lands, (2005)[4];
- The Impact of Coal Mining on the Gardens of Stone, Colong Foundation for Wilderness, (2010); and
- Alteration of Habitat Following Subsidence due to Longwall Mining – Key Threatening Process Listing, Office of Environment and Heritage, (2005).

This review identified the common theme and desire to protect, conserve, preserve and rehabilitate the environmental values of the Newnes Plateau for recreation and tourism purposes. This includes consideration of:

- Threats to conservation values that include (but are not limited to) fire, pests and weeds;
- Methods to establish the health status of swamp communities to guide management decisions, as discussed in Chapter 10.3 of the EIS;
- Impacts of mine water discharge on swamp communities, as discussed in Chapter 2 and Chapter 8 of the EIS;
- Value of pagoda systems that occur within the Banks Wall and Burra Moko Head Sandstones, as discussed in Chapter 2 and Chapter 10.1 of the EIS[5];
- Impacts of mining related activities to areas with potential conservation value, including construction of access roads and utility corridors, historical cliff collapses, potential changes to hydrology; as discussed in Chapter 2 and Chapter 10.1, 10.2 and 10.3 of the EIS;
- Support by Centennial Coal Company Ltd for the reservation of Mugii Murum-ban State Conservation Area in a State Conservation Area in 2011;
- A heritage assessment for the Mount Airly Oil Shale Ruins, completed by Centennial Airly Pty Ltd in 2013;

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[4] Including *The Gardens of Stone Park Proposal Stage Two Illustrated: A proposal to extend the Gardens of Stone and Blue Mountains National Parks and create a Gardens of Stone Conservation Area and a Western Escarpment State Conservation Area*, Blue Mountains Conservation Society and the Colong Foundation for Wilderness, 2005.

*Seeing the Gardens…the other Blue Mountains: Nature based tourism and recreation in the Gardens of Stone Stage Two Park Proposal*, Blue Mountains Conservation Society and the Colong Foundation for Wilderness, 2009

[5] The EIS refers to the Environmental Impact Statement of the Springvale Mine Extension Project and the Angus Place Colliery Extension Project, unless specified otherwise.

- A heritage assessment of the St Johns Church, Wallerawang, completed as part of the Lidsdale Siding Upgrade Project;

- Discharge of water away from the World Heritage Area and reuse of water for industrial purposes, as discussed in Chapter 10.2 of the EIS;

- Subsidence protection zones whilst maintaining economically viable operations, as discussed in Chapter 8 of the EIS;

- Collection of real time and relevant data to inform understanding of the biodiversity and geo-diversity values, as discussed in Chapter 2 and Chapter 10 and 10 of the EIS;

- Management and monitoring of underground mining operations to achieve predicted height of fracturing, thereby minimising to the greatest extent possible surface related impacts, as discussed in Chapter 2 and Chapter 8 of the Springvale Mine Extension Project EIS and the Angus Place Mine Extension Project EIS; and

- Recognition of the geo-diversity of pagoda systems and avoidance of impacts to these systems within the EIS (Chapter 8).

By taking into consideration the measures identified above, the conservation values of the Newnes Plateau, and the Ben Bullen State Forest, and the management strategies to avoid and mitigate impacts, the mining operations at Angus Place and Springvale can be managed to achieve a future conservation outcome.

On 7th August 2014, the Independent Expert Scientific Committee (IESC) released three reports on Temperate Highland Peat Swamps on Sandstone (THPSS). These reports were commissioned in 2012 by the then Interim Independent Expert Scientific Committee in response to advice sought by SEWPaC on the referrals described above. The Interim IESC advice concluded that:

*Given the likelihood that further longwall developments will be proposed in areas containing the listed endangered ecological community, the Interim Committee agreed that it would seek approval from the Minister to commission a program of independent research into issues such as: the capacity to predict subsidence-related impacts on peat swamps from longwall mining; mitigation and remediation techniques, including self-amelioration; the hydrological and hydrogeological characteristics of the temperate highland peat swamps on sandstone community; and the relationship of the orientation and dimensions of longwall mine plans to potential subsidence risk.*

These reports are:

- Temperate Highland Peat Swamps on Sandstone: longwall mining engineering design – subsidence prediction, buffer distances and mine design options, knowledge report (Coffey Geotechnics).

- Temperate Highland Peat Swamps on Sandstone: ecological characteristics, sensitivities to change, and monitoring and reporting techniques, knowledge report (Jacobs SKM).

- Temperate Highland Peat Swamps on Sandstone: evaluation of mitigation and remediation techniques, knowledge report (University of New South Wales).

The reports were heavily referenced in the advice provided by the IESC on the Springvale MEP and the Angus Plce MEP on the 25 August 2014.

At the request of the Department of Planning and Environment, Centennial Coal has prepared a response, supported by further technical assessment by subsidence and hydrogeological experts, to the three reports produced by the IESC. This response is included in **Appendix 13**, **Appendix 14** and

**Appendix 15**. Responses to the comments raised by the IESC in the advice of 25 August 2014 are included in this RTS.

In general the IESC Reports:

- Do not consider all of the relevant publicly available information in developing arguments about the effects of longwall mining on Temperate Highland Peat Swamps on Sandstone communities (THPSS).

- Where publicly available data has been used in the preparation of the reports certain data has been excluded where it does not support the position argued in the IESC reports.

- Certain reference sources cited in the IESC report contain material which is not based on data and is biased against coal mining.

As noted above, Centennial Coal has invested substantial time and resources into meeting, and exceeding, its compliance obligations under existing approvals, and will continue to do so in the future. Centennial Coal has done this in five broad areas:

1. Investigation of impacts to THPSS, namely East Wolgan Swamp and the consequent Enforceable Undertaking entered into in 2011;

2. Development of an adaptive management framework and response, following the conclusion of investigations;

3. Comprehensive analysis and review of the mine design at both the Springvale and Angus Place operations;

4. Further analysis and review of the potential for impacts to THPSS; and

5. Investigation into the potential impacts of water discharged from the underground mining operations on the receiving environment.

These areas are discussed further below, and are comprehensively addressed in the Springvale MEP EIS, the Angus Place MEP EIS and **Section 3.1.14** of this RTS.

### 1.3.1 Investigating Impacts to THPSS

Centennial acknowledged in Chapter 2 and Chapter 8 of the Springvale MEP EIS and the Angus Place MEP EIS that longwall mining has caused impacts to certain THPSS, however, as identified in these documents, this has not been the case in all instances.

Chapter 2 of both the Springvale MEP EIS and the Angus Place MEP EIS acknowledged that subsidence impacts to swamp hydrology have been noted at two swamps (Kangaroo Creek Swamp and East Wolgan Swamp). Where impacts to certain THPSS on the Newnes Plateau have occurred, Centennial has conducted extensive research to understand the causes of the impacts. Centennial has used the findings of the research to avoid and mitigate both past and future impacts of longwall mining and related activities to THPSS on the Newnes Plateau.

Extensive research and investigation, lead primarily by work commissioned by the then DEWHA (the Goldney 2010 Report), has shown that impacts to THPSS on the Newnes Plateau have been caused primarily by:

- Licenced discharge of mine water through THPSS; and
- Changes to swamp hydrology caused by cracking of rock substrate beneath THPSS as a result of mine subsidence.

The Goldney 2010 Report found that *the principal cause of impacts* to East Wolgan Swamp and Narrow Swamp was water discharged from the underground mining operations. This finding has been reinforced by research conducted by the University of Queensland, most recently an ACARP report published in July 2014 on monitoring upland swamps the subject of mine subsidence using high resolution imagery. As a result of the finding, Centennial has not discharged mine water through THPSS on the Newnes Plateau since 2010 and is committed to managing mine water through the Water Transfer Scheme (WTS), which transfers mine water off the Newnes Plateau. The finding of major impacts caused by mine water discharge is not acknowledged in the IESC Reports. Further, neither these reports (the Goldney 2010 Report and the University of Queensland research), nor Centennial's response to the findings, have been referenced in the IESC Reports.

Following completion of the DEWHA investigation and the Goldney 2010 Report, in November 2011, Centennial (through its Joint Venture) and the Minister for the Environment entered into an Enforceable Undertaking under section 486DA of the Environment Protection and Biodiversity Conservation Act 1999. Under this Enforceable Undertaking, the Joint Venture entered into a research agreement with the Australian National University to undertake a comprehensive research program into THPSS[6].

It should be noted that within the Enforceable Undertaking, Centennial did not concede to breaching the EPBC Act, however, acknowledged that the Minister considered that the actions taken by Angus Place Colliery and Springvale Mine has resulted in a significant impact to THPSS, specifically, Narrow Swamp, Junction Swamp and East Wolgan Swamp.

More detail on the investigations undertaken by Centennial Coal into the impacts to THPSS is included in Chapter 2 of the Springvale EP EIS and Chapter 2 of the Angus Place MEP EIS and within this RTS at **Appendix 13**, **Appendix 14** and **Appendix 15**, including:

- case studies on all swamps mined under at both Angus Place and Springvale;
- The role of high flow through swamps, in particular, water discharged from underground mining operations;
- The role of major geological fault structures;
- How the longwall orientation and in-situ stress direction/magnitude affects the expression of surface subsidence; and
- The importance of mine design criteria, in particular the use of sub-critical width longwall panels, to reduce the height of continuous fracturing above the longwall.

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[6] It should be noted that in this report, a reference to the federally listed endangered ecological community Temperate Highland Peat Swamps on Sandstone, includes a reference to the State listed endangered ecological communities incorporating the Newnes Plateau Shrub Swamps and Newnes Plateau Hanging Swamps. The extent to which these communities have been described under these listings is discussed further in response to the IESC Report on ecological characteristics of THPSS.

### 1.3.2 Adaptive Management Framework

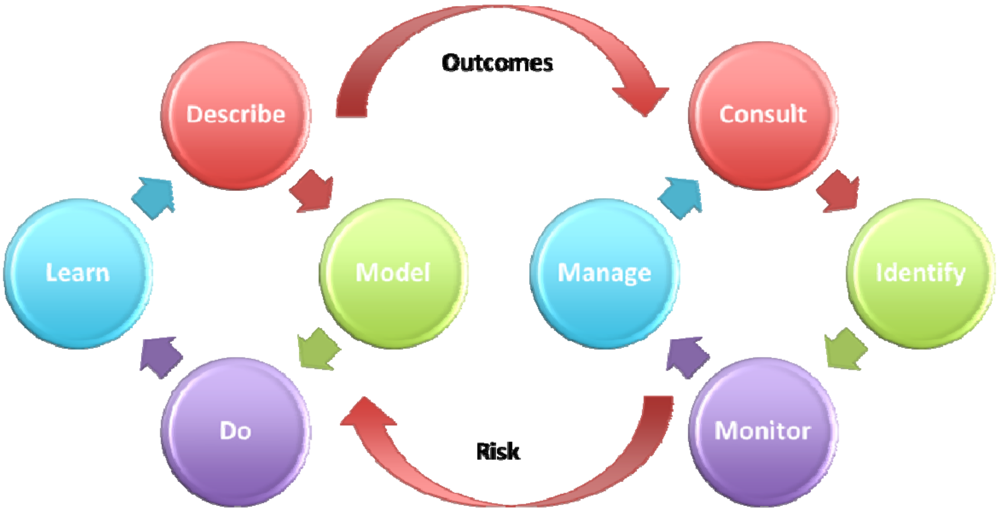
Environmental systems are dynamic and can change through environmental conditions and management actions. Within ecological systems, environmental variation carries an inherent level of uncertainty in the ability to isolate the natural variables that might lead to significant changes. Compounding this, management decisions and expectations can vary over time and can directly and indirectly influence the way environmental systems respond to change.

Uncertainty in natural systems needs to be accounted for in any adaptive management framework, and can include, amongst other things, the inherent environmental variation found in natural systems and the uncertainty around resource definition.

To account for this uncertainty, adaptive management is the structured process of learning through doing, and adapting based on what is learned (Williams, 2011). Williams (2011) suggests that the National Research Council (2004) definition of adaptive management provided a clear understanding of the intent behind an adaptive management framework, notably, one of flexible decision making, adjusted to consider uncertainties, as management outcomes are understood. Monitoring of these outcomes is essential to both scientific understanding as well as iterative management decision making.

Within the Springvale MEP EIS and the Angus Place MEP EIS, new information and the use of new, improved technology have informed Centennial Coal's decision to modify its mine design criteria, currently adopted for Longwall 415 to 417 at Springvale Mine. The outcomes of the information collected from previous longwalls and the longwalls 415 to 417 has been used to inform the mine design used for the Springvale MEP EIS and the Angus Place MEP EIS.

Following the significant body of work undertaken to gain approval under the EPBC Act for the Springvale Mine and Angus Place Colliery described above, in 2012, Centennial Coal commenced a process of establishing an Adaptive Management Framework to each environmental value being assessed through the environmental impact assessment process. This framework consisted of the traditional adaptive management model, complemented by management outcomes, as identified below:



The Framework relies on:

- A description of the environmental value and its role in the landscape, including the aspects of the Project that might result in a significant impact to the environmental value (noting that not all aspects of a project will generate impacts, and that not all aspects of a project will result in a significant impact).

- A model of the environmental response to certain management actions/decisions, supported by the description of the environment, with clearly articulated assumptions.

- Mechanisms to test the model, including the use of sensitivity analyses (where appropriate), and validation of the model with actual data collected (in Centennial's case, this might be site specific data or regional data used where this type of data would add to model interpretation and understanding).

- Engagement with relevant stakeholders in the description of the environment and the development of models, model outcomes and management actions/decisions.

- Identification of clear management objectives for each environmental value.

- Monitoring the system using best available technologies and multiple lines of evidence, to evaluate progress against objectives, determine the status of the system, increase our understanding of the system and the potential impacts to it, and to refine the modelling used to underpin the impact assessment.

- Selection of appropriate management actions, taking into consideration risk, costs, benefits, consequences to resource development and the potential for/likelihood of system recovery.

The outcomes of the framework are reported to relevant stakeholders, with mitigation and remediation actions applied, if required. The whole process is an ongoing system of testing, learning, monitoring and managing. Environmental responses are monitored using multiple lines of evidence to establish threshold criteria against which impacts can be measured. Threshold criteria are based on the environmental response to a range of parameters that, when combined, may result in an undesirable or significant impact. To support this approach, each technical assessment, therefore, within the Springvale MEP EIS and the Angus Place MEP EIS has:

- described the existing environment and included any assumptions/interpretations that were used,

- tested the assessment through predictions of impact that have been subject to sensitivity, validated (using existing data) and/or monitored to evaluate the assessment's effectiveness, and

- provided for the outcomes of monitoring to be analysed against the predictions to understand/refine/modify the assessment and/or the project.

The outcomes derived from the Framework and supporting technical assessments are translated into management plans and/or management commitments.

An example of this adaptive management approach in practice within Centennial Coal was the management of *Persoonia hindii* on the Newnes Plateau following approval of the Springvale Bore 8 Project and the Angus Place Ventilation Facility Project. Both projects were approved to clear 93 and 1269 *P. hindii* respectively. By adopting a management strategy that included maximising avoidance of this threatened species, no plants were removed for the Bore 8 Project and 91 were removed for the Ventilation Facility Project, a reduction of 94%.

The Springvale MEP EIS and the Angus Place MEP EIS included the outcomes of this in several key specialist studies and commitments. These are described further below.

The Adaptive Management Framework is a triple bottom line framework in that, as well as the environmental consequences of the project, it includes consideration of socio-economic impacts and benefits, the costs of these on local and regional communities and the residual consequences of net impacts/benefits on local and regional economies. These assessments include the costs and benefits of the management commitments made within the EIS, and allows for monitoring of the social response to these management actions in the implementation and operational stages of the Projects. As an example of this, further analysis is included Chapter 6 of the Springvale MEP EIS and the Angus Place MEP EIS.

The Centennial Coal Adaptive Management Framework is underpinned by risk. Several risk assessments have been undertaken throughout the development of the Projects to establish a risk profile and ensure that adequate management controls were identified and implemented such that risk and uncertainty could be reduced. Whilst not exhaustive, the key risk areas for the Springval MEP and the Angus Place MEP are:

- Mine design, and its associated subsidence effects resulting in significant or unexpected environmental and social consequences.
- Impacts to State and Federally listed groundwater dependent ecosystems, namely THPSS.
- Impacts to ecosystems of the Upper and Lower Coxs River from water discharges, including impacts to the Sydney Drinking Water Catchment.

As these key risk areas have also been identified by the IESC and the questions presented to that Committee by the joint submission from the Department of Planning and Environment and the Department of the Environment, generalised consideration of these has been included in this section of the RTS. The specific issues raised in submissions on these risk areas are dealt with under **Section 3.1.14** of this RTS.

Other impacts and benefits, including amenity, traffic and agricultural suitability are dealt with individually within this RTS.

### 1.3.3 Mine Design

Underground mining at the Angus Place Colliery commenced in 1979, whilst underground mining at the Springvale Mine commenced in 1993. Monitoring of the environment on the Newnes Plateau substantially commenced in 2002. Monitoring of the underground mining conditions has been ongoing since the mining operations commenced.

Monitoring data is collected using a range of techniques as detailed below.

| Monitored Parameter | Methodology Used |
|---|---|
| Geological and geotechnical constraints | Landsat photo imagery interpretation<br>Aerial photo interpretation<br>Aeromagnetic data interpretation<br>Surface lineament trends<br>Geological mapping<br>Geotechnical mapping<br>Extensometer data trends (including the use of underground telltales)<br>Longwall support hydraulic pressure trends<br>Internal reports on underground mining conditions<br>Exploration borehole data (cores, geophysical |

| | |
|---|---|
| | logging) |
| Surface water (commenced in 2002) | Flow gauges |
| Groundwater (commenced in 2002) | Standpipe piezometers<br>Vibrating wire piezometers |
| Ecology (commenced in 2003) | Unmanned aerial vehicle surveys<br>LiDAR<br>Ground truthing using quadrats/transects<br>Standpipe piezometers<br>Ecotoxicology testing |
| Subsidence (ongoing since 1995) | LiDAR<br>Subsidence lines |

As detailed in Chapter 2 and Chapter 8 of the Springvale MEP EIS and the Angus Place MEP EIS, this data is analysed to establish the extent to which geological and geotechnical factors can influence subsidence outcomes on sensitive surface features. By adopting these multiple lines of evidence, changes that occur at one location in space can be placed into the context of the surrounding environment.

As described in Chapter 8 of the Springvale MEP EIS and the Angus Place MEP EIS, both the Angus Place Colliery and the Springvale Mine have had a history of difficult geotechnical conditions. Due to these conditions, significant effort has been expended on understanding the underground mining conditions that could result in roof failures, thereby placing personnel and equipment at risk.

Roof conditions are generally poorest where major geological structures are present within the mined seam and high vertical and horizontal stresses occur. Coincident with this, surface expression of subsidence is greatest when geological structures have strong surface expression (typically as deep valleys/gorges) and, in the case of Springvale Mine and Angus Place Colliery, are recognised as basement faults from aeromagnetic data.

A review of subsidence results for all extracted longwalls at Springvale Mine show increases in subsidence above the last six longwalls extracted (LW410 to LW415) as compared to the first ten longwalls (LW1, LW401 to LW409.

Springvale Mine has used width-to-depth ratios to inform future mine design as they are the most important predictors of subsidence behaviour. The ratio is expressed as the longwall void width divided by the depth of cover of strata above the seam. The subsidence effects of these ratios are summarised as follows:

- Subcritical longwall panels are deeper than they are wide ($W/H < 0.9$) and cause lower magnitudes of subsidence than shallower panels due to natural arching of the overburden across the extracted coal seam.

- Critical longwall panels that are almost as deep (H) as they are wide (W) (i.e. $0.9 < W/H < 1.4$) and is the point where yielding of the overburden starts to occur and maximum subsidence is likely to develop if the panel widths are increased.

- Supercritical longwall panels are not as deep (H) as they are wide (W) (i.e. W/H > 1.4) and will cause complete yielding of the overburden and maximum subsidence that is proportional to the mining height (up to 60% of the mined seam thickness).

The measured maximum subsidence above the longwalls LW410 – LW415 with 315 m void widths was higher than the earlier panels (LW1 and LW401 to LW409) where void width ranged from 254 m to 266 m and depths of cover between 300 – 400 m. This placed the wider longwall panels outside the sub-critical range, resulting in surface expression of subsidence effects (as described in Section 2.6.2 and Section 8.2.1).

An analysis of the sensitivity of void widths at Springvale Mine identified that:

- marginal subsidence reductions would occur for longwall void widths between 150 m and 260 m and that the greatest reductions can be made from 315 m to 260 m; and

- marginal strain reduction would occur for widths between 150 m and 260 m and that the greatest reduction can be made from 315 m to 260 m.

The relevance of the Springvale Mine experience is that the previously mined narrower sub-critical longwalls had significantly less subsidence than the wider, critical longwalls that contributed to unpredicted environmental consequences above Springvale Mine. The mine design consequence is that narrower panels (261 m void width) are proven to minimise impacts on sensitive surface features.

For both the Springvale Mine Extension Project and the Angus Place Mine Extension Project, Centennial Coal has implemented a management strategy to avoid or minimise the impacts to sensitive surface features:

1. Avoid mining under the sensitive surface feature; or

2. Where avoidance is not possible, mine design under the sensitive surface feature has a sub-critical void width.

A sub-critical void width of 261 metres with chain pillars at least 55 metres wide will be implemented at Springvale Mine for longwalls 416 to 431.

Variable sub-critical void widths will be implemented at the Angus Place Colliery, as the majority of sensitive surface features have been avoided.

Of critical importance to the sub-critical void width is the subsequent management of the continuous height of fracturing as a result of this mine design change. A significant body of work undertaken over the last 40 years on the issue of hydraulic connection and underground mining has been used as evidentiary input into the height of fracturing model undertaken by DgS (2014) for the Springvale MEP and Angus Place MEP. Reference to work undertaken by Holla (1987, 1989, 1991), Mills and O'Grady (1998), Gale (2008) and Mills (2011), amongst others, was included in the peer review of the DgS model undertaken by MSEC (2014). Research published by the Australian Coal Association Research Program (ACARP) and undertaken by CSIRO (2007) (ACARP C14033) and SCT (2008) (ACARP C13013) highlights that the impact of mining induced fractures depends on a complex combination of the mining geometry and the lithology and geology of the overburden strata.

This conclusion contracts significantly with that of Tammetta (2014) and the IESC Reports. Notably, these reports ignore the work of DgS, considered by several peer reviewers as a superior model due to its basis in geotechnical theory, alignment with Australian conditions and inclusion of geology. Further comparison between the Tammetta Model and the DgS Model can be found in **Appendix 6**.

This approach has avoided direct impacts to 97% of cliffs and pagodas, 5 shrub swamps (and numerous hanging swamps), all major water courses (including Carne Creek and Wolgan River) and all but four (4) aboriginal archaeology sites. Centennial acknowledges that indirect impacts, particularly to

THPSS and the tributaries of major watercourses, have the potential to occur within the Springvale MEP and Angus Place MEP Project Application Areas, and beyond. These indirect impacts have been considered in detail within the respective subsections of Chapter 10 of each EIS, and further detailed in specific responses in this RTS.

All documentation supporting this research, investigations and outcomes is available on the Centennial Coal website, www.centennialcoal.com.au.

### 1.3.4 Impacts to State and Federally Listed Endangered Ecological Communities

Centennial Coal has acknowledged the importance of the THPSS in the landscape. Research conducted over the last 5 years (2009 to 2014) by the University of Queensland has worked towards quantifying the nature and extent of the community across the Newnes Plateau. Further work undertaken through the Enforceable Undertaking has been targeted towards:

- The nature and extent of THPSS;
- THPSS water balances;
- Functionality of swamps;
- Environmental history and origins;
- Ecology/biodiversity of major structural species;
- Contribution to the landscape;
- Condition status/mapping;
- Monitoring of selected reference sites; and
- Thresholds for recovery.

The University of Queensland is currently conducting research on communities identified as temperate treeless palustrine swamps in a 268 square kilometre area which includes the Newnes Plateau. Based on publicly available combined mapping from the temperate zone of New South Wales and manual interpretation of the numerous vegetation classifications used, a region containing more than 1000 shrub swamp communities per degree of latitude/longitude was identified which contained the communities mapped as Newnes Plateau shrub swamps. A report based on the research will be published and finalised in 2014.

In 2010, the University of Queensland, via funding from the Australian Coal Association Research Program (ACARP) commenced an investigation into the potential of small unmanned aerial vehicle (UAV) platforms to capture imagery of THPSS. The purpose of the research was to establish whether this technology could be used to develop monitoring tools for detecting change in condition and composition of THPSS communities that may then be correlated to potential impacts from underground mining. The project was successful in generating multi-spectral orthophoto mosaics with resolutions of less than 10 centimetres, resulting in greater coverage of THPSS communities in remote and difficult to access locations. The ACARP report was published in September 2014.

Ultimately, it is the swamp condition and health that will determine whether there has been a significant impact. To assist in understanding how to establish impacts, the University of Queensland have developed a Monitoring Handbook, titled Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps (2014). This Monitoring Handbook identifies that there are three environmental factors with affect floristics (1) geology, through subsidence responses, (2) hydrology (including water quality, groundwater level, flow and infiltration) and (3) flora composition and condition. The Monitoring Handbook identifies performance indicators for vegetation monitoring that take into consideration these factors and their effects on swamp health. Three trigger levels have been established and will be used to determine impacts, when measured against a baseline:

- Reduction in live vegetation cover of more than 20% within the community, compared with baseline data;
- A single patch of non-vegetative cover greater than 400m$^2$ doubles in size compared with baseline data; and
- A significant increase in exotic species cover compared with the baseline data.

The Monitoring Handbook includes a statistically valid sampling design capable of recording change as a result of exceedance of these triggers.

Chapter 2 of the Springvale MEP EIS and the Angus Place MEP EIS describes in detail the research and monitoring outcomes that have been undertaken by Centennial Coal on THPSS of the Newnes Plateau since 2002.This body of data, complemented by a specific exploration drilling program conducted in 2011 and 2012 (incorporating 17 fully cored holes and analysis of a further 84 existing exploration holes with geophysical data) has confirmed a number of assumptions regarding the formation of THPSS, including:

- There are over 3200 THPSS in the Blue Mountains and Southern Highlands, forming over 15000 years ago, and ranging in size from 400m$^2$ to 42 hectares (Fryirs, 2013).
- Geology plays a critical role in the formation of swamps, as evidenced by the comprehensive exploration program of the upper geological sequence.
- THPSS typically form where aquitards within the Burralow Formation (highest geological unit on the Newnes Plateau) direct groundwater flow laterally into incised valleys and gorges.
- The YS4 (SP4 in CSIRO COSFLOW Model) aquitard within the Burralow Formation plays a significant role in separating the upper and lower perched aquifers on the Newnes Plateau and is the aquitard above which most THPSS form.
- The thicker the Burralow Formation, the larger the THPSS.
- THPSS also form within the Banks Wall Sandstone, below the Burralow Formation, however, these swamps are generally narrower and less extensive than those that form within the Burralow Formation.
- THPSS have variable hydrology, ranging from periodically waterlogged in the upper reaches and permanently waterlogged in the lower reaches.
- Vegetation characteristics of THPSS[7] are closely associated with local hydrology, meaning that the vegetation within a swamp can be as diverse and the vegetation between swamps.

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[7] The State listed Newnes Plateau Shrub Swamps (NPSS, MU50) and Newnes Plateau Hanging Swamps (NPHS, MU51) were described in the 2006 listing as low dense fern-dominated communities usually perched on a hillside with few

- The difference in pre and post mining groundwater levels are attributable to near surface aquitards of the Burralow Formation as evidenced through the calibration and validation pf piezometric data.

- Measured strains at Springvale and Angus Place have been in excess of 0.5mm/m tensile and 2mm/m compressive, without causing measurable impacts to groundwater levels in THPSS.

- Impacts to THPSS have occurred where measured strains have been above 5mm/m tensile and 10mm/m compressive, which has occurred only where longwall panel width is in the critical range.

- Swamp water level fluctuations show a strong correlation to the cumulative rainfall deviation and no relationship to longwall mining.

- Water discharged from underground mining operations is the primary contributing factor to mining related impacts on THPSS.

- There is no evidence of severe impacts to THPSS health as a result of mining related subsidence.

A comprehensive analysis of the impacts of mining on THPSS of the Newnes Plateau was included in Chapter 2 of the Springvale MEP EIS and the Angus Place MEP EIS, and has been detailed further in response to the IESC Reports at **Appendix 13**, **Appendix 14** and **Appendix 15**. Specifically, a number of factors must occur together in order for a mining related impact to manifest within THPSS. These are detailed in Chapter 2 of the Springvale MEP EIS and the Angi Place MEP EIS, and are further discussed in **Section 3.2.7** of this RTS. In summary:

- Prolonged surface flows at rates of up to 12Ml/day (in the case of impacts to East Wolgan Swamp, this was through licensed discharge from the underground mining operations);

- intersection of major geological fault structures;

- orientation of the longwall panel sub-parallel to the major structures;

- steepness and depth of the valley within which the swamp occurs;

- prevailing in-situ stress direction and magnitude (for example, Springvale longwalls sub-perpendicular to principal horizontal stress direction);

- critical width longwall panel design;

- location of the geological structure close to the permanent barrier pillar; and

- interaction of adjacent mine workings and subsidence effects due to close proximity.

Removing any one of these factors will reduce the likelihood and severity of mining related impacts on THPSS. Through the removal of two of these factors, prolonged surface flows through licensed discharge and implementation of sub-critical longwall panel design, the likelihood and severity of impacts on THPSS is reduced to negligible.

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trees present and are groundwater dependent. The listing for NPHS was based on two sites, the listing for NPSS was based on seven sites.

Centennial's investment in understanding the nature, extent, occurrence and functionality of THPSS has spanned over a decade and run into many millions of dollars. This has resulted in a high level of confidence in the modelled outcomes, management actions and mitigation strategies adopted and implemented at both the Springvale Mine and Angus Place Colliery. The risk of significant impact to THPSS has been reduced to negligible.

Despite the evidence to support that the changes to the mine design will provide an adequate level of protection for THPSS (that is, not result in a significant impact), Centennial has undertaken to provide a hierarchical management strategy for the THPSS within the respective Project Application Areas for the Springvale MEP and the Angus Place MEP. This management strategy is premised on no direct impacts to THPSS, therefore there is no requirement to provide a direct/like for like offset for the community[8].The Regional Biodiversity Strategy includes a management strategy (detailed below) for the management of indirect and residual impacts to THPSS where mitigation measures are not successful.

This management strategy, and the approach to developing it, is described in detail in **Appendix 4**, and summarised below:

- To ensure impacts to THPSS are within those predicted within the Springvale MEP EIS and the Angus Place MEP EIS, Centennial will:
  - Undertake annual monitoring for ecosystem health using the University of Queensland Monitoring Handbook (Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps, 2014) or its latest version.
    - The objectives of the University of Queensland Monitoring Handbook include, amongst other things:
      - A focus on vegetation community structure and diversity, including biological indicator species.
      - Trigger values focussed on detecting impacts of subsidence and/or changes in groundwater and surface water flows, including information on how the triggers were derived.
      - A sampling design that is statistically capable of detecting changes in the indicator variables.
      - An adaptive management mechanism for refining trigger values and determining the length of time a THPSS is monitored.
    - The following figure, taken from the Monitoring Handbook, identifies how the data collected will be used to inform management decision making.

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[8] This is consistent with the application of the EPBC Offsets Policy and the NSW Offsets Policy for Major Projects.

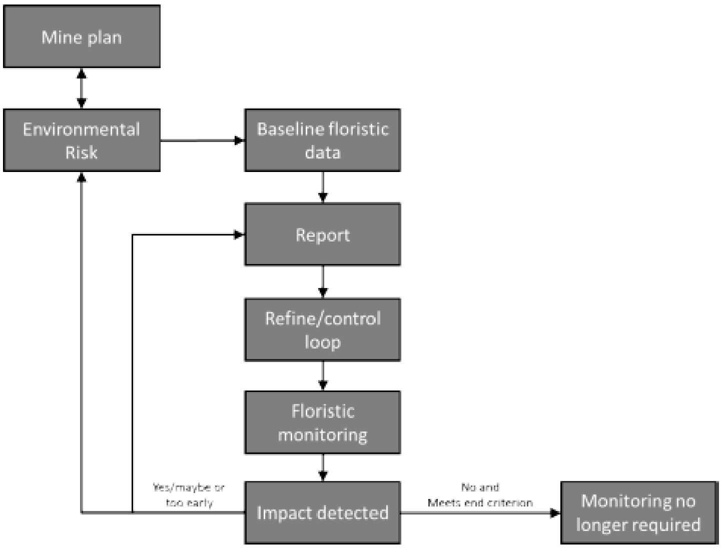


Figure 4.1: Conceptual framework showing how data from flora monitoring informs the environmental risk assessment and monitoring conclusions.

- Where this monitoring identifies mining related impacts, mitigation measures will be implemented (including soft and hard engineering measures discussed further in **Appendix 4**).
- Reconcile the annual monitoring every five (5) years (to allow for trend analysis to occur).
    - Where impacts, attributable to mining, are above triggers, additional mitigation will be undertaken.
    - Where impacts are attributable to mining and cannot be mitigated, or mitigation is not successful, offsets for the residual impacts will be provided.

The combination of offset land, using land with higher conservation priorities, and the THPSS management strategy is considered to adequately compensate for the indirect impacts to THPSS.

### 1.3.5 History of Water Management and Impacts from Water Discharge

The Coxs River drains a catchment of about 2630 km2 on the western side of the Blue Mountains. The Coxs River catchment is bounded to the west by the Great Dividing Range, to the north by the upper Colo River catchment, and to the south by the Wollondilly River catchment. A tributary of the Nepean River, the Coxs River now flows into Lake Burragorang (behind Warragamba Dam), the largest of Sydney's water-supply reservoirs, which is regulated by the Sydney Catchment Authority and managed by Sydney Water.

Before European settlement Aborigines lived in the catchment for many thousands of years. Early explorers provide a picture of the local vegetation, which is of heavily forested hill slopes, opening into more open woodland and some areas of grassland in the wider valleys.

Between 1820 and 1840 many land grants were allocated to settlers, primarily for grazing. To extend grazing areas, the early settlers felled many trees for building homesteads, fences and stockyards.

In 1905 a major bushfire swept through forests and pastures of the upper catchment leaving bare soil and blackened stumps. Following this fire, rabbit populations increased rapidly, leading to widespread land degradation.

Mining in Coxs River catchment commenced in late 1800's and included the now decommissioned Vale of Clywdd, Commonwealth Colliery, Western Main, Eastern Main, Ivanhoe, Lamberts Gully, Wallerawang Collieries and the contemporary mining operations at Pinedale, Springvale and Angus Place.

The Wallerawang Power Station was commissioned in the late 1950's, with Lake Wallace ad Lake Lyall commissioned in 1979. Sawyers Swamp Creek Ash Dam was constructed in 1979 for the Wallerawang Power Station. The Wallerawang Power Station was converted to a dry process in around 2002.

The Mount Piper Power Station was built between 1992 and 1993. Thompson Creek Reservoir was built to provide a staging dam for that Power Station.

Wallerawang and Mount Piper Power Stations require large volumes of water for cooling processes within the system. These power stations operate three reservoirs, Lake Wallace (capacity of 4221 ML), Thompsons Creek Dam (capacity of 27500 ML) and Lake Lyell (capacity of 34192 ML).

Whilst it is acknowledged that the Wallerawang Power Station was placed onto care and maintenance in early 2014, a significant volume of water is required for power generation at the Mount Piper Power Station. On average, almost 40ML per day is utilised for cooling and other purposes at the Mount Piper Power Station. At their peak, the two power stations would draw as much as 69ML per day from the Coxs River catchment.

Lyell Dam was operated transparently (no diversions) until 1991. The effects of the dam on the downstream flow regime were minor during this period. Total flow volumes would have been slightly reduced by evaporation from the reservoir. In 1992 water extraction from the reservoir increased, greatly modifying the flow regime immediately downstream. Intermittent release of water is required from Lake Lyell to provide environmental flows to Coxs River downstream.

**Mine Water Management at Springvale Mine**

Springvale Mine commenced operations in 1993. The underground mine is located within the catchment divide of Coxs River and Wolgan River, whilst the surface facilities lie wholly within the Coxs River catchment. Water collected in the underground mine was originally discharged from the pit top via LDP001 (EPL 3607) to Coxs River via Springvale Creek. However, the need for dewatering of mine inflows, generated during coal extraction from the Lithgow Seam, was established shortly after the mine commenced operations, and a water management plan was developed.

The first licensed discharge of mine water on the Newnes Plateau occurred on 16 April 1997 at the Springvale Bore 1 facility at using seam to surface water pumping systems for the extraction of water from the underground mine. Bore facilities were established at the northern end of the longwall panels, where water accumulated following extraction of coal. Establishment of Bores 2 to 4 in the series followed sequentially. Prior to 2006, the bores transferred water to settlement ponds on Newnes Plateau. This water was then discharged via LDP004 and LDP005 (Springvale Mine EPL 3607) and LDP006 (Angus Place Colliery EPL 467) into the tributaries of the Wolgan River.

Following the listing of Newnes Plateau Shrub Swamps as Endangered Ecological Communities on 15 July 2005 under the Threatened Species Conservation Act 1995, Centennial Coal worked with Delta Electricity (former owner of Wallerawang Power Station) in consultation with the EPA to implement a Springvale Delta Water Transfer Scheme (SDWTS) for the transfer of water from the underground mine to the Wallerawang Power Station, where the water was to be used in the cooling towers. The commissioning of the SDWTS on 5 February 2006 was part of a Pollution Reduction Program and occurred in conjunction with the establishment of the Bore 5 Facility on Newnes Plateau.

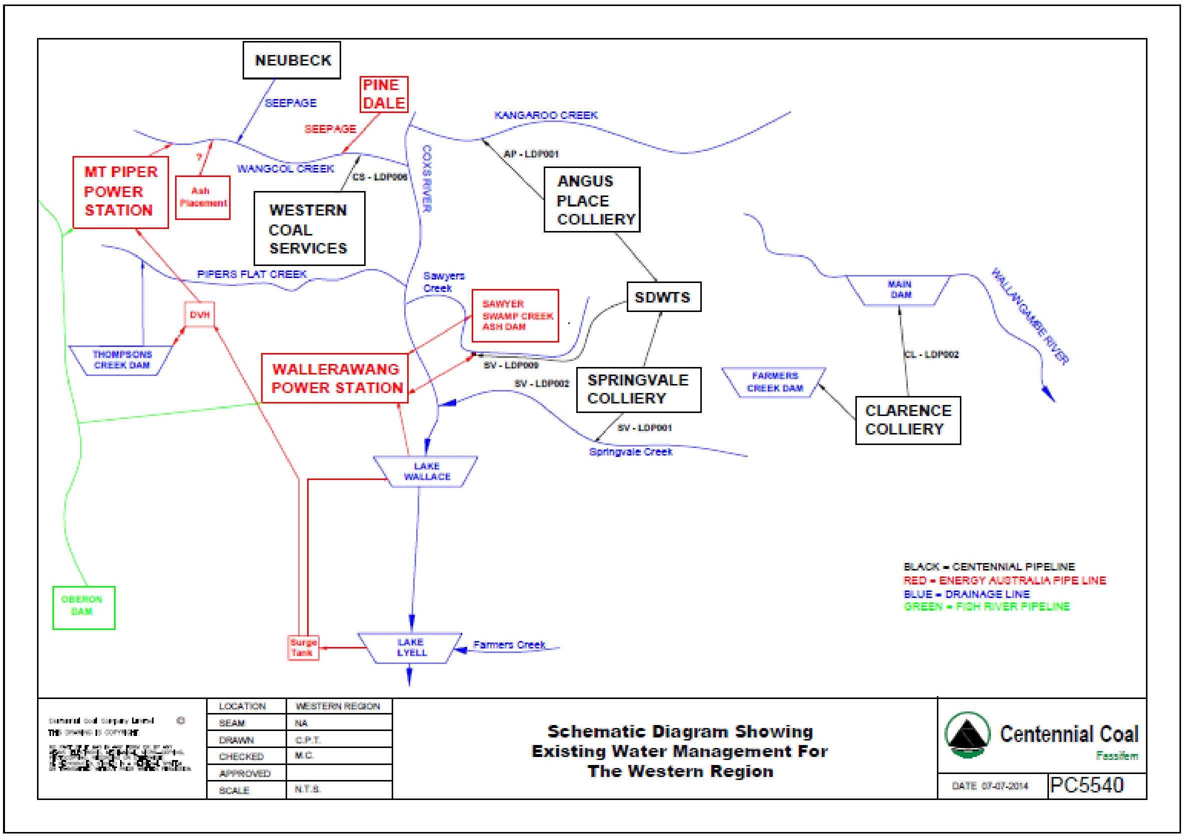
The SDWTS has served two functions since its introduction in 2006. The first was to remove permanent water discharges from the Newnes Plateau and the second was to reduce the volume of water sourced by the local power station (Wallerawang Power Station) from the regional surface rivers and lakes which feed into the Sydney drinking water catchment.

Since the establishment of the SDWTS Springvale Mine has established two additional bore facilities, Bore 6 and Bore 8, on Newnes Plateau. Bore 8 is licensed as a dewatering bore by the NSW Office of Water (10BL603519). One additional Springvale Mine bore facility connects to the SDWTS at Ventilation Shaft 3 (10BL601863). While water is also pumped to the surface via the Pit Top Collection System (10BL602017) for process water this system is not connected to the SDWTS. Excess water from the system is via LDP001 to Springvale Creek.

The SDWTS has a maximum total capacity of 30 ML/day for most of the network except between Springvale Mine’s LDP009 (EPL 3607) and Wallerawang Power Station where the capacity is approximately 58 ML/day.

With the commissioning of the SDWTS, on 3 October 2006 Springvale Mine’s EPL3607 was varied to only allow emergency discharges via LDP004 and LDP005 on the Newnes Plateau. From early 2007 to April 2010, due to issues with the SDWTS infrastructure and management of the system, licensed emergency discharges of mine water to Narrow and East Wolgan Swamps via LDP004, LDP005 and LDP006 were frequently required to ensure the safety of mine workers. The infrastructure issues have been resolved over the life of the SDWTS and there have been no mine water discharges on the Newnes Plateau since 10 April 2010. The Goldney Report found that impacts to East Wolgan and Narrow Swamps were largely the result of mine water discharge from licensed discharge points LDP004 and LDP005 on the Newnes Plateau.

With the removal of water discharges on the Newnes Plateau, the utilisation of the SDWTS became critical for continued dewatering of the underground mine. Turbidity of the water discharged to the scheme required the installation of settling ponds near the Kerosenevale Ash Dam. These ponds were installed in 2010. In 2012, in consultation with the EPA, Springvale Mine began discharging water from these ponds to Sawyers Swamp Creek, a tributary of the Coxs River, via a new discharge point, LDP009. The following schematic shows how water in the Upper Coxs River is managed.



Since 2007, the Springvale Mine Environmental Protection Licence has been varied 19 times with five (5) Pollution Reduction Programs requiring investigation into water quality of the discharges to either the Wolgan River or Coxs River. These Pollution Reduction Programs included completion of ANZECC water quality assessments, options to improve water quality in the Coxs River and ecotoxicology assessments of licensed discharge points. The following table provides a summary of these variations.

| Variation Date | Summary of Variation Notice |
|---|---|
| 24 September 2001 | License review of EPL3607 |
| 4 September 2002 | Pollution Reduction Program for a Wastewater Management Option Study, consistent with the prioritised management actions under the Catchment Management Blueprint; water quality and flow objectives for the Hawkesbury Nepean River System; ecosystem protection targets under the ANZECC Water Quality Guidelines; and Schedule 2 of the Clean Water Regulation 1972 |
| 28 March 2003 | Variation to include ventilation shaft |
| 19 December 2003 | Variation to include coal conveyor |
| 3 September 2004 | Variation to extend the time for the PRP study of 4 Setpebmer 2002 |
| 11 October 2004 | Variation to provide an emergency discharge point for mine dewatering |
| 8 August 2005 | Variation to pH criteria of licensed discharges and |

| | |
|---|---|
| | include blasting limits for the Lamberts Gully operation |
| 26 April 2006 | Variation to remove PRP for water options (deemed to be satisfied) and remove the emergency discharge |
| 3 October 2006 | Variation to include LDP004 and LDP005 as emergency discharges on EPL3607, following commissioning of the SDWTS in 2006 |
| 21 August 2007 | Variation to allow for non-emergency discharges to quantify flow characteristics along ephemeral reaches of the Wolgan River |
| 9 September 2009 | Variation to include a PRP for water quality investigations at LDP006 at Lamberts Gully |
| 10 September 2010 | Variation for further review of water quality at LDP006 at Lamberts Gully |
| 5 July 2011 | Administrative amendments to the license |
| 19 December 2011 | Further water quality investigations at LDP006 and inclusion of the dust PRPs |
| 2 August 2012 | Variation to include LPD009 and a PRP to investigate and report on options to improve water quality at LDP009 |
| 21 May 2013 | Variation to include requirement for ANZECC assessment at LDP006 and POP on turbidity at LDP009 |
| 12 August 2014 | Variation to include a PRP to undertake exotoxicology assessment at LDP009 |

In response to these PRPs and submissions made on the Springvale MEP EIS and the Angus Place MEP EIS, Centennial has undertaken a whole of catchment review of water management in the Upper and Lower Coxs River catchments. This reports supporting this review included:

- Appendices to the Springvale MEP EIS and the Angus Place MEP EIS:
    - Groundwater Impact Assessment (Appendix E).
    - Surface Water Impact Assessment (Appendix F).
    - Regional water and salt balance report, incorporating volume, quality and flow characteristics of the Upper Coxs River (Attachnment E to Appendix F).
    - Aquatic Ecology Impact Assessment, including potential impacts to stygofauna (Appendix G).
    - Terrestrial Ecology Impact Assessment (Appendix H).
    - Regional Biodiversity Strategy Appendix I).
- Appendices to this RTS:

  - Springvale and Angus Place Regional Water Quality Impact Assessment (RPS 2014a) (**Appendix 2**).
  - Revised Regional Biodiversity Offset Strategy (RPS 2014c) (**Appendix 4**).
  - Coxs River Ecotoxicology Assessment (GHD 2014b) (**Appendix 10**).

In summary, this review concluded:

- The Upper Coxs River catchment is heavily modified, following over 100 years of mining and other industrial water uses.
- Salinity from water discharged from the underground mine is not having a detrimental impact on the receiving environment, or ecology, of the Upper Coxs River catchment.
- The quality of water discharged from the underground mining operations meets all water quality criteria at LDP009 and LDP001.
- Dissolved zinc was exceeded in Lake Wallace, dissolved copper and zinc were exceeded in Wangcol Creek, however, the presence of these metals was insufficient to cause toxicity.
- There was evidence of toxicity in the Upper Coxs River, above water discharge points, suggesting lower pH causes an ionic imbalance that is corrected by higher pH downstream.
- Industrial water users in the Upper Coxs River have a heavy reliance on water discharged from the underground mining operations.
- Water quality in Lake Burragorang (Warragamba Dam) will increase slightly due to the water discharged from the underground mining operations, which is well below the salinity levels identified under the Australian Drinking Water Guidelines.

The results of these assessments are further discussed in **Section 3.1.25 and Section 3.1.26** of this RTS.

**Mine Water Management at Angus Place Colliery**

Angus Place Colliery is an extension of the now abandoned Newcom Mine at Kerosene Vale and commenced operations in 1979. The Angus Place colliery holding traverse both the Wolgan River/Carne Creek and Coxs River catchments.

Angus Place Colliery, since its inception in 1979, discharged mine water via LDP001 and LDP004 (EPL467) to Kangaroo Creek, which forms the upper reaches of the Coxs River. . In the early 1980s, the mine was pumping 1.8 ML/day of water into Kangaroo Creek.

Surplus mine water extracted via the Pit Top Collection System (10BL601838) for process water is discharged to Kangaroo Creek at LDP001. On 16 May 2002, EPL 467 was varied to allow licensed discharges from LDP001 from 9.5 ML/day to increase to 20 ML/day.

In 2005, Angus Place Colliery commenced the process of obtaining a contemporary approval for the underground and surface mining operations. In 2006, the Colliery was granted Project Approval under the former Part 3A of the EP&A Act, PA 06_0021. For the purposes of discharge of water from the underground mining operations, the Angus Place Colliery Environmental Assessment (EA), dated January 2006, included at section 2.8:

*Water make from the coal face is pumped from temporary holding dams (fish tanks) and then to longwall goaf areas to settle. Water is then pumped to an underground collection point and then to the* *surface into concrete tanks. Overflow from the concrete tanks is into two surface settling ponds for further treatment.*

*Water from the surface concrete tanks is recycled underground for fire fighting, dust suppression and process purposes. Water from these tanks is also used for fire fighting on the surface.*

*The surface water management system at Angus Place relies on the separation of clean and dirty water surface runoff and the management of mine water make that is pumped to the surface from underground. Integral to the surface water management system are licensed discharge points that are managed in accordance with the requirements of Angus Place's Environment Protection Licence (EPL). Water is discharged from the Colliery to the Cox's River Catchment.*

At section 2.3.3 of the EA:

*The EPL cover Angus Place activities to a scale of 2 – 3.5 Mtpa, a sewage treatment plant and prescribes volume limits and water quality limits for each discharge point. A variation of the EPL is not considered necessary as this application does not propose activities outside the existing Colliery Holding, which represents the EPL defined premises.*

In 2006 the 930 Bore facility (10BL601852) was installed on Newnes Plateau for the extraction of mine water from Longwall 930 and transfer to the SDWTS. 930 Bore was decommissioned in 2007 and Bore 940 facility (10BL601851) (was installed on the Newnes Plateau to remove water from Longwall 940 for the transfer of mine water into the SDWTS. 940 Bore remains in service.

On 13 October 2006, EPL 467 was varied to permit emergency discharge of mine water into Narrow Swamp at LDP006. As a result of changes to the mine water management system at Angus Place emergency discharge provisions at LDP006 were able to be relinquished and on 29 July 2013 EPA varied EPL467 to remove LDP006 from the licence. This change resulted in a need to ensure all water collected in the underground mine workings could be discharged from the mine via LDP001. This was an essential requirement to maintain a safe underground working environment.

On 17 July 2007, the EPA varied EPL467 to increase licensed discharges from LDP001 from 20 ML/day to 30 ML/day and remove LDP004 from the licence. This variation was consistent with the description in the EA supporting PA 06_0021, allowing water from the underground mining operations to be discharged through LDP001 to Kangaroo Creek and was essential in maintaining a safe underground working environment.

With the majority of underground water being directed from the Angus Place workings into the SDWTS, in 2011 EPL 467 was varied by the EPA and required Angus Place Colliery to modify the underground pumping regime such that no mine water would be discharged through LDP001 under normal operating conditions by 30 June 2013. Angus Place Colliery has modified its underground pumping regime and decreased the flow into Kangaroo Creek through LDP001 since mid-2012 from in excess of 6 ML/day to 1-2 ML/day. This reduction in discharge of mine water into Kangaroo Creek was achieved by increasing utilisation of 940 Bore facilities to transfer water to the SDWTS, and utilisation of disused underground workings to store excess water. However, the available storage within the underground workings is reaching capacity, requiring the volumetric discharge at LDP001 to be increased to ensure a safe underground working environment.

The SDWTS is currently transferring approximately 23 ML/day of mine water to Springvale Mine's LDP009 (EPL 3607), of which approximately 7 ML/day is transferred from Angus Place 940 Bore.

The SDWTS represents a multi-million dollar investment for Centennial Coal, which was designed to service the life of mine water management needs and allowed the water to be used by a local industrial user (Delta Electricity, now Energy Australia).

At the time of commissioning the SDWTS was awarded several green globe awards by the NSW Government Department of Energy, Utilities, and Sustainability for superior performance in the development and delivery of water efficiency initiatives, as follows:

- Water recycling and conservation leadership.
- Water and energy savings action plan - excellence achievement.
- Water champion business achievement.

With the commitment in 2009 to cease discharging underground water to the Newnes Plateau, alternative water management strategies have been investigated, and to the extent these were practical and feasible, implemented. This has included:

- Installation of sedimentation ponds at the Kerosene Vale Ash Dam to manage turbidity.
- Installation of a water treatment system (flocculation) at the LDP009 discharge site, to manage elevated arsenic (in particular).
- Re-organisation of the underground water management systems to allow for utilisation of limited underground storage spaces for water retention and management.
- Significant capital investment through dewatering bores, pipelines, gravity tanks and the like to transfer water from the underground mining operations to the Coxs River catchment for use by significant industrial water users.
- Extensive and ongoing investigations into alternative water management options, requiring significant investment from government and other stakeholders in order to be realised.
- Repeated investigations into the quality of water discharged from the underground mining operations, the results of which indicate that the water discharged is not having a significant detrimental impact on the catchment.
- Significant investment, through the Revised Regional Biodiversity Strategy contained at **Appendix 4** of this RTS, in the restoration and rehabilitation of the Upper Coxs River to improve amenity, water quality and biodiversity.

# 2.0 SUMMARY OF SUBMISSIONS

The Springvale MEP was placed on public exhibition from 12 April to 26 May 2014. During this period, 333 submissions were received.

Of the 333 submissions received:

- 13 were from government agencies;
- 15 were from special interest groups; and
- 305 were from community individuals.

Government agency submissions were received from:

- Commonwealth Department of the Environment (DotE) (including the Independent Expert Scientific Committee (IESC));
- Lithgow City Council;
- NSW Department of Trade Investment Regional Infrastructure and Services - Division of Resources and Energy (DRE);
- NSW Department of Primary Industries – NSW Office of Water (DPI NOW);
- NSW Department of Primary Industries – Crown Lands (DPI – Crown Lands);
- NSW Department of Primary Industries – Fisheries NSW;
- NSW Department of Primary Industries - Office of Agricultural Sustainability and Food Security (DPI – OAS&FS);
- NSW Environment Protection Authority (EPA);
- NSW Health – Nepean Blue Mountains Local Health District (NSW Health - NBMLHD);
- NSW Office of Environment and Heritage (OEH);
- Roads and Maritime Services (RMS);
- Sydney Catchment Authority (SCA); and
- TransGrid.

Of the 15 submissions from special interest groups:

- 8 were in objection to the Project;
- 6 were in support of the Project; and
- 1 provided comment on the Project

Of the 305 community individual submissions received:

- 80 submissions were in support of the Project

- 221 submissions were in objection to the Project; and
- 4 provided comment on the Project.

Additionally the NSW Department of Planning and Environment and the Commonwealth Department of the Environment, in a letter dated 2 July 2014, jointly referred the development applications for both the Angus Place and Springvale MEPs to the Independent Expert Scientific Committee for its consideration and advice. As a result of the submissions received, additional commitments have been made by Springvale Coal and included in a revised Statement of Commitments provided in **Section 5.0** of this RTS.

## 2.1 Summary of Issues Raised

A summary of the issues raised by the government agencies is provided in **Table 1**, a summary of the issues raised by special interest groups is provided in **Table 2** and a summary of the submissions made by individual community members is provided in **Table 3**. Detailed responses to each of the issues raised are provided in **Section 3.0**.

**Table 1 - Summary of Government Agency Submissions**

| Area of Concern | Raised By | Summary of Issue |
|---|---|---|
| Aboriginal Heritage<br>(Section 3.1.1) | NSW Office of Environment and Heritage (OEH) | OEH considers that a more definitive assessment of the probability of roof fall collapse is required in rock shelters that have cultural deposits. In other assessments the standard used in assessing subsidence effects on Aboriginal Cultural Heritage (ACH) in longwall mining operations has been based on percentage estimates. A minimum 10% chance of roof fall collapse is an accepted threshold range from which decisions about appropriate mitigation can be considered. It is OEH's view that in circumstances where the chance of roof fall collapse exceeds 10% the appropriate mitigation is to excavate the shelter for salvage of Aboriginal objects and extract as much information that is appropriate for interpretation and educational purposes. |
| | | OEH considers that structurally sensitive Aboriginal sites should also be monitored during the progression of adjacent longwalls and as the underlying longwall progresses. If damage begins to appear during progression of mining in proximity to the sites, appropriate action should be taken. This should be incorporated in the Cultural Heritage Management Plans, which should be developed in consultation with the Registered Aboriginal Stakeholders and OEH. |
| | | The action relating to skeletal remains should be reworded. |
| | Lithgow City Council | The Applicant shall ensure that the development does not cause any direct or indirect impact on identified Aboriginal sites located outside of the approved disturbance area of the development on the site. |
| Air Quality<br>(Section 3.1.2) | NSW Health | To minimise any potential health impacts it is recommended that, should the project be approved, the proponent is required to implement all reasonable and feasible measures to minimise particulate matter emissions. Such measures might include reactive dust management systems. |

| Area of Concern | Raised By | Summary of Issue |
|---|---|---|
| | | The modelling that has been conducted includes only external sites that are operational or have been approved and will be operational in the near future when considering cumulative dust and particulate matter. The modelling does not include proposed developments, such as Neubeck, Cullen Valley and Invincible Mines which may become operational during the lifespan and Springvale and Angus Place Mines. The cumulative effect of all the developments which are in close proximity to each other may result in air quality exceedences for sensitive receivers. |
| Biodiversity Strategy<br>(Section 3.1.3) | NSW Office of Environment and Heritage (OEH) | OEH considers that the Regional Biodiversity Strategy included in the EISs does not fulfil the Director-General's requirements as it has not demonstrated that the biodiversity values of the region will be maintained or improved in the medium to long term. Importantly, the proponent has only assessed offsetting requirements for impacts associated with vegetation clearing activities and has not considered losses to habitat and ecosystem condition that will be a direct impact from rock fracturing and changed hydrology in its offsetting strategy. In addition, the selection of the proposed offset is not justified and the proposed Regional Biodiversity Strategy does not fulfil all of the NSW Offset Principles for Major Projects as presented in the Draft Policy. |
| | Commonwealth Department of the Environment (DotE) | The proponent must meet the requirements of the EPBC Environmental Offsets Policy (October 2012) and Offsets Assessment Guide, including legal arrangements and funding provision for in-perpetuity management of offset lands, prior to the finalisation of an EPBC approval. |
| | | The Department notes that whilst both EIS documents acknowledge the potential for some impacts on the THPSS ecological community (the total area of THPSS being mined under being 96.6 ha), the proposed offset area does not contain any THPSS nor does it appear to have any habitat for EPBC listed threatened species (such as the Blue Mountain Water Skink) that may be impacted by the proposed action. |
| | | The Response to Submissions reports should provide information that shows how the proposed offsets comply with the Offsets Policy including, if necessary, the location of THPSS offsets (to account for any residual impact to THPSS once any avoidance has been taken into account), their current condition, the management actions proposed to improve ecological condition and the preferred mechanism for in-perpetuity conservation. Any other matters of national environmental significance requiring an offset should also be covered. |
| Construction | Lithgow City Council | The applicant is to apply for a construction certificate with Lithgow City Council or Private Certifier for all building construction works. |

| Area of Concern | Raised By | Summary of Issue |
|---|---|---|
| Section 3.1.4) | | A Construction Management Plan is to be prepared in consultation with Lithgow City Council and implemented for the duration of the construction phase at each project site. |
| Cumulative Impacts<br>(Section 3.1.5) | NSW Office of Environment and Heritage (OEH) | The interaction of the two mines where they come into close proximity to one another does not appear to have been specifically addressed in the EIS apart from an indication in Table 9.4 of the Springvale EIS. |
| Exploration<br>(Section 3.1.6) | Division of Resources and Energy (DRE) | Proposed exploration activities must be notified to DRE and, where applicable, to the Forestry Corporation of NSW including copies of due diligence assessments and site assessments where available. Exploration must not commence until appropriate approvals and/or consents have been obtained from these agencies. |
| | | Section 4.2 of the EIS covers proposed exploration. The level of detail does not clearly identify whether there is likely to be a significant impact or provide commitment to avoid sensitive areas identified in proposed studies. |
| | | There is no estimate of the number or location of holes to be drilled. |
| | NSW Office of Environment and Heritage (OEH) | No information regarding how much disturbance is required per drill hole or how many drill holes are estimated over the life of the Projects. There is no information provided regarding how much cumulative disturbance the exploration programme has caused in the past, nor how much is anticipated in the future. This has the potential to impact a large area over time. While it is proposed that assessments will be provided to DP&E, there is no information provided regarding whether these will be reviewed, or whether further approvals will be required. OEH considers that the EISs do not contain sufficient information to enable an informed and legally defensible decision to be made regarding the proposed exploration programme. |
| | | While it is proposed that assessments will be provided to DP&E, there is no information provided regarding whether these will be reviewed, or whether further approvals will be required. OEH considers that the EISs do not contain sufficient information to enable an informed and legally defensible decision to be made regarding the proposed exploration programme. |
| | Lithgow City Council | Drill sites and associated access tracks are to be located where possible to avoid threatened flora species, avoid hollow bearing trees, avoid EECs, minimise clearing and avoid identified Aboriginal heritage sites. |
| General<br>(Section 3.1.7) | Lithgow City Council | Lithgow City Council is to be notified of any modifications and determinations. |
| | | The applicant is to prepare and submit Annual Reviews (formerly Annual Environmental Management Reports) to Lithgow City Council to review. |

| Area of Concern | Raised By | Summary of Issue |
|---|---|---|
| | | The applicant may carry out coal transportation and processing operations on the site for up to 13 year from the date of this consent. Rehabilitation works are able to proceed after this end date. |
| | | The applicant shall produce up to 4 million tonnes of coal per year for up to 25 years. |
| | Division of Resources and Energy (DRE) | Inconsistent statements regarding the depth of cover in the EIS. In Section 8.2 cover is referenced at between 300m and 430m, while other sections clearly show and state depth of cover between 180 and 420m..), |
| | | The EIS contains conflicting numbering reference for the Burralow Formation (AQ5 or AQ6?) |
| | | Conflicting referencing in the EIS regarding the area of land clearing (11.44 ha or 11.8 ha - both stated on page 441). |
| Groundwater<br>(Section 3.1.8) | NSW Office of Water (NOW) | The expansion of the groundwater monitoring network, and the associated monitoring schedules to be updated in the Water Management Plan (WMP), should carried out in consultation with the Office of Water. |
| | | The modelling used to support the EIS should be regularly updated to enable confirmation that the predicted mine water takes are not exceeding, and are not likely to exceed, the predictions made in the EIS. These periodic reviews should be incorporated within the overall annual environmental monitoring plan and the results made available to NOW in a suitable electronic format. |
| | | The proponent must maintain records of annual water take from water sources impacted by the development and reported in the annual environmental report. |
| | | The specific impacts of the permanent reductions (and in some cases increases) in baseflow to local swamps and surface streams are not discussed in the hydrogeological impacts report. These impacts are not discussed at all in the Surface Water Impact Study but are included in the ecological assessments. |
| | | NOW suggest a commitment to comply with the Water Sharing Plan in the Statement of Commitments. |
| | Commonwealth Department of the Environment (DotE) | The EIS, including the groundwater model, does not provide a reasonable assessment of impacts to THPSS. Confidence in the groundwater model's capacity to predict site specific impacts to individual THPSS is low. In particular the model scale is not appropriate to predict impacts to THPSS, and a number of THPSS are not included within the groundwater model and therefore groundwater related impacts to these swamps cannot be predicted. |

| Area of Concern | Raised By | Summary of Issue |
|---|---|---|
| | | The groundwater model has been constructed using industry best practice methods and is acceptable for predicting mine inflows. However, the scale of the groundwater model is inappropriate to predict groundwater related impacts to individual THPSS. Further, a number of swamps are not incorporated into the groundwater model. Finer scaled, site specific models, informed by a conceptualisation of the hydrology and hydrogeology, would be needed to have confidence in the predictions of groundwater impacts to individual swamps. |
| | | Confidence in groundwater model predictions is limited by a lack of site specific hydrogeological data and lineament groundwater flow behaviour. The assessment of surface water impacts, including cumulative impacts, needs to consider contaminants such as copper, zinc, nitrogen and phosphorus, which groundwater quality monitoring shows all exceed ANZECC guidelines. |
| | | Is the groundwater model suitably robust, and are the resulting quantitative predictions accurately and reasonably described? |
| | | The groundwater model is a regional scale model that provides generally robust predictions of mine groundwater inflows. These are reasonably described. However, due to the scale of the groundwater model, it is limited in its capability to predict groundwater related impacts to surface water systems including those affecting THPSS and proximal reaches of the Coxs River. This results in a low level of confidence in the predictions of impacts to Cox's River and THPSS baseflows described within the EIS. |
| | NSW Office of Environment and Heritage (OEH) | No extensometer data is reported, but it is noted that a wide range of impacts have been measured on groundwater aquifer levels over both Springvale and Angus Place mines. |
| Infrastructure<br>(Section 3.1.9) | TransGrid | Lot 5 in DP829137 appears to be the closest parcel of land to TransGrid's infrastructure. Any development proposed near TransGrid's infrastructure is subject to SEPP (Infrastructure) 2007, in particular regulation 45. |

| Area of Concern | Raised By | Summary of Issue |
|---|---|---|
| | | Lot 11 in DP1139978 is imminently close to TransGrid's Wallerawang 330KV Transmission Line Outlet Easement and the State significant infrastructure situated therein. The south west corner of this parcel of land (Lot 5 in DP1139978) is located only 2 metres from the outer edge of TransGrid's easement; approximately 26 metres from the actual transmission line catenary (even less when the transmission line is at maximum operating temperature) and within 29 metres of the transmission line stanchion (tower). Horizontal clearances apply to all TransGrid easements and infrastructure, especially near stanchions that are constructed with subterranean earthing straps that protrude at least 15 metres diagonally from each leg of the tower. Therefore, no excavation or other earth works are to be undertaken near this tower. |
| | | The land near TransGrid's easements and infrastructure must not become vulnerable to mine subsidence. |
| | | A safe working platform must be preserved along the easement and surrounding land, so maintenance can be undertaken to the transmission line and structures. As the transmission line changes direction at the location of Structure 5 (Feeder 70/71), it is particularly important to preserve a safe working platform around this structure which should be at least a 50 metre radius. |
| Landowner Consent<br>(Section 3.1.10) | Crown Lands | A review by Crown Lands of the Project Application form has noted that Section 7, Landowner's consent, has not been completed. As Crown land together with a number of Crown Roads is located with the Project Boundary Application Area, the Applicant would need to seek consent from Crown Lands. |
| Mine Design<br>(Section 3.1.11) | Commonwealth Department of the Environment (DotE) | The Department of the Environment considers, consistent with the advice from IESC in 2012 reproduced below, for the mining of longwalls 415, 416 and 417, that there is a high risk of severe impact to Temperate Peat Highland Swamp on Sandstone (THPSS) that are directly above or laterally adjacent to the proposed longwall panel. The mitigation measures proposed by the proponent are unlikely to reduce the risk of future potential impacts to acceptable levels. The Department believes that a precautionary approach will be necessary to avoid an unacceptable risk of impacts to THPSS. |

| Area of Concern | Raised By | Summary of Issue |
|---|---|---|
| | Independent Expert Scientific Committee (IESC) | Longwall mining in areas directly below known high quality sites of temperate highland peat swamps on sandstone should be restricted which may potentially reduce the risk of unacceptable impacts on the endangered ecological community, particularly if appropriate buffers that reflect the local geological characteristics are incorporated between the longwall mining panels and high quality swamps. The Interim Committee supports the proposal that this condition could be revisited if the proponent is able to demonstrate that a proven technology or engineering methodology can be used that prevents the risk of subsidence in the listed ecological community, or that would allow any subsidence related impacts to be remediated. |
| Mining Title<br>(Section 3.1.12) | Division of Resources and Energy (DRE) | The project area is within mining titles held by the company and extends into the company's Exploration Licence 6317. The company will submit a mining lease application for the right to mine within the exploration license area. |
| Monitoring/Management<br>(Section 3.1.13) | NSW Office of Environment and Heritage (OEH) | OEH considers that, given the potential for fracturing of bedrock in drainage lines, monitoring of groundwater and flows on drainage lines within 800 m of the Gardens of Stone National Park is required. |
| | | There is no appropriate monitoring of flow in streams which is capable of testing the veracity of the claims made in the EIS of no impact to flows. |
| | | There is no indication of what actions will be taken if monitoring indicates that mining-induced impacts occur. |
| | Sydney Catchment Authority (SCA) | The absence of any proposed monitoring for Marrangaroo Creek is considered unsatisfactory. It is considered that as a minimum, full hydrological monitoring should again be undertaken for this significant tributary of the Coxs River, and water quality monitoring also undertaken. |
| | NSW Office of Water (NOW) | The proposed surface water and groundwater management plans should identify critical impact thresholds in groundwater levels and quality and surface water flows and water quality to enable adaptive response and management of operations within the proposed Surface and Groundwater Management Plan. A mechanism for identifying and reporting variations from predictions should be clearly stated within the Plan. |
| | | To improve the coverage of baseline characterisation data, it is recommended data loggers be installed in key monitoring bores to enable continuous monitoring of groundwater levels in response to rainfall events. |
| | | The expansion of the groundwater monitoring network, and the associated monitoring schedules to be updated in the Water Management Plan (WMP), should be carried out in consultation with the Office of Water. |

| Area of Concern | Raised By | Summary of Issue |
|---|---|---|
| | | A minimum of 2 years of baseline data should be applied for all GDE sites within range of longwall panels. |
| | Independent Expert Scientific Committee (IESC) | A comprehensive monitoring and management plan should be produced that takes into account the hydrological and geological context in which the swamps sit and includes:<br>i. potential geological and hydrological impacts in upstream tributaries that feed into the peat swamps and in areas laterally adjacent to peat swamps;<br>ii. potential downstream geological and hydrological impacts;<br>iii. potential lateral geological and hydrological impacts. |
| | NSW Fisheries | Prior to construction commencing, the applicant must prepare a detailed Environmental Monitoring Program as part of a Subsidence Management Plan. This plan should include the monitoring of surface water drainage lines for subsidence impacts as well as monitoring impacts on swamps, wetlands, and water dependent ecosystems for subsidence impacts. |
| | | Fisheries NSW should be notified if monitoring detects significant impacts on 3rd order surface drainage lines (Strahler Ordering System) as a result of subsidence. |
| | | The proponent should develop a Riparian Habitat Management Plan regarding management and protection of riparian areas aimed at minimising riparian clearing and maintaining adequate riparian buffer zones as per the departments' Policy and Guidelines for Fish Habitat Conservation and Management (Update 2013). |
| Newnes Plateau Shrub Swamps/Hanging Swamps<br>(Section 3.1.14) | NSW Office of Environment and Heritage (OEH) | Having significantly damaged Newnes Plateau Shrub Swamp EECs in the past, the EISs do not provide any definitive evidence or guarantee that further NPSS will not be impacted by the current mine plan or future longwalls. |
| | | The irreversibility of impacts to EECs is a significant consideration for OEH. If the relatively impermeable base of the Newnes Plateau Shrub Swamps or Hanging Swamps is fractured, then any perched aquifer is likely to drain downwards into the fracture network, thereby altering natural groundwater levels within the swamp and leading to increased desiccation. These impacts have already been demonstrated for Centennial's longwall operations at both Springvale and Angus Place mines. They have also been well documented in the Southern Coalfield for coastal upland swamps. |

| Area of Concern | Raised By | Summary of Issue |
|---|---|---|
| | | In contrast to the experience at Springvale and Angus place Place mines; OEH notes the comparative lack of impact at Centennial's Clarence Colliery operations to NPSS which uses an alternative mining methodology. The recently approved 900 Series at Clarence Colliery are located just on the other side of the Pine Plantation from the proposed Springvale mine Mine longwalls and operates in similar depths of cover. Subsidence at Clarence Colliery is of the order of 100 mm compared to 1500-2000 mm at Springvale and Angus Place. |
| | | The History of Mining Beneath Swamps section of the Subsidence Impact Assessments fails to discuss the interaction of geological structures and swamp impacts. |
| | Commonwealth Department of the Environment (DotE) | Longwall mining beneath THPSS may fracture the sandstone substrate and alter the swamp's water balance. The Department is unaware of any proven strategies to effectively mitigate longwall mining impacts other than avoiding impacts through changes to mine plan layout. |
| | | The frequency of subsidence impacts (caused by longwall mining) on swamps appears to be low but when such impacts occur they are likely to have a high impact on the ecological functioning of individual swamps. |
| | | The Subsidence Impact Assessment predicts values for subsidence, upsidence, tilts, curvatures, hogging and sagging that if realised would, according to the EIS, have minimal impacts on the swamps. Similar estimates have been made for projects on the Newnes Plateau in the past (Springvale and Angus Place). In these cases it has been documented that longwall mining (conducted under EPBC approval 2011/5952- Angus Place Colliery) resulted in major impacts on East Wolgan Swamp (subsidence and cracking) and significant impacts on Kangaroo Creek Swamp (undermined, with water losses from the ecosystem). |
| | | The current EIS fails to acknowledge the failure of past predictions and that longwall mining below the swamps could result in further irreparable damage to THPSS. |
| | | Neither EIS provides convincing evidence that THPSS will be immune from similar impacts to those that damaged the ecological community in the past. The reduction in longwall widths to 261m provides no reassurance that THPSS will not be impacted by bed rock fracturing as some of the previous impacts (Kangaroo Creek Swamp) occurred with 262m wide longwalls (longwall 940). |

| Area of Concern | Raised By | Summary of Issue |
|---|---|---|
| | | Impacts to undermined THPSS have historically been severe, resulting in changes to the hydrological and hydrogeological regimes, vegetation composition and structure, and large reductions in THPSS extent. These changes have been significant and are considered to be beyond the ability of the ecological community to recover naturally. As yet, there is no scientific evidence or industry based results to indicate that such impacts to THPSS can be remediated successfully. |
| | | The subsidence related impacts affecting overlying and adjacent THPSS would be expected to include fracturing of underlying bedrock, a water storage capacity increase within the bedrock fracture network, a decrease in surface water flow provision from upstream tributaries and a corresponding decrease in standing surface water level. Other impacts to THPSS may include nick point erosion, peat slumping, changes to the swamp inundation regime and a decline in the biological diversity and/or species composition of swamps. Such impacts are highly likely to be severe and potentially irreparable. |
| | | Due to the low level of confidence in the groundwater model's capacity to predict hydrological impacts to individual THPSS, the likelihood, extent and significance of groundwater impacts to swamps cannot be determined with certainty. Swamps that are directly undermined or overlie structural lineaments are more likely to be severely impacted due to the instability of underlying strata and locally increased subsidence effects. Given the temporal variability and time lags with which impacts are observed in THPSS, the significance of groundwater impacts may not be readily determined for some time. |
| | | Avoidance of undermining and locating longwalls such that tensile and compressive strains are below 0.5 mm/m and 2 mm/m respectively at THPSS sites are considered the most effective ways to manage the potential impacts to THPSS. This strategy should also be applied to any upstream tributaries that provide a significant proportion of surface flow to THPSS. |

| Area of Concern | Raised By | Summary of Issue |
|---|---|---|
| | | The only known strategy to reduce the risk of impact to THPSS ecological communities within the project area would be to alter the mine layout such that swamps are not undermined by longwall panels and longwalls are sufficiently removed from THPSS such that tensile and compressive strains at THPSS sites are below 0.5 mm/m and 2 mm/m respectively. This avoidance strategy should also be applied to any upstream tributaries that provide a significant proportion of surface flow to THPSS. This approach is the most likely to prevent impacts to THPSS given the potential severity of impacts, difficulties in the accurate and confident prediction of impacts, and the ineffectiveness of other mitigation and management measures. Further, there is no currently available scientific evidence to demonstrate that remediation activities are able to successfully restore the ecological and hydraulic functions of these threatened ecological communities to preimpact condition. |
| | | The groundwater model is a regional scale model that provides generally robust predictions of mine groundwater inflows. These are reasonably described. However, due to the scale of the groundwater model, it is limited in its capability to predict groundwater related impacts to surface water systems including those affecting THPSS and proximal reaches of the Coxs River. This results in a low level of confidence in the predictions of impacts to Cox's River and THPSS baseflows described within the EIS. |
| | | There appears to be a high risk of severe impact to the EPBC Act listed (endangered) Temperate Highland Peat Swamps on Sandstone that is present directly above or laterally adjacent to the proposed longwall panels associated with the Centennial Coal mining proposal; with this risk being greater for the proposed Springvale Colliery than the Angus Place Colliery. |
| | | The evidence that longwall mining under the Newnes Plateau may have at least partially contributed to previous damage to the listed endangered ecological community in that area suggests that the likelihood of the risk being realised is also high. |
| | | The mitigation measures proposed by the proponent are unlikely to reduce the risk or the likelihood of the risk being realised to an acceptable level. |
| | | The hydrological requirements of the peat swamps are not well enough understood to accurately predict the cumulative impacts of longwall mining. |

| Area of Concern | Raised By | Summary of Issue |
|---|---|---|
| | | The proponent has not characterised existing surface water, groundwater and ecological conditions for the majority of THPSS within the proposed project area. Seasonal surface water flow and an assessment, or estimation, of the baseflow component of the Coxs River are not provided and are needed to enable the prediction of impacts to seasonal flows within, and interactions between, surface water and groundwater systems, including those associated with THPSS. This information would also improve predictions of discharge and baseflow losses within the Coxs River and the potential for downstream impacts to occur. |
| | | Does the EIS, and in particular the groundwater model and the treatment of subsidence and fracturing predictions, provide a reasonable assessment of the likelihood, extent and significance of impacts on overlying adjacent swamps? |
| | | The EIS, including the groundwater model, does not provide a reasonable assessment of impacts to THPSS. Confidence in the groundwater model's capacity to predict site specific impacts to individual THPSS is low. In particular the model scale is not appropriate to predict impacts to THPSS, and a number of THPSS are not included within the groundwater model and therefore groundwater related impacts to these swamps cannot be predicted. |
| | | Impacts to undermined THPSS have historically been severe, resulting in changes to the hydrological and hydrogeological regimes, vegetation composition and structure, and large reductions in THPSS extent. These changes have been significant and are considered to be beyond the ability of the ecological community to recover naturally. As yet, there is no scientific evidence or industry based results to indicate that such impacts to THPSS can be remediated successfully. |
| | | The subsidence related impacts affecting overlying and adjacent THPSS would be expected to include fracturing of underlying bedrock, a water storage capacity increase within the bedrock fracture network, a decrease in surface water flow provision from upstream tributaries and a corresponding decrease in standing surface water level. |
| | | Due to the low level of confidence in the groundwater model's capacity to predict hydrological impacts to individual THPSS, the likelihood, extent and significance of groundwater impacts to swamps cannot be determined with certainty. Swamps that are directly undermined or overlie structural lineaments are more likely to be severely impacted due to the instability of underlying strata and locally increased subsidence effects. Given the temporal variability and time lags with which impacts are observed in THPSS, the significance of groundwater impacts may not be readily determined for some time. |

| Area of Concern | Raised By | Summary of Issue |
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| | | The EIS states that fracturing up to 50 mm wide is predicted to occur within the shallow bedrock of THPSS wherever they are undermined. Impacts to THPSS are considerably more likely to occur where swamps are directly undermined. Fracturing to further THPSS and their upstream tributaries would be expected to occur where compressive and tensile strains exceed 0.5 mm/m and 2 mm/m respectively. Strain is caused by the horizontal movement of the ground surface relative to two fixed points. Tensile strain occurs where the distance between two points increases and compressive strain occurs where the distance between two points decreases. |
| | | Avoidance of undermining and locating longwalls such that compressive and tensile strains are below 0.5 mm/m and 2 mm/m respectively at THPSS sites are considered the most effective ways to manage the potential impacts to THPSS. This strategy should also be applied to any upstream tributaries that provide a significant proportion of surface flow to THPSS. |
| | | The proponent has stated that cracks are predicted to form within the sandstone substrate underlying many swamps within the project area. The proponent states that these cracks will naturally fill with soil and peat (self-ameliorate), and therefore impacts related to these bedrock fractures are “considered unlikely”. However, THPSS are exceptionally slow to self-heal or self-ameliorate. Examples of lowland swamps from the Southern Coalfields of New South Wales show that without attempted rehabilitation, self-amelioration is not evident within two lowland swamps over a 25 to 30 year period5. Based on a lack of supporting evidence and available literature, self-amelioration is not considered to be a reliable or effective remediation method. |
| | | The only known strategy to reduce the risk of impact to THPSS ecological communities within the project area would be to alter the mine layout such that swamps are not undermined by longwall panels and longwalls are sufficiently removed from THPSS such that tensile and compressive strains at THPSS sites are below 0.5 mm/m and 2 mm/m respectively5. This avoidance strategy should also be applied to any upstream tributaries that provide a significant proportion of surface flow to THPSS. This approach is the most likely to prevent impacts to THPSS given the potential severity of impacts, difficulties in the accurate and confident prediction of impacts, and the ineffectiveness of other mitigation and management measures. |
| Noise | Lithgow City Council | Noise monitoring and management should be implemented where possible. |

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| (Section 3.1.15) | NSW Health | There is increasing evidence that exposure to noise is associated with health effects. We recommend that the noise mitigation strategies listed in the application become part of the conditions of approval to ensure there are minimal impacts on the local community from noise. |
| Physical Impacts<br>(Section 3.1.16) | Commonwealth Department of the Environment (DotE) | The Department notes that the proposed project footprint borders the Greater Blue Mountains World Heritage Area (Gardens of Stone National Park) and that surface impacts resulting from longwall mining may impact on the values of this Area. |
| Planning Agreement/Contributions<br>(Section 3.1.17) | Lithgow City Council | Council would like the opportunity to enter into a Voluntary Planning Agreement for both projects. Council also has a Section 94A Contributions Plan which imposes a 1% Contribution on all developments over $200,000. Should the proponent not enter into a Voluntary Planning Agreement for the proposal then a condition should be placed on the consent requiring payment of a contribution in accordance with Council's Section 94A Contributions Plan. |
| Rehabilitation<br>(Section 3.1.18) | Division of Resources and Energy (DRE) | The Proponent shall rehabilitate the site to the satisfaction of the Secretary of the Department of Trade and Investment, or his delegate. Rehabilitation must be substantially consistent with the Rehabilitation Objectives described in the EIS and the Statement of Commitments in Chapter 11 of the EIS. |
| | | The Proponent must prepare and implement a Rehabilitation Plan. |
| | | The existing Mining Operations Plan (MOP) will need to be replaced by a new MOP. |
| | | It is noted that the final sentence on Page 456 states the final landform will comprise the domains of Woodland, Grassland and a Water Management Area. However, in the previous section 'Rehabilitation Outcomes', Grassland has now been removed from the post mining rehabilitation outcomes. It is unclear why the grassland rehabilitation outcome has been removed as it would appear to have been an appropriate final land cover for sections of the pit top site. |
| | | Domain 2 in Table 10.49 indicates Domain 2 as a Water Management Area, while previously this has been referred to as Domain 3. |
| | Lithgow City Council | A Rehabilitation Management Plan is to be prepared in consultation with Lithgow City Council and implemented for the project. |

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| | Commonwealth Department of the Environment (DotE) | Remediation strategies in areas affected by longwall mining are primarily designed to restore flows and the hydrological regime. Other remediation strategies have been focused on sealing fracture networks on cracked stream beds and have not addressed fractures occurring beneath peat sediments. The Department is unaware of any examples of THPSS impacted by longwall mining that have been successfully remediated. |
| | Independent Expert Scientific Committee | There is little evidence that the suite of remediation measures proposed would be effective in repairing damage to the endangered ecological community if the proposed longwall mining did lead to impacts such as fracturing of a peat swamp basin. Previous experience with implementation of such remediation measures has shown little or no success. |
| Stygofauna<br>(Section 3.1.19) | NSW Office of Environment and Heritage (OEH) | It is important to note that stygofauna (and potential stygofauna) were actually found. Since this was the first survey of its kind for stygofauna in the area, there is the potential for the species collected to be unique. Unfortunately the taxonomic level of identification is currently inadequate to investigate whether these animals are new to science, and the implications of potential impacts from longwall mining affecting groundwater aquifers in which the stygofauna exist cannot be ascertained. |
| Subsidence<br>(Section 3.1.20) | NSW Office of Environment and Heritage (OEH) | MSEC has provided no data, statistical analysis or graphics to support the factor of 10x maximum curvature used in their stress calculations. the derived maximum strains and levels of stress obtained by the DgS (2014) methodology should be used for subsidence predictions rather than the 10x maximum curvature calculation. |
| | | The potential for impacts generally result from differential movements (i.e. curvature and strain), rather than from vertical subsidence. It is expected that the compressive strains at the lineaments above the proposed LW1001 to LW1019 will be similar to those observed above the previously extracted longwalls at Angus Place and Springvale Collieries, which were typically between 5 mm/m and 15 mm/m. |
| | | Information should be provided on the height of fracturing that has occurred as a result of earlier Springvale and Angus Place mining operations. |
| | | OEH has concerns regarding predictions for stress, upsidence and valley closure. |
| | | MSEC provides no scientific evidence that diverted surface water re-emerges in the catchment. |
| | | The assessment of potential subsidence impacts to streams in the EIS is does not include a specific assessment of 3rd order streams. |

| Area of Concern | Raised By | Summary of Issue |
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| | | It is likely that fracturing of bedrock under the swamps and drainage of perched aquifers will also lead to a loss of flow in these 3rd order streams. |
| | | OEH does not support the definitions of cliff and minor cliff presented the Subsidence Impact Assessments. |
| | Division of Resources and Energy (DRE) | After reviewing the EIS, DRE is of the view that risks of mine subsidence related to the above-mentioned subsidence issues are similar to those at the mine's current mining operation and should be manageable through the Extraction Plan process. |
| | Commonwealth Department of the Environment (DotE) | On page 5 of the Springvale Subsidence Impact Assessment it is stated that diversion of surface water flows beneath the swamps could occur due to valley related upsidence movements, however, the likely impacts are likely to be low because the drainage lines upstream of the swamps are generally ephemeral and therefore surface water flows occur during and shortly after rainfall events. The EIS fails to identify a key concern that should diversion occur, the swamps will no longer have access to this water, which could have significant impacts on their long term survival. Many Australian ecosystems rely solely or mainly on ephemeral surface water flows. |
| | | Page 82 of the Angus Place Subsidence Report states that fracturing could occur in the top most bedrock in swamps directly above the proposed longwalls. The Report also states that the shrub swamps comprise significant quantities of sediment and fracturing of shallow bedrock beneath these swamps is likely to be filled with soil during subsequent flow events along the drainage lines. Examples of where this has been known to occur should be provided. |
| | | The incremental profile method utilised in the EIS provides reasonable predictions of subsidence likely to occur as a result of the proposed longwall design. However, there is a lower degree of confidence in subsidence predictions proximal to “type 1” and “type 2” lineaments, which are the shallow manifestations of deep, underlying faults. As a result, the EIS subsidence and flora impact assessments based on the subsidence predictions do not adequately consider the potential site specific subsidence impacts to overlying individual THPSS. |
| | | A series of lineaments (shallow manifestations of deep, underlying faults) have been identified within the geological strata of the project area and are, in some areas, several hundred metres wide. Four lineament types were identified, and two of these types (“type 1” and “type 2”) are considered important in determining the structural stability of the underground mining areas add the overlying geological strata. These lineament zones increase the risk and severity of subsidence in their vicinity. |

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| | | While the incremental profile method applied within the subsidence assessment generally provides reasonable predictions of subsidence parameters, there is low confidence in the approach of increasing subsidence predictions by 25 per cent in the vicinity of “type 1” and “type 2”structural lineaments. The EIS states, (Appendix D, p. 33), observed subsidence effects in the vicinity of these lineaments at the existing operations are highly variable and are, in places, up to eight times greater than predictions derived using this approach. Subsidence over previously mined longwall panels, in proximity to “type 1” and “type 2” structural lineaments, at the existing Angus Place operations contributed to severe impacts to overlying THPSS. |
| | | Based on the documentation provided in the EIS nine THPSS (including groups or swamp clusters) are located within the potential subsidence impact zone, and a number of these, such as Trail 6 Swamp and Tri Star Swamp, are proposed to be undermined. The EIS (p. 274) states that fracturing up to 50 mm wide is predicted to occur within the shallow bedrock of THPSS wherever they are undermined. Impacts to THPSS, such as those identified in paragraph 16, are considerably more likely to occur where swamps are directly undermined. Fracturing to further THPSS and their upstream tributaries would be expected to occur where compressive and tensile strains exceed 0.5 mm/m and 2 mm/m respectively. Strain is caused by the horizontal movement of the ground surface relative to two fixed points. Tensile strain occurs where the distance between two points increases and compressive strain occurs where the distance between two points decreases. |
| | | The risk and potential severity of impacts is higher for Tri Star Swamp and Trail 6 Swamp. These swamps are both proposed to be undermined with the resulting conventional subsidence predicted to be 1.9 and 0.95 m, respectively. Additionally, Tri Star Swamp is situated above a “type 2” structural lineament and longwall panels below Trail 6 Swamp are, in places, critical in width (longwall width to depth of cover ratio of 0.96). |
| | | Critical panel widths and structural lineaments were factors resulting in severe impacts to East Wolgan Swamp and Narrow Swamp, which were previously undermined on the Newnes Plateau. Impacts to East Wolgan Swamp and Narrow Swamp have been identified in literature and also described within the EIS (Appendix D, p. 77). Impacts included rapid decline of groundwater, peat desiccation and associated slumping, loss of natural surface flows through swamp channels and almost complete decline of THPSS flora species. Surface flows were found to be flowing into the subsidence induced bedrock fracture network and not resurfacing downstream. At East Wolgan Swamp, it was later identified that this water was pooling within bedding separation of strata approximately 60 to 70 m underneath the swamp. |

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| | | Avoidance of undermining and locating longwalls such that tensile and compressive strains are below 0.5 mm/m and 2 mm/m respectively at THPSS sites are considered the most effective ways to manage the potential impacts to THPSS5. This strategy should also be applied to any upstream tributaries that provide a significant proportion of surface flow to THPSS. |
| | | The proponent has designed the longwall mine layout to avoid some THPSS (Twin Gully Swamp and several unnamed swamps), and to minimise subsidence through narrowing of several longwalls and increasing chain pillar widths. However, a number of THPSS remain overlying or within the potential subsidence impact zone of the proposed longwalls. Fracturing in the bedrock below these swamps is expected to occur where tensile and compressive strains caused by conventional subsidence exceed 0.5 mm/m and 2 mm/m respectively5. Fracturing within the bedrock of tributaries upstream of THPSS is also predicted to occur. The risk of bedrock fracturing is reduced by minimising the exposure of bedrock to strain. Ensuring that tensile and compressive strains are below 0.5 mm/m and 2 mm/m respectively at THPSS sites is the only measure known to prevent impacts to THPSS5. To avoid impacts to the surface water hydrological regime of THPSS, this avoidance strategy would also need be applied to upstream tributaries that provide a significant proportion of surface water flows to downstream THPSS. |
| | | The only known strategy to reduce the risk of impact to THPSS ecological communities within the project area would be to alter the mine layout such that swamps are not undermined by longwall panels and longwalls are sufficiently removed from THPSS such that tensile and compressive strains at THPSS sites are below 0.5 mm/m and 2 mm/m respectively. This avoidance strategy should also be applied to any upstream tributaries that provide a significant proportion of surface flow to THPSS. This approach is the most likely to prevent impacts to THPSS given the potential severity of impacts, difficulties in the accurate and confident prediction of impacts, and the ineffectiveness of other mitigation and management measures. Further, there is no currently available scientific evidence to demonstrate that remediation activities are able to successfully restore the ecological and hydraulic functions of these threatened ecological communities to pre-impact condition. |

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| | | The proponent has stated that cracks are predicted to form within the sandstone substrate underlying many swamps within the project area. The proponent states that these cracks will naturally fill with soil and peat (self-ameliorate), and therefore impacts related to these bedrock fractures are "considered unlikely". However, THPSS are exceptionally slow to self-heal or self-ameliorate. Examples of lowland swamps from the Southern Coalfields of New South Wales show that without attempted rehabilitation, self-amelioration is not evident within two lowland swamps over a 25 to 30 year period. Based on a lack of supporting evidence and available literature, self-amelioration is not considered to be a reliable or effective remediation method. |
| Surface Disturbance<br>(Section 3.1.21) | Division of Resources and Energy (DRE) | The proponent shall carry out all surface disturbing activities in a manner that, as far is reasonably practicable, minimises potential for dust emissions and shall carry out rehabilitation of disturbed areas progressively, as soon as reasonably practicable, to the satisfaction of the Secretary or his delegate. |
| Traffic Management<br>(Section 3.1.22) | Roads and Maritime Services (RMS) | The intersection of Mine Access Road with the Castlereagh Highway should be upgraded to a Channelised Right Turn in accordance with Part 4A Austroads Guide to Road Design 2010. The intersection upgrade is to be completed prior to 2017, or when the Castlereagh Highway peak traffic volume exceeds 400 vehicles per hour should that occur earlier than 2017. |
| | | The intersection upgrade is located on a state road and the developer will be required to undertake private financing and construction of works on a road in which Roads and Maritime has a statutory interest. A formal agreement in the form of a Works Authorisation Deed (WAD) is required between the developer and Roads and Maritime prior to works commencing. |
| | Lithgow City Council | A Traffic Management Plan be prepared in consultation with Lithgow City Council and implemented for the duration of the operational phase at each project site. |
| | | All construction heavy vehicle trips to/from the Newnes State Forest sites be undertaken during daylight hours, which would generally require them to occur between 6.00am and 6.00pm. |

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| Water Flows<br>(Section 3.1.23) | NSW Environment Protection Authority (EPA) | The monitoring of flows at the NSW Office of Water (NOW) gauging station on the Coxs River upstream of Lake Wallerawang indicate that median flow in the Coxs River at this point is approximately 13.3 ML/day. The proposed discharge from LDP009 (30ML/day rising to 50ML/day if both mine projects are approved) means that the discharge is approximately twice the median flow in the Coxs River at this point and is projected to increase to almost 4 times the median flow in the Coxs River at this point. Further, some of the flows measured at the NOW gauge actually already include discharges from Centennial's other operations in the Upper Coxs River catchment (i.e. Angus Place). |
| Water licencing<br>(Section 3.1.24) | NSW Office of Water (NOW) | The take of surface water requires further assessment. Assessment should consider:<br>• Capture of surface run off from dams<br>• Indirect losses or reduction in surface water flows due to impacts from underground mining<br>• Reduction of storages of swamps due to impacts from underground mining. |
| | | The EIS does not include details of any unregulated category licences held by the proponent or any discussion on how they are planning to comply with the WMA requirements. The proponent must identify licensable take and hold unregulated category access licences from the relevant water source of the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011. |
| | | Any ongoing take of water post-closure of the mine will need to be accounted for by holding or maintaining licences. |
| | | The proponent must maintain records of annual water take from water sources impacted by the development and reported in the annual environmental report. |
| | | It is not clear from the EIA/GIA documentation that the losses of surface baseflow have been included in the total estimate of groundwater take. This should be clarified during licensing. |
| Water Management<br>(Section 3.1.25) | NSW Environment Protection Authority (EPA) | Much of the proponent's reasoning for discharging the large volumes of untreated mine water is based on a stated demand for mine water which currently does not exist, and any future use is subject to changes to the operation of the nearby power stations. |

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| | | The recent situation of Wallerawang Power Station, with one electricity generation unit being closed permanently and the other one mothballed until further notice, has resulted in about a halving of the demand for water usage by Energy Australia for use by this power station. The 40 ML/day requirement for Mount Piper is less than the daily maximum volume of mine water to be produced by the proposed mine expansion. |
| | | Mine water until recently was only transferred to the Wallerawang Power Station via the dedicated mine water transfer pipeline SDWTS. As the SDWTS does not continue on to Mount Piper, mine water cannot be transferred directly to Mount Piper Power Station. In addition, the EPA understands that Energy Australia has expressed no interest at present in utilising the mine water and no interest in extending the SDWTS to the Mount Piper Power Station. With Wallerawang Power Station currently not operating the SDWTS is now no longer being utilised and most mine water (all Springvale and a portion of Angus Place) is now currently discharged through the Springvale Colliery licensed discharge point LDP009 (up to approximately 30 ML/day) to the Coxs River catchment with a very low level of treatment (i.e. for suspended solids). |
| | | The EISs can be considered to be highly misleading because the overwhelming bulk of the water impact assessment assumes the SDWTS is operating when it currently is not, and its future is dependent on the operational capacity of Wallerawang Power Station. Both the Angus Place and Springvale EISs have sections detailing water balance and salt balance modelling for mine water discharges. However, since both models have assumed that there are transfers via the SDWTS which is either not happening or based on changed circumstances at Wallerawang Power Station, the modelling and subsequent conclusions are flawed. Water and salt balances for the Coxs River catchment need to be redone under the real proposed scenario which is direct discharge of 30MLlday (rising to 50MLlday if both mine projects are approved) of poorly treated, high salinity mine water into the Coxs River catchment. |
| | | The discharge limits that have been applied to mine water discharges (LDP001 and LDP009) to the Coxs River by the EPA, were established on an interim basis to enable the mines to continue to operate while undertaking works identified in pollution reduction programs (PRPs) attached to both licences to identify and implement a solution to the mine water discharge quality. The PRPs have required either the development of options to cease water discharges (such as redirecting mine water at Angus Place backed into old underground workings) or to develop options to treat mine water to ensure any discharge can meet the ANZECC (2000) trigger value for upland rivers of 350 µS/cm. |

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| | | To date no option(s) to cease or treat the mine water has been developed by Centennial Coal. Centennial's approach to mine water is to continue and to increase the discharge from LDP001 and LDP009 to the environment for the next 3 decades without treating the mine water to an appropriate standard. The EPA's ongoing programs are not based on the continuation of the discharging of high volumes of potentially toxic, saline mine water often containing high (relative to ANZECC) levels of metal contaminants to the receiving environment of the Upper Coxs River catchment. Furthermore, it is misleading to suggest that a discharge of this magnitude and poor quality directly into Coxs River tributary streams will have a neutral or beneficial effect on water quality in Sydney's drinking water catchment or the upper Coxs River and its tributaries in terms of hydrology and aquatic health. |
| | | Discrepancies identified in what the Project estimates will be the mine water discharge volumes from both Angus Place and Springvale combined for each year. The total volume of predicted mine water each year to be discharged to LDP's and the SDWTS from both mines should be the same. |
| | NSW Office of Environment and Heritage (OEH) | OEH is aware that electricity generation from Wallerawang Power Station has been suspended, a process that began in early 2014. The EIS has not been updated to reflect this change in circumstances. OEH assumes, therefore, that the proposal would result in a significant increase in waste water being discharged via the licenced discharge point into Coxs River, with none of the mine water being utilised for power production. OEH considers that the EIS and associated documents need to be revised to take into account the closure of Wallerawang Power Station. In particular, the expected discharges and associated impacts on the Coxs River need to be re-assessed. |
| Water Quality<br>(Section 3.1.26) | Sydney Catchment Authority (SCA) | Salinity predictions have not been undertaken for scenario (1) no upgrade of SDWTS and (2) no SDWTS availability and all mine discharges (28.6ML/day) being discharged to the Kangaroo Creek and Coxs River. |
| | | The model predictions for the average Coxs River salinity should include an envelope around the average showing 10th and 90th percentiles. |
| | | There is no assessment on whether elevated salt levels are likely in the Coxs River where it enters Lake Burragorang. |
| | | The EIS states that based on data available, the estimated error in predictions is approximately ±±30%30%. It is not clear if the upper limits would still fall within an acceptable level of impact. |

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| | | The SCA is concerned about the proposal to transfer mine water to the local power stations (Mt Piper and Wallerawang) which the SCA understands will have limited and reduced availability due to the recent decision to place the Wallerawang power station in care and maintenance. As a consequence, there may be additional discharges of mine water into receiving watercourses of approximately 30 ML/d from this project. These discharges would further impact the quality of receiving waters and the EIS has not addressed this issue. The SCA considers that the Proponent should· either consider an alternative opportunity for mine water reuse or treatment of mine water to a higher level before discharge. |
| | | Salinity predictions have been undertaken upstream of Lake Wallace, not where discharge occurs in Swayers Swamp Creek (LDP009). No predictions are made on what would be an expected increase in salinity compared to the current conditions at the discharge point LDP009 and impacts on water quality in Coxs River downstream of Lake Wallace. The model predictions for average Coxs River salinity should include an envelope around the average showing 1Oth and 90th percentiles. |
| | NSW Environment Protection Authority (EPA) | The EISs also do not adequately consider the environmental health effects of discharging 30ML/day (rising to 50ML/day if both mine projects are approved) of poorly treated mine water into the Coxs River catchment. |
| | | The surface water impact assessment provides a very poor characterisation of the effluent discharged through Springvale's Licenced Discharge Point 9 (LDP009). There is no time series for water quality or flow for LDP009 discharges provided in the EIS for Springvale. Of note, though based on the limited data that is available, is that LDP009 already exceeds ANZECC (2000) default water quality criteria for Conductivity and Aluminium (for protection of 95% of species). |
| | | Based on the data presented and EPA/OEH data on previous LOP discharges, the poorly treated mine water is also potentially toxic to aquatic biota. Toxicity assessments have not been done for the Springvale and Angus Place expansion EISs. On 8 May 2014, the EPA/ Office of Environment and Heritage (OEH) collected water samples from the LDP009 discharge and the preliminary toxicity screening results indicate toxicity to at least one species (cladoceran). Earlier toxicity testing by Delta Electricity also raised concerns about the toxicity of the Springvale mine water and the EPA will be following up these matters with Centennial to assess the likely causes and measures to reduce any toxicity. |

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| | | The Angus Place EIS acknowledges that salinity in the Coxs River is currently in excess of ANZECC guidelines for the protection of aquatic ecosystems and that modelling indicates that salinity will increase due to the extension of Angus Place Colliery. However, the EIS maintains that aquatic and riparian ecosystems are adapted to this environment and predicated salinity is within the range experienced historically in the Coxs River catchment. These conclusions are not supported by the research work of Department of Environment, Climate Change and Water scientists in September to October 2009 that had found that salinity levels in the Coxs River had increased since the 1980's, and that the aquatic ecosystems were now dominated by pollution tolerant taxa, and that Kangaroo Creek downstream of the Angus Place discharge at LDP001 was found to have an impoverished diversity of macroinvertebrate fauna. |
| | | There is also a major issue with contaminant load because all the mine water flows to the Coxs River and then into Lake Wallace and Lake Lyell. Some of this water also ultimately flows to Warragamba Dam. The potential salt load alone (7,500 to 13,000 tonnes per annum) is extremely large for a freshwater system. The EIS has not appropriately considered the potential impacts of the very large contaminant loads proposed to be discharged to the receiving environment. |
| | Commonwealth Department of the Environment (DotE) | The cumulative water quality impacts of Angus Place and Springvale mine water discharges to the Coxs River, an important contributing source to Sydney's drinking water supply, were not modelled for all relevant contaminants, did not consider all likely discharge conditions, and are therefore not accurately and reasonably described. |
| | | Salinity was the only water quality variable modelled for cumulative impacts. The cumulative impact of other contaminants was not provided, even though the EIS states (Appendix C within Appendix F) that levels of copper, zinc, nitrogen and phosphorus have been elevated above ANZECC 95th percentile protection level for slightly to moderately disturbed ecosystems. The contributing water quality impacts to Coxs River from other mines in the area are not quantified. |
| | | Water quality impact estimations for the Coxs River for both Angus Place and Springvale were conducted for scenarios that included the transfer of large volumes of water through the Springvale Delta Water Transfer Scheme (SDWTS) to the Wallerawang Power Station. This may no longer be a viable option because the Wallerawang Power Station has been placed into care and maintenance. Increased discharge volumes resulting from reduced demand from the Wallerawang Power Station would affect the outcome of the cumulative water quality impact assessment and should be considered as a potential discharge scenario. |

| Area of Concern | Raised By | Summary of Issue |
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| | | The proponent's estimation of downstream impacts was limited to site water balance and cumulative salt mass balance modelling that did not model impacts beyond the upper Coxs River catchment (i.e. not downstream of Lake Lyell). In addition, the existing condition of the Coxs River was not adequately described and the downstream impact modelling that was undertaken included transfer of large volumes of water through the SDWTS to the Wallerawang Power Station, which may no longer be a viable option. |
| | | Water quality impact estimations for the Coxs River need to consider increased discharge volumes to Coxs River resulting from reduced demand from the Wallerawang Power Station. The assessment of mine water discharges needs to consider the resulting cumulative concentrations of a range of contaminants, in addition to salt, within Coxs River. |
| | | Are the cumulative water quality impacts of discharges to the Coxs River accurately and reasonably described? |
| | | The cumulative water quality impacts of Angus Place and Springvale mine water discharges to the Coxs River, an important contributing source to Sydney's drinking water supply, were not modelled for all relevant contaminants, did not consider all likely discharge conditions, and are therefore not accurately and reasonably described. |
| | | Salinity was the only water quality variable modelled for cumulative impacts. The cumulative impact of other contaminants was not provided, even though the EIS states (Appendix C within Appendix F) that levels of copper, zinc, nitrogen and phosphorus have been elevated above ANZECC 95th percentile protection level for slightly to moderately disturbed ecosystems. The contributing water quality impacts to Coxs River from other mines in the area are not quantified. |
| | | Water quality impact estimations for the Coxs River for both Angus Place and Springvale were conducted for scenarios that included the transfer of large volumes of water through the Springvale Delta Water Transfer Scheme (SDWTS) to the Wallerawang Power Station. This may no longer be a viable option because the Wallerawang Power Station has been placed into care and maintenance. Increased discharge volumes resulting from reduced demand from the Wallerawang Power Station would affect the outcome of the cumulative water quality impact assessment and should be considered as a potential discharge scenario. |

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| | | Is the information provided sufficient to predict any changes to either water quality or water quantity in the Coxs River at Kelpie Point which would arise as a result of the mining operation? (Kelpie Point – station no. 563000 – is located on the Coxs River close to its entry location into Warragamba Dam. The Sydney Catchment Authority has undertaken flow and quality monitoring at this location for extended periods). |
| | | The proponent's estimation of downstream impacts was limited to site water balance and cumulative salt mass balance modelling that did not model impacts beyond the upper Coxs River catchment (i.e. not downstream of Lake Lyell). In addition, the existing condition of the Coxs River was not adequately described and the downstream impact modelling that was undertaken included transfer of large volumes of water through the SDWTS to the Wallerawang Power Station, which may no longer be a viable option. |
| | | What are the predicted changes to water quality water quantity in the Coxs River at Kelpie Point and what are the consequences for stored water within Warragamba Dam? |
| | | Water quantity and quality changes in the Coxs River at Kelpie Point cannot be reliably estimated based on the information presented in the EIS documentation, as detailed in the response to Question 7. For similar reasons, the consequences for stored waters in Warragamba Dam also cannot be reliably estimated from information in the EIS. |
| | | Protection of the long-term ecosystem health of Coxs River should include consideration of the ANZECC and ARMCANZ (2000) Guidelines, through an agreed set of approval trigger discharge values and management protocols. Where salinity or other contaminants of concern are likely to exceed trigger values, management and treatment options may include, but are not limited to, reverse osmosis and ion exchange technologies. |
| | Office of Agricultural Sustainability and Food Security (OAS&FS) | It is important however that the current water quality conditions will be maintained and it is recommended that this commitment is reflected in the conditions of approval. |

### Table 2 - Summary of Special Interest Group Submissions

| Area of Concern | Raised By | Summary of Issue |
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| Biodiversity Strategy<br>(Section 3.2.1) | Lithgow Environment Group (LEG)<br>And<br>The Colong Foundation for Wilderness | The Director General's requirements for the offset strategy requires Centennial Coal to develop 'An offset strategy, which is clearly quantified, to ensure that the development maintains or improves the terrestrial and aquatic biodiversity values of the region in the medium to long term'. Centennial Coal and RPS have taken a miserly interpretation of this direction. |
| | | Only Matters of National Environmental Significance and Endangered Ecological Communities are considered in relation to indirect impacts. For example, the offset analysis has not been applied to the 200 hectares of the Birds Rock Flora Reserve that will be damaged by the proposed mining. |
| | | Centennial claim that 'the residual impacts following avoidance and mitigation are not significant, as such direct offsets are not required'. Centennial, having found themselves not responsible for impacts, magnanimously offers an offset 'provision of land to compensate potential impacts' to these nationally endangered swamps. |
| | | Centennial Coal proposes to protect for the conservation by setting aside 342.2 hectares of former farmland in the Capertee Valley it claims may have 160 fauna species and various endangered communities. None of the proposed offset compensate 'like-for- like' the loss of nationally endangered swamps or the impacted Tablelands Snow gum - Black Sallee, - Candlebark and Ribbon Gum Grassy Woodland on or below Newnes Plateau. |
| | | Lot 135 also covers the new Angus Place Vent Shaft No 2 and Springvale Bore 8, as well as the Western Coal Services Upgrade Project. The proposed offset is also to cover, for reasons that are not explained, the Clarence Reject Emplacement Area VI. |
| | | The total of 100 hectares of swamps and 31.5 hectares of native forest cleared for infrastructure for the two current mine extensions as explained in the tables 11 to 15 is misleading. It is unclear how much clearing and so-called indirect impacts on EEC are being compensated by this one offset, perhaps an additional 200 hectares, perhaps much more land is directly impacted. |
| | | The omission of the total land area to be cleared and that 'indirectly impacted' means that the offset analysis in Appendix I does not comply with the Director General's requirement for clear quantification. To be clear, the offsets for Angus Place Vent Shaft No 2 and Springvale Bore 8, Western Coal Services Upgrade Project and the Clarence Reject Emplacement Area VI are not quantified. |
| | | Lot 135 DP 755757 is only 86.7 hectares in size (App I, section 6.2 and Table 17), so the earlier reference to '342.2 hectares of critically endangered ecological community and habitat for over 160 fauna species' on page 3 is wrong. The area of endangered ecological community is very small. |

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| | | Table 18 reveals that only 10 hectares of a critically endangered Box Gum Woodland and Derived Native Woodlands exists on the site. All the claimed threatened animals listed in Table 18 are not recorded from observation, rather it is claimed that the woodlands are 'very likely' to provide habitat for such wildlife (page 23 and note that title of Table 18 is species recorded in the site and locality. |
| | | As non-threatened degraded woodland species are used for the credits, then non-threatened species for the indirectly impacted woodlands and forests on Newnes Plateau should also be part of the offset calculation. The proposed Angus Place extension covers 2,638 hectares and the proposed Springvale extension covers 1,860 hectares (including the 131.5 hectares of EECs and clearing). These impacted forests are part of a reserve proposal initially put forward by the National Parks and Primitive Areas Council in 1932. |
| | | The offset analysis is further confused by the statement that 'Both the Springvale Mine Project and the Angus Place Project will not impact upon 'credit species' and therefore only ecosystem credits are required' (Page 30, App. I). This statement is wrong. Giant Dragonfly, Blue Mountains Sink, and Boronia deanei will be impacted causing the loss of local populations. |
| | | The offset analysis does not properly consider naturally rare ecosystems, like the three swamp EECs and other Groundwater Dependent Ecosystems. In Table 21 all the Temperate Highlands Peat Swamps on Sandstone (BioBank Units 562 and 592, equivalent to MU's 50,51 and 52), for example, receive a total score of only -1,306 units and this is for damaging 100 hectares in 63 near-pristine EEC swamps. This score compares with a total score of -1,424 units given for clearing 23 hectares open forest and shrubby woodlands at the proposed Angus Place extension for facilities. The latter result seems reasonable for common sclerophyll forests and woodlands, the former result is grossly underestimated for swamps extending over five times the area being impacted by a key threatening process. |
| | | The Ecosystem Credit Balance in Table 21 does not properly recognise the important value of these swamps and is completely unacceptable. The analysis demonstrates that reducing ecosystems to numbers does not inform decision making, but rather confuse the issue. |
| | | The offset analysis is deficient as the values for known populations of threatened species at risk of local extinction are not individually calculated. |
| | | The statement regarding MU20 made on page 32 and in Table 23 is not reported in Table 17 and appears as double counting. It should be ignored. |

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| | | Eliminating the 8 hectares of cleared derived grassland that appears to be cattle paddocks leaves just 2 hectares of a critically endangered community in the proposed offset. The proposed exchange of 2 hectares of critically endangered box gum woodlands on farmland for 100 hectares of diverse, intact EEC swamps is presented in a misleading manner. |
| | | LEG does not consider the proposed research to be an appropriate supplementary measure for the loss of threatened plants and animals through development. Recovery plans and research are needed, but not at the expense of retaining important habitat. |
| Compliance<br>(Section 3.2.2) | Lithgow Environment Group (LEG) | Between 2000 and 2012 1039 Incidents of Licence Non-compliance were recorded under Environmental Protection Licences (EPLs) issued to Angus Place (EPL 467) and Springvale Colliery (EPL 3607) under the Protection of the Environment Operations Act 1997 (POEO Act). None of these Non-compliances, Penalty Notices, or Pollution Reduction Notices are mentioned anywhere in the EIS. Why not? |
| Consultation<br>(Section 3.2.3) | The Colong Foundation for Wilderness | None of the Colong Foundation's concerns were properly addressed. The Colong Foundation has not been approached by Centennial for a meeting in the last four years. Very few, if any, of the concerns raised by the Colong Foundation have been 'closed out' as suggested by Centennial in Table 7.1. The claim that 'Centennial will continue to consult and engage with these groups to achieve outcomes of the Consultation Strategy' has not been the Colong Foundation's experience in the last four years. |
| Ecology<br>(Section 3.2.4) | Nature Conservation Council of NSW (NCC) | The sandstone rock supporting the 41 nationally endangered swamps, and particularly the 11 shrub swamps affected by the proposal, will also develop a large number of fractures. Centennial predicts these cracks to be 5 to 50mm wide And 10 to 15 metres deep. All these nationally endangered swamps will dry Out and the peat soils that support these swamps will decompose. Over a period of years eucalypts and banksias will migrate into these dying swamps as they evolve to dry land communities. |
| | Blue Mountains Conservation Society (BMCS) | The consultants have asserted 'that any effects on potential populations of the endangered Adams Emerald Dragonfly will be insignificant'. It is impossible to make such a statement, considering that there have never been any ecological studies of this species and limited aquatic sampling was undertaken for this project. |
| | | The BMCS strongly supports the consultants' recommendation to undertake more comprehensive, and better designed, pre-mining surveying, and finer resolution taxonomic identification of stygofauna; such surveying must be implemented if this project proceeds to ensure that the diversity of stygofauna is properly assessed and potential risks of the project determined. |

| Area of Concern | Raised By | Summary of Issue |
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| | | One of the more important components of the Newnes Plateau environment is the system of shrub swamps (NPSS). The expansion of these mines would put at risk 17 swamps listed as nationally endangered, plus 31 hanging swamps. These swamps store water and release it gradually, maintaining stream flow even in drier periods. The loss of water into cracked streambeds upstream of, or under, these swamps leads to their desiccation and the complete destruction of the ecosystem in each affected valley. |
| | | Dr Baird disputes the conclusion of the consultants that there will be no significant impact in relation to the Key Threatening Process of subsidence from longwall mining. |
| | The Colong Foundation for Wilderness | Newnes State Forest has only been subjected to selective logging in certain places, and is mostly unlogged old growth forest, contrary to the claims on page 97, s 2.8.1 in Vol. 1 of the EIS. The claim that 'as a consequence of forest harvesting and fires, large areas of forest are relatively young with a low to moderate density of hollow-bearing trees' is an overstatement. These eucalypt forests and woodlands are adapted to wild fire and mostly old-growth with a high density of hollows. Further, the sheltered gully forests offer protection for wildlife and even the hottest fires do not entirely burn Newnes Plateau due to its dissected, rocky terrain. The overall importance of this forest should not be discounted as claimed by Centennial Coal. |
| | | Sandstone supporting the 41 nationally endangered swamps, and particularly the 11 shrub swamps affected by the proposal, will also develop a large number of fractures. Centennial predicts these cracks to be 5 to 50mm wide and 10 to 15 metres deep. All these nationally endangered swamps will dry out and the peat soils that support these swamps will decompose. Over a period of years eucalypts and banksias will migrate into these dying swamps as they evolve to dry land communities. |
| | Lithgow Environment Group (LEG) | Centennial distinguished plant communities that are allegedly indirectly impacted from those that are directly impacted. By indirectly impacted, Centennial means plant communities that have been subjected to longwall mining where it claims there is no significant impact to these communities. Notwithstanding the fact that longwall mining is a Key Threatening Process for nationally threatened swamps, Centennial has convieniently found that longwall mining is 'unlikely' to have an impact on these swamps. |
| | | The Lithgow Environment Group disputes that the impacts on the three EECs that comprise the Temperate Highlands Peat Swamps on Sandstone (THPSS) are indirectly impacted by the proposed longwall mining operations. Longwall mining is a Key Threatening Process and is likely to directly impact on THPSS through mine subsidence. Damage to swamps above the area of direct influence of the mining operations is clearly a likely impact. |

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| | | Centennial claims the proposed longwall mining will have no likely cause extinction for local populations of the Giant Dragonfly, Blue Mountains Skink, and Boronia deanei due to the drying out of nationally endangered swamps that paradoxically would be a direct impact of mining. The analysis of the impact on these species is not unlikely or low, as claimed, but likely as longwall mining is a key threatening process to the swamp habitat in with they live. |
| | | LEG believes that the monitoring of the nationally endangered swamps is misleading and that proper mapping of these swamps is still incomplete after decades of ineffective management. Despite the expense, the mapping is inadequate so that dramatic changes to mined vegetation communities over time have not been reported. |
| | | The swamps to be impacted upon by the proposed mining are the best remaining on Newnes Plateau. The reported findings in Table 2 to Table 5 (App. I) are inaccurate and misleading in relation to swamps and the abovementioned species found within them as they are inconsistent with the evidence. |
| | | The claim in Appendix I that the proposed mining is consistent with the threat abatement plan for Blue Mountains Skink is wrong, as the impacts are not adequately mitigated by the proposed longwall mining arrangements. |
| | | In Table 4 of Appendix I that bulldozing an unnecessary road and ten metre wide pipeline easement through a Tablelands Snow gum - Black Sallee - Candlebark and Ribbon Gum Grassy Woodland is unlikely to have an adverse impact on this Threatened Ecological Community is also wrong. |
| | | The analysis regarding frog impacts in Table 2 to Table 5 is wrong, as it assumes that swamps and streams are unaffected by the proposed longwall mining. |
| | | Swamp ecosystems cannot be replanted or repaired following damage by longwall mining. |
| | Stop Coal Seam Gas Blue Mountains (SCSGBM) | Important terrestrial and stream environments in this significant part of the Gardens of Stone region must not be damaged by longwall mining but instead protected in a state conservation area. |
| | | The sandstone strata supporting the 41 nationally endangered swamps, including the 11 shrub swamps must not be fractured. |
| | | The sandstone strata supporting the 22 nationally endangered swamps, including the 7 shrub swamps must not be fractured. |

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| Economic<br>(Section 3.2.5) | The Australia Institute (TAI) | Various - TAI raised a number of concerns in relation to the adequacy of the Economic Assessment for the Project in the context of:<br>• Its compliance with 'state and federal guidelines' for preparation of cost benefit analyses; and<br>• Its failure to 'meet standards expected in the economics profession'. |
| General<br>(Section 3.2.6) | Blue Mountains Conservation Society (BMCS) | The proposed 15 year Consent Period is far too long given the history of 'unforeseen' impacts associated with Angus Place and Springvale Colliery's including cliff falls, swamp deaths, and water quality breaches. Planning consent should be limited to a maximum of 5 years, and must be subject to performance 'triggers' that ensure the health and integrity of nationally endangered swamps, the Coxs River and Sydney Drinking Water Catchment, and national and World Heritage values. If the trigger levels are exceeded then the Consent should be reviewed to address any failures. |
| | Stop Coal Seam Gas Blue Mountains (SCSGBM) | The Angus Place and the adjoining Springvale mine extension proposals must be subject to a Planning Assessment Commission review with concurrent Public Hearings. |
| Historic Impacts<br>(Section 3.2.7) | Nature Conservation Council of NSW (NCC)<br>Blue Mountains Conservation Society (BMCS)<br>The Colong Foundation for Wilderness<br>Lithgow Environment Group (LEG) | Various special interest groups have raised concerns regarding a number of impacts considered to be attributable to the mining operations of Angus Place Colliery. These historic issues raised can be summarised into 5 specific areas which include:<br>• Loss of water flow in creeks as a result of subsidence cracking;<br>• Changes to ecological communities;<br>• Impacts to water quality;<br>• Impacts to swamps; and<br>• Cliff falls. |
| | Nature Conservation Council of NSW (NCC) | Centennial Coal must not be allowed to simply replicate the damage it has already caused to nationally threatened upland swamps on the Newnes Plateau for which it was required by the Commonwealth Government to pay $1.45 million in reparations. |
| | Blue Mountains Conservation Society (BMCS) | Local mining history has demonstrated that subsidence damage and/or eco-toxic mine water effluent discharges from Angus Place and Springvale Colliery's have caused irreparable damage to a Federally Listed Endangered Ecological Community THPSS at Junction Swamp, Narrow Swamp, East Wolgan Swamp, Kangaroo Swamp, and Lamb's Creek Swamp. That is clearly an unacceptable situation. |

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| | Lithgow Environment Group (LEG) | In addition to mine subsidence and mine water discharge damage there are other mine related impacts to endangered swamps which must be avoided. For example, LEG believes that the trail bike tracks below running from Campbell's Road down into East Wolgan Swamp were initially started by Consultants monitoring for Springvale and/or Angus Place Colliery, and subsequently have been used by other trail bike riders. The resultant erosion gullies are very deep and is causing localised drying out of a hanging swamp. We believe that Centennial should be required to remediate the tracks put in by their Consultants. |
| | | Bushfire is a serious problem for damaged swamps, as the peat can burn deeply, can massively accelerate erosion, and subsequently affect natural regeneration. Centennial's rehabilitation efforts at East Wolgan Swamp could all be gone in a matter of minutes. It is better not to damage swamps in the first place, but when they have been damaged some fire management planning must be undertaken by those responsible. |
| | Stop Coal Seam Gas Blue Mountains (SCSGBM) | Centennial Coal must not be allowed to simply replicate the damage it has already caused to nationally threatened upland swamps on the Newnes Plateau for which it was required by the Commonwealth Government to pay $1.45 million in reparations. |
| Mine Design<br>(Section 3.2.8) | The Colo Committee | Centennial Coal must be required to consider alternative bord and pillar mining methods for its proposed Angus Place extension. Centennial's Airly mine in the Capertee Valley operates to a depth of 405 metres underground in the same geology. If Centennial can operate Airly Colliery as a bord and pillar mine, then it can also operate Springvale mine in this manner. |
| | | The intensity of longwall mining is reduced so that all nationally endangered swamps are protected – this includes significantly narrowing longwalls in the northern longwalls 416 to 422 to prevent surface cracking under the best developed, largest and most intact swamps on Newnes Plateau; Shortening longwalls 432, 431, 430 and 429 to prevent damage to the Marrangaroo swamps, and shortening longwalls 425 and 426 to prevent Paddys Creek Swamp; Longwall 501 should also be shortened to protect cliffs and pagodas; |
| | Blue Mountains Conservation Society (BMCS) | Bord and pillar is a clearly more benign process, and has been practiced at Centennial's nearby Clarence Colliery. However, in this instance, the mining method was chosen for reasons of engineering safety (the stope back was too solid to collapse in a controlled manner) rather than any display of environmental sensitivity. |

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| | | The intensity of longwall mining is reduced so that all nationally endangered swamps are protected – this includes significantly narrowing longwalls in the northern longwalls 416 to 422 to prevent surface cracking under the best developed, largest and most intact swamps on Newnes Plateau; shortening longwalls 432, 431, 430 and 429 be incorporated in order to prevent damage to the Marrangaroo swamps, shortening longwalls 425 and 426 to prevent Paddys Creek Swamp; and longwall 501 should also be shortened to protect cliffs and pagodas. |
| | The Colong Foundation for Wilderness | The mining footprint must be significantly lessened and mining methods reduced in intensity to protect Carne Creek, pagodas, cliffs and the nationally endangered swamps of the proposal area. Centennial Coal must be required to consider alternative bord and pillar mining methods for the proposed extension to Springvael Springvale Colliery. Centennial's Airly Mine in the Capertee Valley operates to depth of 405 metres in the same geology, which includes bad mine roof conditions and many structural features. If Centennial can operate Airly Colliery as a bord and pillar mine, then it can also operate Springvale mine in this manner. |
| | Lithgow Environment Group (LEG) | The mining footprint of the Springvale Mine Extension must be significantly lessened and the intensity of mining methods reduced to protect nationally endangered swamps, Carne Creek, pagodas and cliffs. Centennial Coal must be required to consider alternative bord-and-pillar mining methods in these environmentally sensitive areas. |
| | | The intensity of longwall mining should be reduced so that all nationally endangered swamps are protected – this includes significantly narrowing longwalls in the northern longwalls 416 to 422 to prevent surface cracking under the best developed, largest and most intact swamps on Newnes Plateau; Shortening longwalls 432, 431, 430 and 429 to prevent damage to the Marrangaroo swamps, and shortening longwalls 425 and 426 to prevent Paddys Creek Swamp; and Longwall 501 should also be shortened to protect cliffs and pagodas. |
| | The Colong Foundation for Wilderness | All 1,860 hectares affected by the proposed longwall mining will be subject to surface cracking. Whole sub-catchments will be fractured to a depth of 15 to 20 metres. These fractures will link with remobilised faults and joints that extend across the area mined. Surface groundwater aquifers will become more permeable and interconnected. Centennial predicts surface aquifer drawdown in the Burralow Formation, the topmost strata and an unconfined aquifer, to range from 10 metres under ridges to 0.5 metres under shrub swamps. For such groundwater dependent swamps such a drop in groundwater level is significant because the peat will remain drier more often and for longer. (Colong Foundation) |

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| Monitoring<br>(Section 3.2.9) | The Colong Foundation for Wilderness | The monitoring has not provided the necessary information to assist decision-makers regarding the damage to these swamps and streams. This could be as simple as the provision of clear images to regulators of the worst examples of dead swamp vegetation and streambed cracking. Groundwater monitoring bores, for example, meet regulatory requirements but do not appear to identify problems that can be observed in dying swamp vegetation. |
| | The Colo Committee | Subsidence monitoring should be by a third party agency, such as the Office of Environment and Heritage, and monitoring should be paid for by Centennial Coal. Monitoring of surface flow and near-surface groundwater monitoring must create a comprehensive picture of the sub-catchments affected by mining. Monitoring of changes in ecosystem condition must include well exposed, wide angle impacts of affected areas with GPS co-ordinates. |
| Physical Impacts<br>(Section 3.2.10) | Blue Mountains Conservation Society (BMCS) | Minimal impact is zero impact. Since the document then states that "Impacts that do arise would be managed by …" clearly indicates that impacts are expected, not minimised. |
| Rehabilitation<br>(Section 3.2.11) | The Colo Committee | All past tracks and trails created by Centennial Coal and its consultants, including those established by trail bikes, should be recorded and plans set in place as soon as practicable to rehabilitate these trails on an on-going basis and as part of the rehabilitation program for this mine. |
| | Nature Conservation Council of NSW (NCC | Progressive rehabilitation undertaken by Centennial has proven ineffective and incomplete. Many tens of kilometres of access roads have not been closed and rehabilitated. (NCC) |
| Subsidence<br>(Section 3.2.12) | Nature Conservation Council of NSW (NCC) | All 1,860 hectares affected by the proposed longwall mining will be subject to surface cracking. Whole sub-catchments will be fractured to a depth of 15 to 20 metres. |
| | | The mining footprint must be significantly lessened and mining methods reduced in intensity to protect Carne Creek, pagodas, cliffs and the nationally endangered swamps of the proposal area. |
| | Blue Mountains Conservation Society (BMCS) | There should be no surface cracking of stream beds, under swamps or of pagodas, rock outcrops or cliffs. |
| | | The western coalfield has a history of cliff collapses due to subsidence from longwall mining. As was demonstrated by the nearby Coalpac Consolidated Project, the companies involved greatly underestimated the level of cliff collapse that has already occurred. Conservation volunteers have been able to find, locate and document a great many instances that mining consultants failed to find. |
| | The Colong Foundation for Wilderness | All 1,860 hectares affected by the proposed longwall mining will be subject to surface cracking. Whole sub-catchments will be fractured to a depth of 15 to 20 metres. |

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| Surface Infrastructure<br>(Section 3.2.13) | Stop Coal Seam Gas Blue Mountains (SCSGBM) | The scenic western edge of the Newnes Plateau must be protected from further scarring by new roads, pipeline and electricity easements. |
| | The Colong Foundation for Wilderness | The proposed SDWTS augmentation would inappropriately duplicate the easement off Newnes Plateau. This proposal will needlessly bulldoze a second road and ten metre wide easement for a 710mm diameter pipeline off the Newnes Plateau through a Brown Barrel forest between two large, dramatic pagoda-studded ridges and then a nationally endangered grassy tableland forest. This proposal, instead of a parallel duplication of the existing pipeline is unjustified in the EIS and totally unacceptable. |
| | | The proposed duplication of the SDWTS must keep to the existing alignment. The current proposal for an additional road and pipeline easement descending off Newnes Plateau will cause totally unacceptable scarring to a scenic part of the Gardens of Stone region. |
| | | Figure 4.1 page 155 (Vol. 1) reveals that that the proposed SDWTS does not follow the existing corridor in the most sensitive area of the western edge of Newnes Plateau. The road and 10 metre wide easement proposal descends into Sawyers Swamp Creek from the northern side southwards from the Old Bells Line of Road. |
| | | The existing SDWTS infrastructure alignment further to the south must be followed. This will avoid the destruction of a Sheltered Peppermint – Brown Barrel Shrubby Forest between two significant and well featured Pagoda spurs above the creek. It would avoid unnecessary bisection and severe damage to a Tableland Gully Snow Gum – Ribbon Gum Montane Grassy Forest, an endangered ecological community. |
| | Blue Mountains Conservation Society (BMCS) | As this mine progressively advances under the plateau, there is a concomitant advance of the associated industrial landscape across largely pristine woodland. The development of the bores, pipelines and access roads referred to in the project specification is indicative of the forest destruction that can be expected. All this industrial development significantly adds to the burden of infrastructure on Newnes Plateau in the Gardens of Stone region; to date progressive rehabilitation has proven ineffective. |
| Surface Water<br>(Section 3.2.14) | Emirates | Carne Creek is our only source of water. Any impacts to water volumes in Carne Creek impacts our business. |
| | Stop Coal Seam Gas Blue Mountains | Carne Creek is currently in a pristine state, and its waters that flow through the Greater Blue Mountains World Heritage Area are of the highest standard. This creek must not run bright orange or suffer reduced flows, just like the Wolgan River after Centennial Coal wrecked it. |
| Tourism<br>(Section 3.2.15) | Blue Mountains Conservation Society (BMCS) | The growing and sustainable tourist industry is being consistently damaged by the impacts of coal mining in this spectacular region. The price of this development is too high. |

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| Water Management<br>(Section 3.2.16) | Nature Conservation Council of NSW (NCC) | NCC objects to the proposed discharge of up to 43.8ML/day of untreated eco-toxic mine effluent to the Coxs River via the Springvale-Delta Water Transfer Scheme (SDWTS). This inappropriate discharge is inconsistent with the Sydney Catchment Authority Sydney Drinking Water Audit 2010 recommendations that require improved treatment of such licensed discharges. |
| | | The Wallerawang Power Plant is shut, possibly permanently, and the current proposal to supply cooling water is not viable. |
| | | Before discharge, the mine water must be treated to a standard that protects undisturbed aquatic ecosystems. The mine effluent, currently running at 12.5 Ml/day must be treated using reverse osmosis technology to remove all metals and salts. |
| | | Any malfunction of SDWTS, such as following a bushfire, must not result in emergency discharges to the World Heritage Area via Wolgan River or Carne Creek but be reinserted underground into the mine. |
| | The Colo Committee | All proposed discharge of up to 43.8ML/day of mine effluent to the Coxs River via the Springvale-Delta Water Transfer Scheme (SDWTS) is treated by reverse osmosis technology to remove salt and metals to a standard that protects, the Coxs River, the downstream drinking water supply and near-pristine ecosystems in the World Heritage Area. |
| | | In the event of a malfunction of SDWTS, such as during and following a bushfire, emergency discharges must be reinserted underground into the mine and under no circumstances released to the World Heritage Area via Wolgan River or Carne Creek. |
| | | Reinserted mine effluent must be properly treated and not allowed to re-emerge in an unauthorised or unregulated manner. |
| | Stop Coal Seam Gas Blue Mountains (SCSGBM) | The proposed discharge of up to 43.8ML/day of eco-toxic mine effluent must be treated using reverse osmosis technology to remove all metals and salts before discharge to the Coxs River. |
| | Blue Mountains Conservation Society (BMCS) | Malfunction of SDWTS, such as following a bushfire, must not result in emergency discharges to the World Heritage Area via Wolgan River or Carne Creek but reinserted underground into the mine. |
| | Lithgow Environment Group (LEG) | The ownership and responsibility for the SDWTS is very unclear, as the situation regarding who is responsible for rehabilitating the Kerosene Vale Fly Ash Repository. Critical Issues such as the EPL’s, land ownership, and final rehabilitation of the entire route of the SDWTS should have been clarified in the EIS, and must be clarified prior to any consent approval. |

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| | | The EIS claims that untreated discharges will go to Wallerawang Power Station, but it has ceased operation and is expected to remain so. As a result these untreated discharges will go directly into the Coxs River via the licenced discharge point LDP009, or into LDP1 in Kangaroo Creek upstream of Lake Wallace. |
| | | Figure 26 from the EIS clearly shows that salinity levels will spike dramatically reaching a peak from 2020 to 2025. Section 4.2.2, p. 65, identifies that the median salinity at LDP001 is 1,010µS/cm. Several Metals at LDP1 already exceed the ANZECC guidance including Copper at 0.002mg/L (guidance 0.0014mg/L); Aluminium of 0.02mg/L; and Zinc at 0.046mg/L (guidance 0.008mg/L). These pollution effects will be magnified during drought conditions, which are likely to become more prevalent during the life of these mines due to climate change. |
| | | On 9 May 2010 the EPA issued Angus Place (EPL 467) with a Pollution Reduction Notice to reduce the estimated 1,000 tonnes of salt deposited from LDP1 into Kangaroo Creek each year based on the average flow rate of 731ML. This Proposal aims to increase that flow rate 3 – 14 times. The proponent proposes to treble the flow from LDP1 to 2,300ML, and if the SDWTS is unavailable, to increase the flow from between 6 and 14 times (4,750ML up to 10,457ML). In total this proposal will discharge and some 31 tonnes/day (or 11,247 tonnes/year) of metal-rich Salts into the Coxs River which supplies Sydney with drinking water. |
| | | At LDP005 LEG Streamwatch volunteers recorded a Salinity level of 1030 µS/cm; Turbidity of 40 NTU (exceeded EPL limit); pH 7.5; Dissolved Oxygen 4.3 mg/L (52%); Available Phosphate 0.07 ppm; and Water Temperature of 25°C. The water had a chemically odour – attributable we believe to Solcenic water-soluble hydraulic oils, used in and spilled in vast quantities by long wall mining equipment. |
| | | The proposed discharge of 43.8 ML/day of eco-toxic saline minewater will have adverse impacts on aquatic life and natural ecosystems in the Coxs River, Sydney Drinking Water Catchment and Greater Blue Mountains Heritage Area which it flows through, as well as potentially for Carne Creek, the Wolgan River, and Wollemi National Park if any SDWTS malfunctions necessitate further Emergency Discharge’s on Newnes Plateau. |
| | | At the source of the Coxs River in Long Swamp LEG Streamwatch volunteers have consistently recorded salinity levels of 30 µS/cm. Just 4.8km downstream at LDP001 the median salinity is 33 times higher at 1,010 µS/cm and 1,055 µS/cm at LDP009. The high salinity of this mine water will significantly affect aquatic and riparian ecosystems that have evolved under very low nutrient conditions, and water users in the Sydney Drinking Water Catchment. |

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| | | The proposed discharges from LDP001 and LDP009 are inconsistent with the Sydney Catchment Authority Audit 2010, which included recommendations requiring improved treatment of POEO licenced discharges in the Coxs River Catchment. Numerous reports since 1966 have highlighted the highly polluted condition of the Coxs River. |
| | | The proposed discharges risk cancelling out negotiations between the EPA, Blue Mountains Conservation Society, and Delta Electricity to establish EPL limits for concentrations of Copper, Zinc, Aluminium, Boron, Fluoride, Arsenic, Nickel and Salts being discharged from LDP009 into the Coxs River. Delta had agreed to construct a Reverse Osmosis (RO) Plant to treat the SDWTS effluent after use for cooling, and pipe the brine waste to Mt Piper Flyash Repository for disposal. The closure of Wallerawang Power Station jeopardises this. |
| | | It is in the public interest to control metal and salt pollutants at their source – the coal mines that operate within the Sydney Drinking Water Catchment. The current SDWTS proposal to provide cooling water to Wallerawang Power Station is no longer viable. The closure of this plant means these salts and metals will instead be flushed into the Coxs River through the Greater Blue Mountains World Heritage Area and into Lake Burragorang – Drinking Water Supply for 4 million people. Before discharge, this mine water must be treated to a standard that protects undisturbed aquatic ecosystems and the health of downstream water-users. The only effective way to treat the high levels of turbidity, heavy metals (including Aluminium, Zinc, Copper and Nickel) and salinity is by requiring Centennial to install reverse osmosis (RO) technology to remove all metals and salts. |
| | | A map was provided to LEG at a Delta Western Reference Group Meeting in 2008. It shows the SDWTS Pipeline route, and identifies that a section of Pipeline is managed by Centennial, while Delta Electricity is responsible for another section. Despite 1000's of pages of documents in the EIS, it is still unclear whether Energy Australia has accepted responsibility for Delta's section of the Pipeline, whether Energy Australia are happy for Centennial staff/contractors to access Energy Australia owned land at Kerosene Vale Fly-Ash Repository (KVAR) and Licence Discharge Point LDP009, and who is ultimately responsible for the EPL Licences for all parts of the SDWTS. |
| | The Colong Foundation for Wilderness | Any malfunction of the SDWTS, such as the destruction of the pipeline during a bushfire, must not result in emergency discharges to the World Heritage Area via Wolgan River or Carne Creek. These discharges must be reinserted underground into the mine instead. |

| Area of Concern | Raised By | Summary of Issue |
|---|---|---|
| | | The proposal to redirect emergency mine inflows from the SDWTS underground into the Angus Place Colliery's 900 water storage area via the existing Angus Place 940 Bore facility is conditionally supported, provided that these transfers do not then re-emerge to the surface and escape the mine site as untreated effluent. The Colong Foundation is, however, suspicious of the above arrangement given the previous unauthorised mine effluent discharges. |
| | | The Colong Foundation notes that no daily capacity estimates have been provided for this proposed re-insertion arrangement. Given that the capacities are up to 43.8ML/day, requiring 710 mm diameter pipes laid underground, these unspecified arrangements seem highly dubious and require further consideration by the regulatory authorities. The Colong Foundation suspects that the 900 area would be flooded unless constantly kept dry by a major pumping effort. The Colong Foundation notes that the 900 area is contiguous with the 300 area and that unauthorised discharges are still operative on Lambs Creek. |
| | | The Springvale Delta Water Transfer Scheme (SDWTS) seeks to inappropriately dispose of up to 43.8 ML/day of untreated mine effluent to the Coxs River, adding 30 tonnes of metal enriched salts per day to Sydney's drinking water supplies. |
| | | All effluent discharges from the SDWTS must be subjected to reverse osmosis treatment to remove all salts and metals so that these discharges do no harm to sensitive downstream environments. |
| Water Resources<br>(Section 3.2.17) | Nature Conservation Council of NSW | Surface groundwater aquifers will become more permeable and interconnected. Centennial predicts surface aquifer drawdown to be 10 metres under ridges to 0.5 metres under shrub swamps. This range seems to be an underestimate as the longwall mining proposed at Angus Place Mine is more intensive than at Springvale Colliery, but the same degree sandstone cracking and groundwater drawdown is predicted. |
| | | Carne Creek is currently in a pristine state, and its waters that flow through the Greater Blue Mountains World Heritage Area are of the highest standard. The extensive fracturing of the sandstone associated with longwall mining of headwater swamps will release high levels of metals, notably manganese and iron, polluting Carne Creek and making it run bright orange, just like the Wolgan River did once. Flows in Carne Creek will also become irregular. |
| | The Colo Committee | Emergence of near surface groundwater with elevated levels of salt or metal precipitate in Carne Creek must be prevented. |
| | Emirates | There are the construction works (new bore holes, power lines, pipelines and access roads) being undertaken at the moment in the area of Sunny Ridge Road (off Blackfellows Hand Road). This activity resulted from recent approvals for long wall mining expansions into the Carne Creek catchment area. This is our water supply and the lifeline of the Wolgan further down. |

| Area of Concern | Raised By | Summary of Issue |
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| | Blue Mountains Conservation Society (BMCS) | This development application involves plans to pump up to 43 million litres of contaminated water a day into the same river, which feeds into the Lake Burragorang, an important part of Sydney's drinking water supply. Under the current proposal, the mine water would apparently be released into the river untreated, despite having elevated salt and heavy metal levels. The specific route is via Sawyers Swamp Creek into the Coxs River. |
| | | The discharge to be made under the current application, of to 43.8 ML/day of untreated eco-toxic mine effluent, would flow to the Coxs River via the Springvale Delta Water Transfer Scheme (SDWTS). Such an inappropriate discharge is inconsistent with the SCA Sydney Drinking Water Audit 2010 Recommendations. |
| | | Any discharge needs to be subject to high level remediation, such as via reverse osmosis filtration, to remove environmentally damaging heavy metals and salts, so the treatment must be undertaken prior to the water leaving the mine site. It is essential that the Centennial Angus Place guarantees that ANZECC guidelines for upland waterways will be heeded. The responsible approach would be to discharge only water that has been treated to a pristine level. |
| | | It needs to be emphasised that Carne Creek is currently in a pristine state, and its waters are of the highest standard. This creek was a key determinant in the location of the Emirates eco-resort. The extensive fracturing of the sandstone associated with longwall mining of headwater swamps will release high levels of metals, notably manganese and iron, polluting Carne Creek. The comparative water qualities at the junction of Carne Creek and the Wolgan River, near the resort, clearly demonstrates the degree of pollution of the latter. |
| | | There is considerable concern on the figures quoted by the company, specifically the water discharge amounts. We are led to believe that the 43 million litres per day (max) for the life of the mine (5 times the mine's current discharge) will come only from the seam and not from nearer surface aquifers. This requires an apparently unreasonably large volume of produced water from the seam and no breaching of aquicludes above the seam being mined. This appears inaccurate and should be verified by an independent study. In this regard, the Society supports the establishment of a system of truly independent consultants to conduct all environmental impact assessments. |
| | | Appendix E, part 1 of The Groundwater Impact Assessment for the proposal, asserts that ground cracking under the swamps would be temporary due to the cracks being filled by sediment. This presupposes that loose sandy sediment would have low permeability, a dubious contention that the Society rejects. For a start, it would depend on the size distribution of the particular sediment. It is instructive to reflect that coal seam gas extraction from fracking is enabled by the injection of sand into microfractures, yet in a curious twist the gentle washing of sand into the cracks under these swamps supposedly inhibits fluid flow. |

| Area of Concern | Raised By | Summary of Issue |
|---|---|---|
| | | The East Wolgan swamp demonstrated a rather perverse endless loop of increasing toxicity. Water from the mine was discharged above the swamp, damaging the downstream section until the water disappeared into the ground. Despite the undemonstrated assertion from the mine consultants that the water would resurface further downstream, due to the streambed cracking being attributed by the company to upsidence, the clear fate of the water would be to re-enter the mine workings via the broken, collapsed sequence above the long wall panel. The water would then have to be pumped and discharged again, presumably collecting more toxic components from successive trips through the coal seams. |
| | | The aquifer interference policy requires that a proponent demonstrates variability to lawfully take water within the limits of their licence and the water sharing plan. The Society notes that there appears to be a discrepancy (deficit) between the extraction licence and the estimated inflow in 2023. That deficit is in relation to what is required for the Richmond groundwater source, and is approximately 7 GL. Furthermore, the society is of the opinion that there is insufficient water to allow this level of extraction. |
| | The Colong Foundation for Wilderness | Carne Creek is currently in a pristine state, and its waters that flow through the Greater Blue Mountains World Heritage Area are of the highest standard. This creek was a key determinant in the location of the Emirates eco-resort. The extensive fracturing of sandstone associated with longwall mining under its headwater swamps will release high levels of metals, notably manganese and iron, polluting Carne Creek and making it run bright orange, just like the Wolgan River once did. Flows in Carne Creek will also become irregular. |
| | | Centennial Coal claims that much of the water disappearing from fractured streambeds may re-emerge further downstream. There is evidence to the contrary for East Wolgan Swamp. Such re-emergent surface water is often heavily contaminated with groundwater polluted with salt and metals. This re-emergent, potentially eco-toxic water could not help a swamp or affected stream reach upstream that had suffered water loss. Any downstream sensitive instream environments and riparian environments, such as some shrub swamps and the Greater Blue Mountains World Heritage Area, could be impacted by eco-toxic groundwater effluent. |

| Area of Concern | Raised By | Summary of Issue |
|---|---|---|
| | | The consultants for Centennial Coal make assertions that there is no net loss of water from stream catchments and that 'Any diverted surface water is likely to re-emerge into the catchment further downstream'. The consultants for Centennial conclude 'It is unlikely, however, that this would result in adverse impacts on the overall quality and quantity of water flowing from the catchment.' This statement is misleading. It is more likely that what has happened previously to the Wolgan River and to Kangaroo Creek will be repeated in the streams above the proposed longwall mining area. In these areas, water was lost downstream as well as within the mining area. Even if this was not the case, the water diverted into the near-surface groundwater does not assist the natural functioning of swamps undermined, even if the water does emerge downstream. |
| | | The extensive sandstone fracturing under headwater swamps associated with longwall mining will release high levels of metals, notably manganese and iron, polluting Carne Creek and making it run bright orange, just like the Wolgan River did once. |
| | | Centennial alleged that Area 300 can store water 'at an average rate of approximately 4.7 megalitres of water per day. This underground water storage appears to be the source of water emerging nearby at Lambs Creek which was subjected to longwall mining several decades ago. The Colong Foundation has observed a large amount of water welling up from the ground into a wetland on Lambs Creek near where the creek emerges onto private land. Upstream of this swamp, the creek is dry due to longwall mining operations at a shallow depth of cover. This water re-emergence appears to be an unlicensed discharge from the underground water storage, Area 300, Angus Place Colliery. This discharge was not considered in the Water Balance provided in the Environmental Assessment for modification of the Project Approval. The emergence of water make into Lambs Creek should be investigated to confirm that it has water make characteristics. If it has, then the applicant should be asked to explain why it has not notified authorities of this source of mine effluent for the last three decades. |
| | Lithgow Environment Group (LEG) | The Emirates Wolgan Valley Resort & Spa, Newnes Hotel and Cabins, local farmers, graziers and residents depend on this water for survival. Centennial must be required to enter into compensation arrangements in the event that Carne Creek or the Wolgan River either cease flowing, or become polluted to the point of being unfit for human consumption due to emergency mine water discharges. |
| | | The conclusion of the EIS after hydraulic investigation and modelling is that after cracking the ground of 1000's of hectares and subsequently pumping away 43.8 ML/day will have "…minimal impact on the shallow and perched aquifer systems across Newnes Plateau ". Given the volume of water to be pumped out from the mine as well as the undoubted effect this will have on underground aquifers (which it is impossible to predict), any normal person would agree that conclusion defies scientific evidence and logical argument. |

## Table 3 - Summary of Community Individual Submissions

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| Air Quality<br>(Section 3.3.1) | SV160 | Centennial claims only a small contribution to the amount of State and Federal GHG emissions, but omit the Scope 3 emissions about which they say the greatest emission sources associated with the Project are those related to the downstream combustion of the coal (Scope 3), the management of which is not in Centennial Angus Place's control. |
| | SV280 | Centennial argue that GHG emissions of all machinery required in the operations and all clearing of forest required for above ground supporting infrastructure is "negligible". However the entire purpose of this project is to sell for combustion 4.5 million tons of the thermal coal p.a. for 13 years. |
| Consultation<br>(Section 3.3.2) | SV002, SV006, SV007, SV014, SV016, SV024, SV027, SV030, SV031, SV033, SV035, SV037, SV039, SV041, SV043, SV045, SV048, SV049, SV054, SV055, SV056, SV058, SV059, SV060, SV062, SV063, SV064, SV065, SV070, SV073, SV074, SV075, SV076, SV080, SV081, SV083, SV084, SV085, SV086, SV089, SV090, SV092, SV094, SV099, SV100, SV102, SV103, SV104, SV105, SV106, SV109, SV111, SV113, SV118, SV124, SV126, SV128, SV129, SV131, SV133, SV134, SV136, SV147, SV148, SV152, SV153, SV157, SV159, SV167, SV169, SV170, SV171, SV175, SV176, SV177, SV178, SV182, SV183, SV184, SV186, SV187, SV190, SV191, SV196, SV199, SV200, SV202, SV210, SV212, SV218, SV222, SV223, SV224, SV227, SV229, SV231, SV233, SV235, SV236, SV237, SV238, SV242, SV243, SV245, SV246, SV247, SV248, SV249, SV252, SV255, SV257, SV258, SV259, SV260, SV262, SV264, SV265, SV266, SV267, SV269, SV270, SV273, SV274, SV275, SV276, SV277, SV278, SV279, SV281, SV282, SV283, SV285, SV288, SV289, SV290, SV291, SV292, SV293, SV294, SV295, SV296, SV297, SV298, SV299, SV300, SV301, SV302, SV303, SV304 | The Springvale and adjoining Angus Place mine extension proposals must be subject to a Planning Assessment Commission review with concurrent Public Hearings |
| | SV096, SV165, SV189, SV226 | This proposal and the adjoining Angus Place extension proposal should be subject to a stringent planning assessment and PAC review process. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV280 | Chapter 7 states that: "The public, including community groups and adjoining and affected landowners were identified and consulted with as part of the consultation and engagement strategy "(p201). None of the Wolgan Valley residents were contacted by Centennial including Emirates Wolgan Resort and Spa. Nor were The Blue Mountains Conservation Society, the Colong Foundation for Wilderness or the Lithgow Environment group. |
| | SV280 | After requesting to make a presentation to the Centennial Community Consultation Committee meeting of 8 April, 2014 I was refused by the Chairman, Howard Fisher. However my written presentation was read out during that meeting through committee member Ian Coates. Apparently, there was no discussion and he was told that I would receive a response from Centennial. I have not heard from them. |
| Cultural Heritage<br>(Section 3.3.3) | SV230, SV232 | The Garden of Stone area has profound cultural and physical heritage values that should be preserved. |
| | SV192 | The project will hamper tourism therefore destroying the opportunity for local Aboriginal people to benefit in a positive way as tour guides of the many local art sites. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| Ecology<br>(Section 3.3.4) | SV024, SV035, SV104, SV148, SV196, SV204, SV210, SV231, SV246, SV288, SV002, SV007, SV014, SV016, SV027, SV029, SV030, SV031, SV033, SV037, SV039, SV041, SV043, SV045, SV048, SV054, SV055, SV056, SV058, SV059, SV060, SV062, SV063, SV064, SV065, SV070, SV073, SV074, SV075, SV076, SV080, SV081, SV083, SV084, SV085, SV086, SV088, SV089, SV090, SV092, SV094, SV099, SV100, SV106, SV107, SV109, SV118, SV124, SV126,SV128, SV129, SV131, SV133, SV134, SV136, SV147, SV152, SV153, SV157, SV159, SV167, SV169, SV170, SV171, SV175, SV176, SV178, SV182, SV183, SV184, SV186, SV187, SV190, SV191, SV199, SV200, SV202, SV212, SV218, SV222, SV223, SV224, SV227, SV229, SV233, SV235, SV236, SV237, SV238, SV242, SV243, SV245, SV247, SV248, SV249, SV252, SV254, SV255, SV257, SV258, SV259, SV260, SV262, SV264, SV265, SV266, SV267, SV269, SV270, SV273, SV274, SV275, SV276, SV277, SV278, SV279, SV281, SV282, SV283, SV285, SV289, SV290, SV291, SV292, SV293, SV294, SV295, SV296, SV297, SV298, SV299, SV300, SV301, SV302, SV303, SV304 | Important terrestrial and stream environments in this significant part of the Gardens of Stone region must not be damaged by long wall mining but instead protected in a state conservation area. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV002, SV006, SV007, SV014, SV016, SV027, SV029, SV030, SV031, SV033, SV035, SV036, SV037, SV039, SV041, SV043, SV045, SV048, SV054, SV055, SV056, SV058, SV059, SV060, SV062, SV063, SV064, SV065, SV070, SV073, SV074, SV075, SV076, SV080, SV081, SV083, SV084, SV085, SV086, SV088, SV089, SV090, SV092, SV094, SV099, SV100, SV104, SV106, SV107, SV109, SV113, SV118, SV124, SV126, SV128, SV129, SV131, SV133, SV134, SV136, SV147, SV148, SV152, SV153, SV157, SV159, SV167, SV169, SV170, SV171, SV175, SV176, SV178, SV182, SV184, SV186, SV187, SV190, SV191, SV199, SV200, SV202, SV204, SV210, SV212, SV218, SV221, SV222, SV223, SV224, SV227, SV229, SV231, SV233, SV235, SV236, SV237, SV238, SV242, SV243, SV245, SV246, SV247, SV248, SV249, SV252, SV254, SV255, SV257, SV258, SV259, SV260, SV262, SV264, SV265, SV266, SV267, SV269, SV270, SV273, SV274, SV275, SV276, SV277, SV278, SV279, SV281, SV282, SV283, SV285, SV288, SV289, SV290, SV291, SV292, SV293, SV294, SV295, SV296, SV297, SV298, SV299, SV300, SV301, SV302, SV303, SV304 | Centennial Coal must not be allowed to simply replicate the damage it has already caused to nationally threatened upland swamps on the Newnes Plateau for which it was required by the Commonwealth Government to pay $1.45 million in reparations. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV002, SV006, SV007, SV014, SV016, SV027, SV030, SV031, SV033, SV035, SV037, SV039, SV041, SV043, SV045, SV048, SV049, SV054, SV055, SV056, SV058, SV059, SV060, SV062, SV063, SV064, SV065, SV070, SV073, SV074, SV075, SV076, SV080, SV081, SV083, SV084, SV085, SV086, SV089, SV090, SV092, SV094, SV099, SV103, SV106, SV109, SV113, SV118, SV124, SV126, SV128, SV129, SV131, SV133, SV134, SV136, SV147, SV152, SV153, SV157, SV159, SV167, SV169, SV170, SV171, SV175, SV176, SV178, SV182, SV184, SV186, SV187, SV190, SV191, SV199, SV200, SV212, SV218, SV222, SV223, SV224, SV227, SV229, SV233, SV235, SV236, SV237, SV238, SV242, SV243, SV245, SV246, SV247, SV248, SV249, SV252, SV254, SV255, SV257, SV258, SV259, SV260, SV262, SV264, SV265, SV266, SV267, SV269, SV270, SV273, SV274, SV275, SV276, SV277, SV278, SV279, SV281, SV282, SV283, SV285, SV289, SV290, SV291, SV292, SV293, SV294, SV295, SV296, SV297, SV298, SV299, SV300, SV301, SV302, SV303, SV304, SV024, SV035, SV104, SV148, SV177, SV196, SV210, SV231, SV246, SV288 | The sandstone strata supporting the 41 nationally endangered swamps, including the 11 shrub swamps affected by the proposal must not be fractured. |
| | SV024, SV035, SV104, SV148, SV196, SV210, SV231, SV246, SV288 | The proposed clearing of 14 hectares of forest for an additional ventilation facility is excessive and its proposed location close to the Wolgan River is unacceptable. |
| | SV024, SV035, SV104, SV183, SV196, SV210, SV231, SV288 | Carne Creek, pagodas, cliffs and the many nationally endangered swamps that the current proposal puts at risk must not be damaged. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV002, SV006, SV007, SV014, SV016, SV027, SV030, SV031, SV033, SV035, SV037, SV039, SV041, SV043, SV045, SV048, SV054, SV055, SV056, SV058, SV059, SV060, SV061, SV062, SV063, SV064, SV065, SV070, SV074, SV075, SV076, SV080, SV081, SV083, SV084, SV085, SV086, SV088, SV089, SV090, SV092, SV094, SV099, SV100, SV103, SV106, SV109, SV113, SV118, SV124, SV126, SV128, SV129, SV131, SV133, SV134, SV136, SV147, SV152, SV153, SV157, SV159, SV167, SV168, SV169, SV170, SV171, SV175, SV176, SV178, SV182, SV184, SV186, SV187, SV190, SV191, SV199, SV200, SV202, SV212, SV218, SV222, SV223, SV224, SV227, SV229, SV233, SV235, SV236, SV237, SV238, SV242, SV243, SV245, SV246, SV247, SV248, SV249, SV252, SV254, SV255, SV257, SV258, SV259, SV260, SV262, SV264, SV265, SV266, SV267, SV269, SV270, SV273, SV274, SV275, SV276, SV277, SV278, SV279, SV281, SV282, SV283, SV285, SV289, SV290, SV291, SV292, SV293, SV294, SV295, SV296, SV297, SV298, SV299, SV300, SV301, SV302, SV303, SV304 | Carne and Bungleboori Creeks, pagodas, cliffs and the many nationally endangered swamps must not be damaged. |
| | SV213 | The project will negatively impact the Great Barrier Reef. |
| | SV205, SV275 | A number of threatened species and endangered ecological communities will be compromised by the proposed extension. |
| | SV010, SV084, SV091, SV098, SV111, SV161, SV168, SV189, SV246, SV277, SV281 | In total 73 nationally endangered swamps will be damaged by cracking of the underlying sandstone causing the swamps to dry out by the groundwater level falling by 10 m. This will increase bushfire risk and lead to dried out swamps being replaced by dry land floral communities. |
| | SV084, SV091, SV107, SV246, SV280 | The peat soils that supported the swamps will decompose and over a period of years eucalypts and banksias will migrate into the dying swamps as they evolve into dryland communities. |
| | SV029, SV084, SV091, SV130, SV246, SV281 | Impacts to swamps will result in many threatened plants and animals supported by them being killed, including the giant dragonfly. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV004 | The impacts of past mining has been dealt with cursorily in the EIS which essentially argues that there have been no direct impacts on swamps by subsidence. There have clearly been impacts. |
| | SV004 | Both East Wolgan and Narrow have now been severely degraded by mining impacts and acknowledged in the imposition of Enforceable Undertaking, though the impacts of the excess mine water is conveniently used as the cause of the damage, damage which has left the drainage line of East Wolgan in particular a 30 m wide stretch of bare dry earth with no evidence of recovery after nearly 6 years. |
| | SV030 | Kangaroo Swamp, Lambs Creek Swamp, Junction Swamp and East Wolgan Swamp have all been lost, although each was supposed to be protected under both State TSC Act and EPBC Act for Endangered Ecological Communities. |
| | SV001, SV096, SV102 | The project will cause destruction of our natural environments that protect our flora and fauna that also provide clean water, air, a carbon sink, link to our cultural heritage and a tourist attraction. |
| | SV066 | The current surface works are involving extensive clearing. The forests need to be maintained for the future, enough land has been taken from nature. |
| | SV044, SV067 | Centennial " admits its mining will fracture iconic Birds Rock, a Flora Reserve, and the sandstone beds under 73 nationally endangered swamps". |
| | SV032, SV115 ,SV151, SV205, SV221, SV244, | The Commonwealth Department of the Environment has found that Centennial's longwall mining activities on the Newnes Plateau caused a loss of ecosystem function shown by loss of peat, erosion, vegetation dieback and weed invasion in 3 swamps (East Wolgan Swamp, Junction Swamp, Narrow Swamp). This shows they are not capable of protecting the environment and must not happen again. |
| | SV138, SV140, SV142, SV143, SV209, SV226 | Longwall mining under the endangered ecological communities and rock pagodas and cliffs will cause subsidence damage. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV160, SV215, SV225 | The Angus Place and Springvale extension proposals are a direct threat to core of the shrub swamp area in the headwaters of Carne Creek. The EEC listed endangered ecological community of Newnes Plateau Shrub Swamps should not be mined under. |
| | SV201 | Sound from mine ventilation has seen a decline in native animal activity in the area. |
| | SV088, SV107 | The sandstone rock supporting the 41 nationally endangered swamps, and particularly the 11 shrub swamps affected by the proposal, will also develop a large number of fractures. Centennial predicts these cracks to be 5 to 50mm wide and 10 to 15 metres deep. |
| | SV226 | The evidence shows that the protection of the Burralow Formation aquitard AQ6 is critical to swamp protection but that AQ6 will drop well below root depth and by up to 10 m, if mining is permitted. |
| | SV226 | Piezometric traces have been impossible to interpret. The multiple traces on Fig 2.14 and 2.15 make them unreadable. Colour differentiation is indistinct, the traces overlap and the data is unclear. The depths of sediment are not given, nor are the times when the swamps were undermined or the longwalls involved. |
| | SV226 | The Report notes (p 82 and Fig 2.27), Kangaroo Creek1 hydrograph dropped after mining nearby at Angus Place in 2008 and has not recovered. As it is a small swamp, the impacts may not be dramatic, but it shows clearly that undermining does lead to long-term loss of water from the swamp sediments. |
| | SV226 | The mine water discharges into East Wolgan Swamp caused scalding in a narrow line down the valley axis. It did not support the vegetation over most of the swamp but killed it along the line of maximum discharge, encouraging erosion. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV226 | Hanging swamps are the forgotten swamps in the EIS. Section 2.8.3.5 deals with impacts of past undermining - all examples are of valley floor swamps, although Kangaroo Creek could perhaps be described as a hanging swamp. While recognising the importance of the hanging swamps, the Report does not address the impacts of mining on them. Yet they are clearly at least as vulnerable to diversion of water via bedrock cracking as valley floor swamps. |
| | SV149 | This project has the potential to lead to the irrevocable degradation and potential destruction of several Newnes Plateau Shrub Swamps (NPSS), an Endangered Ecological Community (EEC), which forms part of the Commonwealth listed Temperate Highland Peat swamps on Sandstone (THPSS) EEC, with resultant negative impacts upon their associated groundwater dependent species. These species may include threatened flora and fauna, such as the endangered Giant Dragonfly (*Petalura gigantea*), endangered Blue Mountains Water Skink (*Eulamprus leuraensis*), and vulnerable Dean's Boronia (*Boronia deanei deanei*), all of which are obligate mire (peat swamp) dwelling species. |
| | SV149 | Reduced groundwater availability as a result of subsidence from the longwall mining will result in long-term degradation and contraction of the NPSS, compounding predicted effects of climate change. This will result in reduced spatio-temporal distribution of suitable breeding habitat for *Petalura gigantea* (Pg), and will threaten the persistence of other groundwater dependent species, including Boronia deanei, *Eulamprus leuraensis* (El), *Euastacus australasiensis*, and other organisms such as stygofauna. |
| | SV149 | The recommendation to undertake more comprehensive, and better designed pre-mining surveying, and finer resolution taxonomic identification of stygofauna, must be implemented if this project proceeds to ensure that the diversity of stygofauna is properly assessed and potential risks of the project determined. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV149 | Fauna surveying was inadequate for the EIS, if they did not at least find swamp rats *Rattus lutreolus* (evidence observed by I.R.C. Baird in most NPSS) and Antechinus spp. And *Eulamprus leuraensis* in NPSS. The lack of observation of small terrestrial mammals in these swamps is also a serious deficiency. |
| | SV149 | The conclusion that there will not be a significant impact in relation to the KTP in relation to subsidence from longwall mining is incorrect. |
| | SV149 | An additional impact on peat swamps, associated with a drying of surface peats, is the increased combustion of the organic component of the soil during fire events. A long term lowering of water tables will result in significant cumulative effects of subsequent fires, which will be further compounded by predicted climate change scenarios. |
| | SV149 | The Endangered shrub, *Persoonia hindii*, should be added to list of threatened flora which could potentially be affected by this project. |
| | SV149 | The Endangered giant dragonfly, *Petalura gigantea* (Pg) should be added to the list of threatened fauna which could potentially be affected by this project. This is a significant omission. |
| | SV149 | The predicted lowering of the water table in identified NPSS, as a result of mining, is claimed to be not significant. The predicted lowering of water tables will be significant, with a possibility that the extent of lowering will exceed the model results. The proponent acknowledges that there will be a lowering of water levels. Based upon previous evidence, it can be assumed that the actual lowering of water table will be more, and possibly much more. Any lowering of water tables in the long term will affect the ecological functioning of these swamps and negatively affect their suitability for individual species, such as Pg. |
| | SV149 | EIS Main Document Volume 2 p.334, Table 10.9: Incorrectly states that Pg could not potentially occur, when in fact there are multiple records for this species in NPSS in the project area, including new records by I.R.C. Baird in January 2014. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV149 | Assessment for Boronia deanei ssp. deanei is flawed. Any NPSS population of this species, which is subjected to medium to long term lowering of the water table, will be at risk of a reduction and potentially loss of that population in the long term. |
| | SV149 | Assessment for *P. gigantea* is flawed. The requirement for moist to saturated substrate for successful oviposition and larval burrow establishment is the critical factor in the persistence of this species in swamps. Because of the long larval stage, some late stage larvae in established burrows may be able to persist until emergence, even after some lowering of water tables; however, successful reproduction, and thus persistence of populations, will be limited by the availability of suitable wet substrate for ovipositing and larval establishment. |
| | SV149 | Assessment of *Eulamprus leuraensis* is flawed. The report states that El occurs in non-swamp habitat, however, any records for this species in non-swamp habitats are likely to be of wandering or foraging individuals temporarily outside their core swamp habitat. The assessment of no significant impact upon this species is based on the flawed presumption that there will be no significant lowering of the water table in a particular swamp. A relatively minor loss of groundwater could have a deleterious effect on a local swamp population of this species. |
| | SV149 | A comprehensive, systematic pre-mining stygofauna survey must be implemented across the project area, with finer resolution taxonomic identification of stygofauna, to ensure that the diversity of stygofauna is properly assessed and potential risks of the project determined. |
| | SV239 | The 11.44 ha of land clearance should not occur. |
| | SV247 | The project is not to go ahead in the Gardens of Stone which has been recommended by the Office of Environment and Heritage to be protected in a conservation reserve. |
| | SV247 | Ben Bullen State Forest is unique and must be protected. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV004 | Monitoring data in the EIS indicate that there will be drawdown in all the swamps with a maximum drop of 36 cm in Gang Gang Southeast Swamp, though the EIS does not think this will cause any impact, though if the ecological dynamics in the swamp are considered t is evident that a permanent water level drop will cause major drying out of surface substrate and dislocation of swamp species. It is likely that these water level changes will be permanent and result in reduction in size of the swamps over time as swamps gradually dry out and are invaded by woodland species. Certainly the East Wolgan drainage line has been completely dry for the last 5 years and is showing no sign of recovery. |
| | SV160 | The amount and scale of the infrastructure will be increased, including: a 14ha clearing for one mine vent, seven more dewatering sites (for Angus Place) with power, pipelines and tracks and clearings 90m x 110m, and two additional borehole sites (for Springvale). Exploration drill holes and groundwater monitoring holes, as well as subsidence monitoring activities will also occur. |
| | Shine Laboratory, The University of Sydney | The Newnes Plateau Swamps proposed to be undermined support a population stronghold of the Blue Mountains Water Skink in this region, and a significant alteration in hydrology of the swamps, such as a loss of groundwater through subsidence, would negatively affect the suitability of the habitat. This in turn may cause a substantial reduction in abundances within swamps, and an overall reduction in populations of skinks throughout that region. The ability of individuals and populations of the Blue Mountains Water Skink to recover from such an event is unknown. (S Gorissen and R Shine, Shine Laboratory, The University of Sydney) |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| General<br>(Section 3.3.5) | SV002, SV007, SV014, SV016, SV027, SV030, SV031, SV033, SV036, SV037, SV039, SV041, SV043, SV045, SV048, SV054, SV055, SV056, SV058, SV059, SV060, SV062, SV063, SV064, SV065, SV070, SV073, SV074, SV075, SV076, SV080, SV081, SV083, SV084, SV085, SV086, SV089, SV090, SV092, SV094, SV099, SV106, SV109, SV113, SV114, SV118, SV124, SV126, SV128, SV129, SV131, SV133, SV134, SV136, SV147, SV152, SV153, SV157, SV159, SV167, SV168, SV169, SV170, SV171, SV175, SV176, SV178, SV182, SV184, SV186, SV187, SV190, SV191, SV199, SV200, SV202, SV212, SV218, SV222, SV223, SV224, SV227, SV229, SV233, SV235, SV236, SV237, SV238, SV242, SV243, SV245, SV246, SV247, SV248, SV249, SV252, SV254, SV255, SV257, SV258, SV259, SV260, SV262, SV264, SV265, SV266, SV267, SV269, SV270, SV273, SV274, SV275, SV276, SV277, SV278, SV279, SV281, SV282, SV283, SV285, SV289, SV290, SV291, SV292, SV293, SV294, SV295, SV296, SV297, SV298, SV299, SV300, SV301, SV302, SV303, SV304 | The scenic western edge of the Newnes Plateau must be protected from further scarring by new roads, pipeline and electricity easements. |
| | SV002, SV006, SV007, SV014, SV016, SV024, SV027, SV030, SV031, SV033, SV035, SV036, SV037, SV039, SV041, SV043, SV045, SV048, SV052, SV054, SV055, SV056, SV058, SV059, SV060, SV061, SV062, SV063, SV064, SV065, SV070, SV074, SV075, SV076, SV080, SV081, SV083, SV084, SV085, SV086, SV088, SV089, SV090, SV092, SV094, SV099, SV100, SV106, SV109, SV113, SV118, SV124, SV126, SV128, SV129, SV131, SV133, SV134, SV136, SV147, SV152, SV153, SV157, SV159, SV167, SV169, SV170, SV171, SV175, SV176, SV178, SV182, SV183, SV184, SV186, SV187, SV190, SV191, SV196, SV199, SV200, SV202, SV210, SV212, SV218, SV222, SV223, SV224, SV227, SV229, SV231, SV233, SV235, SV236, SV237, SV238, SV242, SV243, SV245, SV247, SV248, SV249, SV252, SV254, SV255, SV257, SV258, SV259, SV260, SV262, SV264, SV265, SV266, SV267, SV269, SV270, SV273, SV274, SV275, SV276, SV277, SV278, SV279, SV281, SV282, SV283, SV285, SV288, SV289, SV290, SV291, SV292, SV293, SV294, SV295, SV296, SV297, SV298, SV299, SV300, SV301, SV302, SV303, SV304 | Centennial must revise the proposal to improve environmental outcomes. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV105 | Centennial Coal has already extensively and severely damaged parts of the Newnes Plateau by blighting the landscape with a network of roads, pipes, survey lines and power lines. |
| | SV001, SV010, SV031, SV066, SV151, SV154, SV057, SV160, SV168, SV194, SV197, SV205, SV209, SV225, SV263, SV301 | Any future mine expansions in the Newnes Plateau region of the Blue Mountains should not be allowed as they will irreversibly damage the unique and fragile environments through cumulative impacts from subsidence, pollution, and water quality threats to ecology, water, air, noise, cultural heritage and local residents. |
| | SV051, SV065 | The price of coal is dropping globally. Once the global coal price drops below $60 per tonne, which will happen by the end of the decade on current trends, the industry is over in Australia. |
| | SV052, SV122 | The Springvale mine has already caused subsidence and pollution and the extension will markedly increase the damage and pollution. |
| | SV122 | Coal is an outdated fuel so any jobs created are short term. |
| | SV099, SV051, SV052, SV065, SV075, SV115 , SV145, SV220, SV237, SV263, SV268 | In this era when we need to focus on renewable sources of energy, there are no viable reasons for extending this mine. |
| | SV032, SV160, SV282, SV288 | Centennial has a bad track record with polluting creeks and streams, plus the ugly scars on the Newnes Plateau area which are made to provide infrastructure to support the mine operation. |
| | SV138, SV139, SV140, SV160 | The amenity of the Newnes Plateau will be spoilt by the great amount of mining surface infrastructure by the three mines operating there side by side. |
| | SV189 | Coal is currently over supplied and thus Centennial should not damage the region for minimal profit. |
| | SV111 | Centennial must be made to fix previous serious environmental damage done by the pre-existing coal mine and provide evidence that they are capable of working in an environment without damaging it before any further extensions can be considered. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV244 | The Development Consent must be subject to periodic third party reviews to ensure that adjoining conservation areas are not adversely affected. |
| | SV105 | This project must not be allowed to go ahead without sufficient environmental protections to the fragile ecosystems. |
| | SV111 | The EIS tends to only be a theoretical document and have little credence in terms of impacts and mitigation actions. |
| | SV280 | The EIS mentions everything that supports the application but leaves out aspects which might speak against it. |
| | SV149 | The proposed Springvale mine extension should not be granted development consent unless Development consent is staged, with a review every five years and is subject to performance standards triggers that ensure the health and integrity of receiving waters and heritage values. |
| Groundwater<br>(Section 3.3.6) | SV066 | Approximately 1.5 m subsidence and cracking caused by the project will destroy the water table. |
| | SV280 | Longwall mining affects groundwater as groundwater will find its way through cliff cracks into the mine affecting the aquifers. |
| | SV280 | The Springvale mine expansion proposes to increase the pumping out of mine water from 20.9 Mega (= million) litres per day to a potential 29.9 ML/d (p.305). The EIS, suggests that after cracking the ground and pumping that much water out from the lowest point there will be "...minimal impact on the shallow and perched aquifer systems across Newnes Plateau "(p.479). In contrast chapter 7.3.1 of Appendix E p.76, states that: "From the piezometric and water table contours presented on Figures 26 to 30, and with reference to Section 5.2.5, it is apparent that the initial groundwater levels are considerably impacted by current and historical mining operations." Given the volume of water to be pumped out from the mine as well as the undoubted effect this volume of water will have on underground aquifers (which it is impossible to predict), this conclusion defies scientific evidence and logical argument. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV266 | The Burralow Formations perched aquifers are described as discontinuous (Main Report pt 1), surficial and independent of regional groundwater. However the mapping such as in Fig. 2.8 shows the brown isopachs of the aquitards (denoted as YS or SP semi-permeable layers in the discussions) as laterally continuous. Hence they are of regional and not local importance. |
| | SV266 | It is misleading and inaccurate to argue that mining has not caused a drop in the water tables of the undermined swamps above the Springvale and Angus Place mines. |
| Mine Design<br>(Section 3.3.7) | SV149 | Shortening longwalls 432, 431, 430 and 429 must be done to prevent damage to the Marrangaroo swamps, and shortening longwalls 425 and 426 must be done to prevent damage to Paddys Creek Swamp. |
| | SV149 | Longwalls should be shortened to avoid undermining THPSS: All discussion in the EIS Main Document Volume 2, of the option of shortening longwalls to avoid undermining NPSS, related to existing longwalls, but did not address the option of shortening longwalls in the proposed extension project to avoid undermining NPSS. The fact that such a modification may reduce the economic feasibility of the entire project should not be a justification for allowing these swamps to be undermined, with the associated risk of damage. |
| | SV149 | In the event that the longwall panels are not shortened to avoid mining under the NPSS, then all longwall panels that pass under swamps should be further reduced in width, with wider pillar widths, to further minimise risk of subsidence that may result in significant lowering of swamp water tables. |
| | SV149 | Mining intensity should be reduced. |
| | SV149 | The proponent’s justification for the currently proposed panel widths under the swamps is not substantiated. |
| | SV149 | Longwall LW501 should be shortened to protect cliffs and pagodas. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV004 | There should be no mining under the swamps as has protected Sunnyside Swamp, or if not possible to reduce the width of the long walls which are proposed to be up to 261 m to between 115-160m as used elsewhere to reduce subsidence. |
| | SV149, SV160 | Centennial says that due to a weak roof and a high stress environment longwall mining is the only option, however Clarence Colliery successfully uses bord & pillar mining methods and the Airly mine in the Capertee Valley operates to depth of 405 metres underground in the same geology, with bad mine roof conditions, including many structural defects. |
| Monitoring<br>(Section 3.3.8) | SV149 | Monitoring of surface flow and near-surface groundwater monitoring must create a comprehensive picture of the sub-catchments affected by mining. |
| | SV149 | Monitoring guidelines must clearly specify how the condition of groundwater dependent indicator plant species and the general condition of groundwater dependent ecosystems will be performed. |
| | SV149 | Representative sites for the piezometers to monitor groundwater in swamps and streams must be chosen by a third party agency. |
| Noise<br>(Section 3.3.9) | SV160 | Centennial states the noise of the dewatering pumps can only be heard up to 100m away, however the noise can travel much further across valleys, up to 1km, and the pumps run non-stop most of the time. |
| | SV201 | Mine ventilation is capable of producing sound energy at frequencies able to cause the population to feel effects from low frequency sound or infrasound. These effects are already being seen in the population. |
| Rehabilitation<br>(Section 3.3.10) | SV149 | All past tracks and trails created by Centennial Coal and its consultants, including those established by trail bikes, need to be recorded and plans set in place to rehabilitate these trails on an on-going basis and as soon as practicable as part of the on-going rehabilitation program for this mine. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| Socio-Economic<br>(Section 3.3.11) | SV008, SV160, SV168, SV188 | This area is a tourist attraction for national and international visitors. The project would destroy NSW's reputation to these tourists by destroying a prestige destination spot now and for future generations. |
| | SV088, SV107, SV109, SV130 | Damage to Carne Creek will have serious consequences for the Emirates Wolgan Valley Resort and Spa. |
| | SV109 | Damage to Carne Creek will have serious consequences for local tour operators such as the 4 x 4 and adventure recreation companies. |
| | SV263 | Any jobs created by the project are false economies based on short term gains, damaging future prospects for generations. |
| Subsidence<br>(Section 3.3.12) | SV088, SV107, SV246 | As a result of subsidence movements, the surface sandstone rock will be cracked to a depth of 15 to 20 metres over the entire area mined. Bird Rock will be fractured. |
| | SV009, SV025, SV149, SV189, SV215, SV216, SV225, SV256 | The possibility of subsidence from longwall mining in these areas and the inevitable impact on the environment from cracking the underlying sandstone layers which support the lakes, stream beds, swamps, pagodas, rock outcrops, walking tracks and cliffs should not be allowed. This subsidence will also increase bushfire risk. |
| | SV160 | The subsidence caused by the project in large areas of the plateau will cause deep cracking and cause aquifers to drop by up to 10 m. This is irreversible. |
| | SV111 | Areas close to the Angus Place Colliery's existing works and other existing mines already show prominent examples of cracking and collapse. This damage must not be allowed to extend to the Gardens of Stone. |
| | SV280 | The Heritage section of the SoEI offers the description of the historic site of a grinding stone at site 45-1-0002. After stating that "no spoiling or cracking is predicted" (p. 479) for cliffs and pagodas "the sandstone where the grinding groove is or was located" can be expected "to fracture and damage the site should it still remain." (p480). Therefore all the cliffs and pagodas will be fine but the grinding stone will fracture and vanish. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
|  | SV280 | Fracturing of the rock underneath the surface will occur as a result of the longwall mining and the use of tentative language in the EIS statement is an attempt to minimize the potential for this serious damage to the cliff and pagoda landscape to occur. |
|  | SV088, SV107 | All 1,860 hectares affected by the proposed longwall mining will be subject to surface cracking. Surface groundwater aquifers will become more permeable and interconnected. |
|  | SV149 | Subsidence monitoring should be by a third party agency, such as the Office of Environment and Heritage, and monitoring should be paid for by Centennial Coal. |
|  | SV192, SV262 | Mining should not be allowed at the thinnest points of access where pagodas have developed their most advanced forms. This is seen in longwall panel LW501 which is approximately 40% overlain by a rocky spur. |
|  | SV160 | From the project, steep slopes are predicted to experience tension cracking at the top and sides, and compression ridges at the bottom. |
|  | SV160 | The project will cause some cliffs, pagodas and other rock formations are likely to experience fracturing and spalling to 1% to 3% of total exposed rock face areas which are located above longwalls. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| Surface Water<br>(Section 3.3.13) | SV002, SV007, SV014, SV016, SV024, SV027, SV030, SV031, SV033, SV035, SV036, SV037, SV039, SV041, SV043, SV045, SV048, SV054, SV055, SV056, SV058, SV059, SV060, SV062, SV063, SV064, SV065, SV070, SV073, SV074, SV075, SV076, SV080, SV081, SV083, SV084, SV085, SV086, SV089, SV090, SV092, SV094, SV099, SV100, SV104, SV106, SV109, SV113, SV114, SV118, SV124, SV126, SV128, SV129, SV131, SV133, SV134, SV136, SV147, SV148, SV149, SV152, SV153, SV157, SV159, SV167, SV169, SV170, SV171, SV175, SV176, SV178, SV182, SV184, SV186, SV187, SV190, SV191, SV196, SV199, SV200, SV202, SV210, SV212, SV218, SV222, SV223, SV224, SV227, SV229, SV231, SV233, SV235, SV236, SV237, SV238, SV242, SV243, SV245, SV247, SV248, SV249, SV251, SV252, SV254, SV255, SV257, SV258, SV259, SV260, SV262, SV264, SV265, SV266, SV267, SV269, SV270, SV273, SV274, SV275, SV276, SV277, SV278, SV279, SV281, SV282, SV283, SV285, SV288, SV289, SV290, SV291, SV292, SV293, SV294, SV295, SV296, SV297, SV298, SV299, SV300, SV301, SV302, SV303, SV304 | The proposed discharge of up to 43.8 ML/day of eco-toxic mine effluent must be treated using reverse osmosis technology to remove all metals and salts before discharge to the Cox's River. |
| | SV002, SV007, SV014, SV016, SV024, SV027, SV029, SV030, SV031, SV035, SV036, SV037, SV039, SV041, SV043, SV045, SV048, SV054, SV055, SV056, SV058, SV059, SV060, SV062, SV063, SV064, SV065, SV070, SV073, SV074, SV075, SV076, SV080, SV081, SV083, SV084, SV085, SV086, SV088, SV089, SV092, SV094,SV099, SV100, SV104, SV106, SV107, SV109, SV113, SV114, SV118, SV124, SV126, SV128, SV129, SV131, SV133, SV134, SV136, SV147, SV152, SV153, SV157, SV159, SV167, SV169, SV170, SV171, SV175, SV176, SV178, SV182, SV184, SV186, SV187, SV190, SV191, SV196, SV199, SV200, SV202, SV210, SV212, SV218, SV222, SV223, SV224, SV227, SV229, SV231, SV233, SV235, SV236, SV237, SV238, SV242, SV243, SV245, SV246, SV247, SV248, SV249, SV252, SV255, SV257, SV258, SV259, SV260, SV262, SV264, SV265, SV266, SV267, SV269, SV270, SV273, SV274, SV275, SV276, SV277, SV278, SV279, SV281, SV282, SV283, SV285, SV288, SV289, SV290, SV291, SV292, SV293, SV294, SV295, SV296, SV297, SV298, SV299, SV300, SV301, SV302, SV303, SV304 | Carne Creek is currently in a pristine state, and its waters that flow through the Greater Blue Mountains World Heritage Area are of the highest standard. This creek must not run bright orange or suffer reduced flows, just like the Wolgan River after Centennial Coal wrecked it. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV102, SV130, SV194, SV216, SV230, SV232, SV256, SV280, SV305 | The discharge from both mines of metal-rich salts will impact the Coxs river that supplies Sydney with drinking water, part of the Warragamba catchment. This will lead to possible contamination of Sydney's drinking water. |
| | SV091, SV096, SV098, SV149, SV161, SV246, SV280 | The combined effluent from both mines will be 43.8 ML/day in 2023. 30.8 tonnes/day of toxic effluent will be discharged into the Cox River which supplies Sydney' drinking water. This is unacceptable. |
| | SV009 | The proposal will cause creek flows and swamp waters to move many meters underground and pretend that nothing has happened. |
| | SV030 | No mining discharge water should be allowed to leave a mining site and flow into natural creeks and streams unless it equals the same natural background levels. These streams should be protected. |
| | SV030 | Mining discharge water should be treated with desalination methods and not filtration dams. Mining discharge water from this particular area is over 1000µs/cm which is breaching the ANZECC guidelines. |
| | SV096, SV215 | Carne Creek and other waterways in the area must not be permanently despoiled by reduced water flows and the discharge of toxic effluent. |
| | SV066 | This proposal plans to pollute Sydney's water supply. |
| | SV096 | The mine effluent discharged into the Cox River will lead to negative impacts on the surrounding environment and local recreational fishing. |
| | SV049, SV098, SV111, SV160, SV189, SV246 | The project will impact on Carne Creek, the Wolgan River, Marrangaroo Creek, Bunglebouri Creek, Wolgan River and Rocky Creek headwaters and catchments. These impacts will be unable to be mitigated. |
| | SV142 | The Wolgan River is dry, where it once ran into the valley as a magnificent waterfall. This must not happen to Carne Creek. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV111 | More information on the mitigation of increased concentrations of heavy metals into the Coxs River and Sydney's water supply plus potential health impacts mediated through water quality and security is urgently required. |
| | SV280 | The Wallerawang Power Plant has shut down, possibly permanently. The current SDWTS proposal to provide water to this plant is not viable. |
| | SV280 | Before discharge, the mine water must be treated to a standard that protects undisturbed aquatic ecosystems using reverse osmosis technology to remove metals and salts. |
| | SV280 | The eco-toxic mine effluent currently running at 12.5ML/day has unacceptably high levels of turbidity, heavy metals and salinity. |
| | SV280 | The impact of subsidence on surface water in Appendix F, Chapter 6.4 p.98 investigates impacts on Marrangaroo Creek, Wolgan River and as far as the Colo River. Carne Creek which will be directly undermined is left out. |
| | SV280 | The SoEI states "The consequence of increased discharge to the Cox's River is not significant since there is excess demand for this water resource in this catchment." (p.479). This argument neglects the fact that the mine discharge water is contaminated with heavy metals and is of high salinity. |
| | SV149 | Any malfunction of the SDWTS, such as following a bushfire, must not result in emergency discharges to the World Heritage Area via Wolgan River or Carne Creek. These discharges must be properly treated and reinserted underground into the mine instead. |
| | SV149 | There should be no emergence of near surface groundwater with elevated levels of salt or metal precipitate in Carne Creek. |
| | SV149 | Discharge of what is effectively untreated, highly contaminated mine water to Kangaroo Creek via LDP001, and subsequently to the Cox's River, is inappropriate. The measures proposed to mitigate the ongoing and increasing damage to these aquatic ecosystems are inadequate. |

| Area of Concern | Centennial Submission ID | Summary of Issue |
|---|---|---|
| | SV149 | A complete redesign of the waste water management system is essential, ensuring Centennial is held accountable for ensuring the water management system is designed to cope with all scenarios and ensure that no waste water is ever transferred to watercourses. |
| | SV149 | Emergency discharge points in the Wolgan River and Carne Creek must be eliminated and those discharge licences voided. |
| | SV160 | The effective doubling of discharge via the water transfer scheme (the SDWTS), with flow of saline ground water to the Cox's River catchment will have a detrimental effect on the aquatic biota. |
| Traffic<br>(Section 3.3.14) | SV160 | The project will lead to another increase in traffic on poor quality state forest roads 24 hours a day, 7 days a week. |
| Visual<br>(Section 3.3.15) | SV160 | Centennial says there will be little visual impact at their test sites, but if you travel to say Birds Rock lookout (one of their test sites) you see numerous examples of their mining infrastructure along the way. |

# 3.0 RESPONSE TO SUBMISSIONS

## 3.1 Response to Government Agency Submissions

### 3.1.1 Aboriginal Heritage

**OEH considers that a more definitive assessment of the probability of roof fall collapse is required in rock shelters that have cultural deposits. In other assessments the standard used in assessing subsidence effects on ACH in longwall mining operations has been based on percentage estimates. A minimum 10% chance of roof fall collapse is an accepted threshold range from which decisions about appropriate mitigation can be considered. It is OEH's view that in circumstances where the chance of roof fall collapse exceeds 10% the appropriate mitigation is to excavate the shelter for salvage of Aboriginal objects and extract as much information that is appropriate for interpretation and educational purposes. (OEH)**

As detailed in Section 6.11.5 of the Subsidence Assessment prepared by MSEC and provided as Appendix D to the EIS, there is one site within the Springvale Mine Extension Area comprising a rock shelter, being Site 45-1-0065. This site is located around 200 metres east of the proposed LW424. At this distance, the site is predicted to experience approximately 25 mm of vertical subsidence. While it is possible that the site could experience this very low level of subsidence, it would not be expected to experience any measurable conventional tilts, curvatures or ground strains.

The rock shelter is located along the side of a ridge line and, therefore, is not expected to experience any valley related upsidence movements or compressive strains due to valley closure movements. It is unlikely, therefore, that the rock shelter would experience any adverse impacts resulting from the proposed mining, even if the predictions were exceeded by a factor of 2 times.

Centennial Coal is currently in the process of developing a regional Aboriginal Cultural Heritage Management Plan for its western operations. The regional Aboriginal Cultural Heritage Management Plan is being developed in consultation with relevant Registered Aboriginal Parties and government agencies including OEH. The regional Aboriginal Cultural Heritage Management Plan will include a consistent approach to the monitoring and management of all Aboriginal heritage sites within the extent of mining leases and exploration licences for Centennial's western operations and encompasses Springvale Mine. Monitoring of Aboriginal Heritage sites subject to subsidence will be undertaken prior to, during and at the completion of impacts from mining with any management actions required to be implemented developed in consultation with the relevant Registered Aboriginal Parties and OEH. Potential impacts from mining will be able to be identified early and appropriate management actions taken to minimise the risk where appropriate. Any impacts will be mitigated in consultation with the relevant Registered Aboriginal Parties and OEH.

**OEH considers that structurally sensitive Aboriginal sites should also be monitored during the progression of adjacent longwalls and as the underlying longwall progresses. If damage begins to appear during progression of mining in proximity to the sites, appropriate action should be taken. This should be incorporated in the Cultural Heritage Management Plans, which should be developed in consultation with the Registered Aboriginal Stakeholders and OEH. (OEH)**

Centennial Coal is currently in the process of developing a regional Aboriginal Cultural Heritage Management Plan for its western operations. The regional Aboriginal Cultural Heritage Management Plan is being developed in consultation with relevant Registered Aboriginal Parties and government agencies including OEH.

A project inception meeting for the development of the regional Aboriginal Cultural Heritage Management Plan was held on 16 July 2014 and was attended by a representative from OEH.

The regional Aboriginal Cultural Heritage Management Plan will include a consistent approach to the monitoring and management of all Aboriginal heritage sites within the extent of mining leases and exploration licences for Centennial's western operations and encompasses Springvale Mine. Monitoring of Aboriginal Heritage sites subject to subsidence will be undertaken prior to, during and at the completion of impacts from mining with any management actions required to be implemented developed in consultation with the relevant Registered Aboriginal Parties and OEH.

Once finalised, the regional Aboriginal Cultural Heritage Management Plan will be submitted to NSW Planning and Environment for approval.

**The action relating to skeletal remains should be reworded. (OEH)**

Springvale Coal acknowledges OEH's proposed rewording of this management action and will ensure that through the development of the Aboriginal Cultural Heritage Management Plan following development consent that the management action will read as "In the unlikely event that skeletal remains are identified, work must cease immediately in the vicinity of the remains and the area cordoned off. NSW Police are to be contacted in first instance. No further action is to be taken until the Police provide written advice to the proponent on how to progress. If determined to be Aboriginal, the proponent must contact the Enviro line (on 131 555), a suitably qualified archaeologist and representatives of the local Aboriginal community stakeholders to determine an action plan for the management of the skeletal remains, formulate management recommendations and to ascertain when work can recommence."

**The Applicant shall ensure that the development does not cause any direct or indirect impact on identified Aboriginal sites located outside of the approved disturbance area of the development on the site. Lithgow City Council)**

A Cultural Heritage Impact Assessment was prepared by RPS to support the Project and is provided as Appendix K to the EIS.

As identified in the Cultural Heritage Impact Assessment, no Aboriginal heritage sites were located within areas to be disturbed for surface infrastructure. 34 sites were identified within the Project Application Area or within 50 metres of its boundary. Of the 34 sites, three are at potential risk of harm from mine subsidence. The remaining Aboriginal heritage sites are 'unlikely' or 'very unlikely' to be impacted by the extraction of the proposed longwalls. All sites subjected to subsidence will be monitoring monitored in accordance with the protocols set out in the Regional Aboriginal Cultural Heritage Management Plan currently being developed in consultation with the Registered Aboriginal Parties and OEH.

No impacts to Aboriginal heritage sites beyond the subsidence impact area or surface disturbance areas are predicted.

### 3.1.2 Air Quality

**To minimise any potential health impacts it is recommended that, should the project be approved, the proponent is required to implement all reasonable and feasible measures to minimise particulate matter emissions. Such measures might include reactive dust management systems. (NSW Health)**

As detailed in Section 10.7.2 of the EIS, on-site ambient TSP and $PM_{10}$ monitoring have been undertaken at Springvale Mine since December 2010 with two co-located high volume air samplers measuring TSP and $PM_{10}$ concentrations operating on a 1-in-6-day cycle. In addition, static dust deposition monitoring has been recorded since January 2007 from two locations. The locations of these dust monitors are shown on Figure 3.9 in the EIS.

In addition to the air quality monitoring detailed in the EIS, a TEOM is currently installed and operating at Blackmans Flat. Springvale Coal will commit to installing an additional TEOM as part of a regional air quality monitoring programme that is currently being developed by Centennial Coal for its western operations. This has been included in the revised Statement of Commitments contained in **Section 5.0** of this RTS.

An Air Quality Impact Assessment was prepared by SLR Consulting to support the Project and is provided as Appendix M to the EIS. The air quality impact assessment included the development of a dispersion model for the construction, operation and site rehabilitation phases of the Project. The results of the dispersion modelling are provided in Section 10.7.3 of the EIS and demonstrate dust levels (i.e. TSP, $PM_{10}$, $PM_{2.5}$ and dust deposition) arising from the Project's construction, operation and rehabilitation activities are predicted to be within relevant air quality criteria.

The current air quality management measures employed at Springvale Mine include:

- Spraying,
- Minimisation of exposed areas; and
- Ceasing work during adverse weather conditions.

These management measures will continue to be implemented throughout the life of the Project.

As detailed in Section 11 of the EIS, the Air Quality Management Plan will be updated within 6 months of receiving Development Consent. The Air Quality Management Plan will include all monitoring locations and dust mitigation measures to be implemented for the life of the Project.

**The modelling that has been conducted includes only external sites that are operational or have been approved and will be operational in the near future when considering cumulative dust and particulate matter. The modelling does not include proposed developments, such as Neubeck, Cullen Valley and Invincible Mines which may become operational during the lifespan and Springvale and Angus Place Mines. The cumulative effect of all the developments which are in close proximity to each other may result in air quality exceedences for sensitive receivers. (NSW Health)**

The cumulative assessment of any future proposed developments, such as Neubeck Project, Cullen Valley and Invincible Mines, which may become operational in the future, will be considered by those projects in their respective EISs.

### 3.1.3 Biodiversity Strategy

**OEH considers that the Regional Biodiversity Strategy included in the EISs does not fulfil the Director-General's requirements as it has not demonstrated that the biodiversity values of the region will be maintained or improved in the medium to long term. Importantly, the proponent has only assessed offsetting requirements for impacts associated with vegetation clearing activities and has not considered losses to habitat and ecosystem condition that will be a direct impact from rock fracturing and changed hydrology in its offsetting strategy. In addition, the selection of the proposed offset is not justified and the proposed Regional Biodiversity Strategy does not fulfil all of the NSW Offset Principles for Major Projects as presented in the Draft Policy. (OEH)**

Section 5 and Section 6 of the Regional Biodiversity Strategy (revised August 2014) have been updated to include further detail on the biodiversity values of each Project Application Area and the proposed Offset Land.

Offsets are required where the impacts associated with a project cannot be avoided or mitigated. Where impacts cannot be avoided, the Draft NSW Biodiversity Offsets Policy for Major Projects requires reasonable attempts to be made to minimise the impact (or make the impact less severe). Where all attempts have been made to avoid or minimise the impacts, offsets should be used to compensate for the residual impacts.

Impact assessments for subsidence (MSEC 2013) and groundwater (RPS 2014a) found that significant reductions or reversals of grade that could otherwise cause ponding or scouring are unlikely to occur. Further to this, no losses of infiltrated water and minimal divergence of surface water would be expected within shrub swamps or upstream drainage lines (RPS 2014, Flora and Fauna Impact Assessment). This is due to the expected height of continuous fracturing, as a result of subcritical longwall width, being below the Mount York Claystone, a geological layer significant in its role as a barrier to vertical fracture propagation. These studies, and the Flora and Fauna Impact Assessment for the Project (Appendix H to the EIS) concluded that there are no expected direct impacts to hydrology as a result of rock fracturing. Therefore, there are no residual impacts that would require an offset.

Section 2 of the Regional Biodiversity Strategy (revised September 2014, and included in **Appendix 4** to this RTS), outlines how each project within the Strategy addresses the NSW Offsets Principles (published by the NSW OEH in July 2013). The Draft NSW Biodiversity Offsets Policy for Major Projects was released for public comment in March 2014. Public submissions on the Draft Policy closed on 9 May 2014. Project applications for the Springvale MEP, Angus Place MEP, Airly MEP and the Neubeck Coal Project were submitted prior to, or during the public exhibition phase of the Draft Policy. The Draft Policy will be phased into use through transitional arrangements, which are anticipated to commence in late 2014. The Draft Policy will include flexibility in its application during this transitional period, with the transition taking approximately 18 months once the Draft Policy has been adopted by Government.

Regardless, Centennial Coal has reviewed the Draft Policy and its expectations against the strategy detailed in the Regional Biodiversity Strategy. Amendments have been made in the Regional Biodiversity Strategy (revised August 2014) to reflect this review.

**The proponent must meet the requirements of the EPBC Environmental Offsets Policy (October 2012) and Offsets Assessment Guide, including legal arrangements and funding provision for in-perpetuity management of offset lands, prior to the finalisation of an EPBC approval. (DotE)**

Section 2 of the Regional Biodiversity Strategy (revised September 2014) provides further detail on how the Regional Biodiversity Strategy meets the requirements of the EPBC Environmental Offsets Policy (2012) and the Offsets Assessment Guide.

Section 8 of the Regional Biodiversity Strategy (revised September 2014) provides detail on how the Offset Land will be secured, including anticipated timeframes for securing the land and Section 9 provides detail on the management plan requirements for the offset land.

**The Department notes that whilst both EIS documents acknowledge the potential for some impacts on the THPSS ecological community (the total area of THPSS being mined under being 96.6 ha), the proposed offset area does not contain any THPSS nor does it appear to have any habitat for EPBC listed threatened species (such as the Blue Mountain Water Skink) that may be impacted by the proposed action. (DotE)**

**The Response to Submissions reports should provide information that shows how the proposed offsets comply with the Offsets Policy including, if necessary, the location of THPSS offsets (to account for any residual impact to THPSS once any avoidance has been taken into account), their current condition, the management actions proposed to improve ecological condition and the preferred mechanism for in-perpetuity conservation. Any other matters of national environmental significance requiring an offset should also be covered. (DotE)**

The EPBC Environmental Offsets Policy requires offsets to be considered where there is a residual impact following measures to avoid and mitigate. Particular consideration, in the context of the residual impacts, should be given to the attributes being impacted, how important that attribute is to the ecology of the MNES and how much the attribute is being impacted (that is, the scale of the impact). The offset package should consider the improvements that the offset will deliver for the attribute being impacted and the level of averted loss resulting from the proposed offset with a view to achieving a minimum conservation gain.

The Flora and Fauna Impact Assessments for the Springvale MEP and the Angus Place MEP conclude that there will be no significant impact to MNES, including the THPSS. Chapter 2 of the EIS for each project provides details on the investigation efforts undertaken to establish the mechanisms that could lead to a mining related impact to THPSS and associated fauna species. These investigations have concluded that there are a number of causal factors that, in combination, would result in impacts occurring. Where any one of these causal factors can be avoided, the causal linkage to impact will not be realised. These causal factors and the management controls implemented by Springvale Coal are detailed in in Table 2.6 of the EIS.

Whilst the combination of these assessments have concluded that there will be no significant impact to MNES, and therefore no requirement for a direct offset, Centennial has committed to improving the quality of THPSS within its Project Application Area for each Project through its Revised Regional Biodiversity Strategy. The Regional Biodiversity Strategy a management strategy (detailed below) for the management of indirect and residual impacts to THPSS where mitigation measures are not successful. This management strategy, and the approach to developing it, is described in detail in **Appendix 4**, and summarised below:

- To ensure impacts to THPSS are within those predicted within the SVMEP EIS and the APMEP EIS, Centennial will:
  - Undertake annual monitoring for ecosystem health using the University of Queensland Monitoring Handbook (Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps, 2014) or its latest version.
    - The objectives of the University of Queensland Monitoring Handbook include, amongst other things:

    - A focus on vegetation community structure and diversity, including biological indicator species.
    - Trigger values focussed on detecting impacts of subsidence and/or changes in groundwater and surface water flows, including information on how the triggers were derived.
    - A sampling design that is statistically capable of detecting changes in the indicator variables.
    - An adaptive management mechanism for refining trigger values and determining the length of time a THPSS is monitored.
  - The following figure, taken from the Monitoring Handbook, identifies how the data collected will be used to inform management decision making.

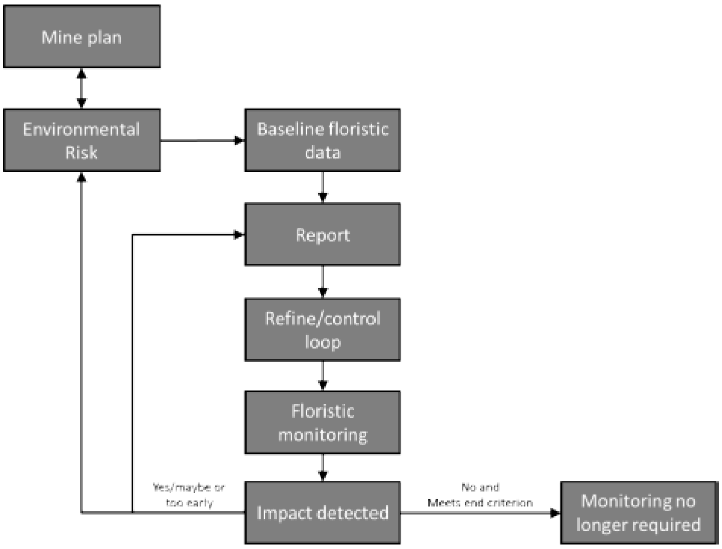


Figure 4.1: Conceptual framework showing how data from flora monitoring informs the environmental risk assessment and monitoring conclusions.

- Where this monitoring identifies mining related impacts, mitigation measures will be implemented (including soft and hard engineering measures discussed further in **Appendix 4**).
- Reconcile the annual monitoring every five (5) years (to allow for trend analysis to occur).
  - Where impacts, attributable to mining, are above triggers, additional mitigation will be undertaken.
  - Where impacts are attributable to mining and cannot be mitigated, or mitigation is not successful, offsets for the residual impacts will be provided.

This THPSS management strategy is considered to adequately compensate for the indirect impacts to that community.

When the EPBC Environmental Offsets Policy is applied to the THPSS, no direct offset is required.

### 3.1.4 Construction

**The applicant is to apply for a construction certificate with Lithgow City Council or Private Certifier for all building construction works. (Lithgow City Council)**

Springvale Coal will apply for a construction certificate with Lithgow City Council or Private Certifier for all building construction works.

**A Construction Management Plan is to be prepared in consultation with Lithgow City Council and implemented for the duration of the construction phase at each project site. (Lithgow City Council)**

As detailed in Section 11.0 of the EIS within the Statement of Commitments, Springvale Coal will commit to developing a Construction Environmental Management Plan in consultation with the Forestry Corporation of NSW six (6) months prior to construction of surface facilities on the Newnes Plateau.

Springvale Coal will commit to providing a copy of the Construction Environmental Management Plan to Lithgow City Council for their consideration. This has been included in the revised Statement of Commitments contained in **Section 5.0** of this RTS.

### 3.1.5 Cumulative Impacts of Mine Subsidence

**The interaction of the two mines where they come into close proximity to one another does not appear to have been specifically addressed in the EIS apart from an indication in Table 9.4 of the Springvale EIS. (OEH)**

The proposed longwalls at the Angus Place and the Springvale MEPs are located at a distance of 780 m apart, at their closest point. The depth of cover in this location is around 420 m and, therefore, the 26.5 degree angle of draw lines extends distances of 210 metres outside the proposed longwalls. The 26.5 degree angle of draw lines from each of the collieries do not overlap and are separated by a minimum distance of 360 m.

The predicted vertical subsidence within the Study Area (i.e. 26.5 degree angle of draw line) for the Angus Place MEP, due to the extraction of the proposed longwalls associated with the Springvale MEP, is less than 20 mm and vice versa. The natural and built features located within the Study Area for the Angus Place MEP, therefore, are not affected by the conventional mine subsidence movements resulting from the proposed longwalls at the Springvale MEP and vice versa.

The predicted vertical subsidence at the surface between the two MEPs and outside the respective Study Areas (i.e. 26.5 degree angle of draw lines), is less than 20 mm due to the extraction of the proposed longwalls at both collieries. The natural and built features in this location are not expected to be adversely impacted by the conventional ground movements.

Valley related and far-field horizontal movements extend outside the 26.5 degree angle of draw lines. For this reason, the impact assessments for the features located between the two collieries which could be sensitive to these movements have considered the cumulative effects of mining at both sites. In Section 5.1 of the subsidence reports, it was stated that:

"The natural features within the Extension Area which have already experienced mine subsidence movements due to the previously extracted longwalls at Angus Place and Springvale Collieries have been assessed based on the predicted movements due to both the existing and proposed longwalls (i.e. cumulative movements). These features include: The Wolgan River; Carne Creek; Shrub swamps within the Wolgan River valley; and Cliffs and pagoda complexes within the Wolgan River valley".

The sections of the Wolgan River and Carne Creek predicted to experience valley related movements resulting from the proposed longwalls at the Angus Place MEP are not predicted to experience any measurable valley related movements due to the proposed longwalls at the Springvale MEP and vice versa. Whilst the impact assessments for these streams and the associated features along their alignments considered the cumulative subsidence movements resulting from the proposed longwalls at both mines, the predicted movements could be considered in isolation since there is no overlap.

The smaller drainage lines located between the Study Areas for the Angus Place and Springvale MEPs could experience small valley related movements from the proposed longwalls at both collieries, but these are not expected to be sufficient to result in adverse impacts.

### 3.1.6 Exploration

**Proposed exploration activities must be notified to DRE and, where applicable, to the Forestry Corporation of NSW including copies of due diligence assessments and site assessments where available. Exploration must not commence until appropriate approvals and/or consents have been obtained from these agencies. (DRE)**

As detailed in Section 4.2 of the EIS, exploration activities will continue throughout the life of the Project within the Project Application Area with a view of refining the site's existing geological model used for detailed mine planning. Approval for these activities is sought as part of the Project.

All exploration activities will be carried out in accordance with the requirements of the Mining Act 1992 and relevant mineral authorities, including the Environmental Impact Assessment and any associated Development Consent.

Proposed exploration activities will be notified to DRE and where applicable to the Forestry Corporation of NSW. All required approvals will be obtained prior to the commencement of any exploration activities. Copies of any due diligence assessments will also be provided to DRE and Forestry Corporation of NSW (or other landowners if not within a State Forest). This commitment has been included in the revised Statement of Commitments contained in **Section 5.0** of this RTS.

**Section 4.2 of the EIS covers proposed exploration. The level of detail does not clearly identify whether there is likely to be a significant impact or provide commitment to avoid sensitive areas identified in proposed studies. (DRE)**

**Drill sites and associated access tracks are to be located where possible to avoid threatened flora species, avoid hollow bearing trees, avoid EECs, minimise clearing and avoid identified Aboriginal heritage sites. (Lithgow City Council)**

Springvale Coal has developed an area-based assessment procedure for exploration activities to ensure that they are conducted in an environmentally responsible manner and with due consideration to the community. This includes a risk-based process for the selection, assessment and environmental management of proposed drill pad sites and access tracks based on environmental, geological, logistical and other operational constraints. This process has successfully been adopted in the past by Springvale Coal.

As detailed in Section 4.2 of the EIS, Springvale Mine will continue to utilise area-based assessment procedures for the management of exploration activities to ensure that they are conducted in an environmentally responsible manner and with due consideration to the community. This will include a risk-based process for the selection, assessment and environmental management of proposed drill pad sites and access tracks based on environmental, geological, logistical and other operational constraints.

Drill sites and associated access tracks will be located where possible to:

- avoid threatened flora species;
- avoid hollow bearing trees;
- avoid endangered ecological communities;
- minimise clearing; and
- avoid identified Aboriginal heritage sites.

**There is no estimate of the number or location of holes to be drilled. (DRE)**

**No information regarding how much disturbance is required per drill hole or how many drill holes are estimated over the life of the Projects. There is no information provided regarding how much cumulative disturbance the exploration programme has caused in the past, nor how much is anticipated in the future. This has the potential to impact a large area over time. (OEH)**

As detailed in Section 4.2 of the EIS, exploration activities will continue throughout the life of the Project within the Project Application Area with a view of refining the site's existing geological model used for detailed mine planning.

The location and number of proposed geological exploration boreholes is currently unknown, and as a consequence, detailed environmental and social impact assessment cannot be undertaken at this time. As the required drill hole locations are determined, Springvale Coal will undertake a series of due diligence assessments to consider ecology, archaeology and noise as relevant. The appropriate industry and legislative guidelines and policies in force at the time will be referenced and the assessments provided to the Department of Planning and Infrastructure.

A standard disturbance footprint for exploration drilling activities is 40 m x 40 m. All drilling activities are to be undertaken within this confine.

Springvale Coal has developed an area-based assessment procedure for exploration activities to ensure that they are conducted in an environmentally responsible manner and with due consideration to the community. This includes a risk-based process for the selection, assessment and environmental management of proposed drill pad sites and access tracks based on environmental, geological, logistical and other operational constraints. This process has successfully been adopted in the past by Springvale Coal.

The decision to locate a drill site is subject to various geological and topographical constraints. It is also subject to agreement from landowners to provide access. As such, it is not possible to provide intended locations for exploration drill sites, or the number of exploration drill sites, for the life of the Project as part of the EIS.

Upon completion of exploration activities, all boreholes and surface disturbance will be sealed and rehabilitated in accordance with the appropriate guidelines at the time. Regular follow up inspections of rehabilitated drill sites will be undertaken to ensure appropriate rehabilitation has been achieved.

Due to the low level of impact on the ecology as a result of exploration drilling, the requirement to adhere to conditions of various exploration licences and a history of successful rehabilitation of exploration drill sites, Springvale Coal does not consider that exploration drilling activities will have any significant impact on the area over time and not required to be offset..

**While it is proposed that assessments will be provided to DP&E, there is no information provided regarding whether these will be reviewed, or whether further approvals will be required. OEH considers that the EISs do not contain sufficient information to enable an informed and legally defensible decision to be made regarding the proposed exploration programme. (OEH)**

As detailed in Section 4.2 of the EIS, the exploration programme will be undertaken throughout the life of the Project and approval for these activities is sought as part of the Project. Only landowner access approval will be required once Development Consent is granted. The process for the selection of exploration drill sites is detailed in Section 4.2 of the EIS. Due diligence assessments will be provided to NSW Planning and Environment for their information only. Copies of any due diligence assessments will also be provided to DRE and Forestry Corporation of NSW (or other landowners if not within a State forest). This commitment has been included in the revised Statement of Commitments contained in **Section 5.0** of this RTS.

### 3.1.7 General

**Lithgow City Council is to be notified of any modifications and determinations. (Lithgow City Council)**

Noted

**The applicant is to prepare and submit Annual Reviews (formerly Annual Environmental Management Reports) to Lithgow City Council to review. (Lithgow City Council)**

Springvale Coal will continue to provide copies of the Annual Reviews to Lithgow City Council.

**The applicant may carry out coal transportation and processing operations on the site for up to 13 year from the date of this consent. Rehabilitation works are able to proceed after this end date. (Lithgow City Council)**

Noted. As described in Section 4.1 of the EIS, Springvale Coal is seeking approval to undertake the activities as described in the EIS for a period of 13 years from date of consent.

**The applicant shall produce up to 4 million tonnes of coal per year for up to 25 years. (Lithgow City Council)**

As described in Section 4.1 of the EIS, Springvale Coal is seeking approval to continue to produce up to 4.5 million tonnes of ROM coal per year during the life of the Project (up to 13 years).

**Inconsistent statements regarding the depth of cover in the EIS. In Section 8.2 cover is referenced at between 300m and 430m, while other sections clearly show and state depth of cover between 180 and 420m). (DRE)**

As noted in Section 1.3 of the Subsidence Impact Assessment (Appendix D of the EIS) and shown in Figures 1.3 to 1.5 in that report the depth of cover to the Lithgow Seam, directly above the proposed longwalls, varies between a minimum of 180 metres above the commencing (southern) ends of the proposed LW501 and LW502, and a maximum of 420 metres above the northern end of the proposed LW416 and the southern ends of the proposed LW417 and LW419.

**The EIS contains conflicting numbering reference for the Burralow Formation (AQ5 or AQ6?) (DRE)**

Aquifers AQ5 and AQ6 are both associated with the Burralow Formation (refer Table 2.5 of the Springvale MEP EIS) and form part of the perched groundwater system within and in the vicinity of the Project Application Area. Table 2.5 in the EIS shows that the AQ6 aquifer is separated from the lower AQ5 aquifer by a semi-permeable fine grained sandstone/siltstone aquitard (denoted SP4). The Burralow Formation, along with Banks Wall Sandstone, Mount York Claystone Burra-moko Head Sandstone and Cayley Formation form part of the Narrabeen Group, the non coal-bearing Triassic strata which directly overlies the Permian Illawarra Coal Measures (refer Figure 2.6 and Table 2.5 of the Springvale MEP EIS).

Section 10.2.2.2 of the EIS (page 283) notes AQ5 is "located in the Burralow Formation" while "AQ6 is located in the upper part of the Narrabeen Group sandstone. This is an unconfined aquifer and only appears near the top of Newnes Plateau". The description for AQ6 should have also noted that it is the top-most aquifer within the Burralow Formation. The description notes that AQ6 only appears near the top of Newnes Plateau, implying that this aquifer does not exist across the region, but is restricted to the top of Newnes Plateau.

**Conflicting referencing in the EIS regarding the area of land clearing (11.44 ha or 11.8 ha - both stated on page 441). (DRE)**

The project is proposing to clear 11.44 ha of native vegetation communities, not 11.8 ha. Table 10.8 of the Springvale MEP EIS and Table 9 of the Flora and Fauna Impact Assessment for the Project (Appendix H of the EIS) lists areas of specific vegetation communities to be cleared within the proposed infrastructure corridor.

### 3.1.8 Groundwater

**The expansion of the groundwater monitoring network, and the associated monitoring The expansion of the groundwater monitoring network, and the associated monitoring schedules to be updated in the Water Management Plan (WMP), should carried out in consultation with the Office of Water. (NOW)**

The groundwater monitoring network, and the associated monitoring schedules, will be updated as part of the revisions to the Water Management Plan which will be developed in consultation with the NSW Office of Water. Groundwater monitoring data that has been and is currently being collected has provided a detailed understanding of the hydrogeological regime at Angus Place Colliery. As such, future groundwater monitoring will be limited and specifically targeted to identify potential knowledge gaps in the understanding of groundwater regimes in order to assist in the identification of potential impacts.

**The modelling used to support the EIS should be regularly updated to enable confirmation that the predicted mine water takes are not exceeding, and are not likely to exceed, the predictions made in the EIS. These periodic reviews should be incorporated within the overall annual environmental monitoring plan and the results made available to NOW in a suitable electronic format. (NOW)**

Groundwater models will be updated every 6 months and a review will be included in the Annual Review. Copies of the Annual Review will continue to be provided to NOW. This commitment has been included in the revised Statement of Commitments provided in **Section 5.0** of this RTS.

**The proponent must maintain records of annual water take from water sources impacted by the development and reported in the annual environmental report. (NOW)**

Springvale Coal will maintain records of annual water take from water sources impacted by the development and report these in the Annual Review.

**The specific impacts of the permanent reductions (and in some cases increases) in baseflow to local swamps and surface streams are not discussed in the hydrogeological impacts report.**

**These impacts are not discussed at all in the Surface Water Impact Study but are included in the ecological assessments. (OEH)**

The Groundwater Impact Assessment prepared by RPS to support the Project and provided as Appendix E to the EIS quantifies the impact on the Newnes Plateau Shrub Swamp (NPSS) or shrub swamps in terms of net change in baseflow contribution in Section 7.3.3. This section discusses in detail and individually the potential impacts on all those creeks and shrub swamps which directly overlie or are immediately adjacent to the proposed longwalls. These swamps include: Carne West Swamp, Carne Creek, Gang Gang Swamp South, Gang Gang Swamp East, Nine Mile Swamp, Pine Swamp, Paddys Creek, Marrangaroo Creek Sunnyside Swamp and Coxs River. The baseflow impacts summary presented at the end of Section 7.3.3 concludes that predicted impacts on baseflows as a result of extraction of proposed longwalls at Springvale Mine are varied and range from positive (increased baseflow or reduced net leakage) to negative (decreased baseflow or increased leakage) for all creeks and swamps noted above, except Coxs River. No impacts on baseflow are predicted at Coxs River.

Table 7.2 of the Groundwater Impact Assessment quantifies the predicted baseflow changes due to Springvale Mine’s operation only, cumulative changes when assessed with Angus Place Colliery’s operations, and the residual difference at 100 years post mining from baseline. Overall a net decline in baseflow of 0.1246 ML/day is predicted from Springvale Mine’s proposed operations. The predicted cumulative impact when Springvale Mine’s proposed operations occur concurrently with Angus Place Colliery’s operations is a decline of approximately 4.7% of the baseline baseflow. The total variation of baseflow impacts at end of mining are predicted to be ±6% and at 100 years post mining are predicted to be ±10%.

The losses of surface baseflow have been included in the total estimate of surface water take rather than groundwater take as it comprises a net reduction in contribution to a surface water feature.

Section 8.2.1, Table 8.5 and Table 8.7 of the Groundwater Impact Assessment discuss the predicted baseflow impacts and surface water licensing requirements from the Wymandy River and Colo River Management Zones relevant to the Project Application Area. For Springvale, the total annual licensing requirement due to baseflow reduction is 65.9 ML/yr for the Wywandy River Management Zone and 129.7 ML/yr for the Colo River Management Zone.

Section 7.3.5 of the Groundwater Impact Assessment refers readers to the specialist Terrestrial Flora and Fauna Assessment (Appendix H of the EIS) for detailed discussion regarding potential impacts of predicted baseflow changes due to Springvale operations on Groundwater Dependent Ecosystems. Section 7.3.5 also states that none of the swamps included in the modelling are predicted to have significant reductions in baseflow.

Section 6.2.2 of the Terrestrial Flora and Fauna Assessment discusses the potential impacts of predicted baseflow changes to Groundwater Dependent Ecosystems based on discussions in the Groundwater Impact Assessment, the Subsidence Impact Assessment (Appendix D of the EIS) and CSIRO’s Groundwater Assessment, provided as Appendix K in the Groundwater Impact Assessment.

**NOW suggest a commitment to comply with the Water Sharing Plan in the Statement of Commitments. (NOW)**

Springvale Coal will continue to consult with the NSW Office of Water regarding the granting of adequate water licences over the life of the Project in order to comply with the relevant Water Sharing Plan over the life of the Project.

**No extensometer data is reported, but it is noted that a wide range of impacts have been measured on groundwater aquifer levels over both Springvale and Angus Place mines. (OEH)**

Section 2.6.2.6 of the EIS presents extensometer data from borehole SPR40. Reviews of the extensometer data have identified three distinct zones of sub-surface fracturing that indicate continuous fracturing between strata units (A-Zone), discontinuous fracturing and strata dilation (B-Zone) and a deformed elastic zone (C-Zone). The relationships of these zones to overlying strata are illustrated in Figure 2.22 of the EIS.

Further information to support the determination of the height of fracturing including additional information from extensometer data is provided in **Appendix 6** to this RTS. An additional peer review was carried out by MSEC with their report provided as **Appendix 7** to this RTS.

**The groundwater model has been constructed using industry best practice methods and is acceptable for predicting mine inflows. However, the scale of the groundwater model is inappropriate to predict groundwater related impacts to individual THPSS. Further, a number of swamps are not incorporated into the groundwater model. Finer scaled, site specific models, informed by a conceptualisation of the hydrology and hydrogeology, would be needed to have confidence in the predictions of groundwater impacts to individual swamps. (DotE)**

A detailed response has been provided in Section 2.1 of **Appendix 16**.

**Confidence in groundwater model predictions is limited by a lack of site specific hydrogeological data and lineament groundwater flow behaviour. The assessment of surface water impacts, including cumulative impacts, needs to consider contaminants such as copper, zinc, nitrogen and phosphorus, which groundwater quality monitoring shows all exceed ANZECC guidelines. (DotE)**

A detailed response has been provided in Section 2.1 of **Appendix 16**.

**Is the groundwater model suitably robust, and are the resulting quantitative predictions accurately and reasonably described? (DotE)**

**The groundwater model is a regional scale model that provides generally robust predictions of mine groundwater inflows. These are reasonably described. However, due to the scale of the groundwater model, it is limited in its capability to predict groundwater related impacts to surface water systems including those affecting THPSS and proximal reaches of the Coxs River. This results in a low level of confidence in the predictions of impacts to Cox's River and THPSS baseflows described within the EIS. (DotE)**

A detailed response has been provided in Section 2.2 of **Appendix 16**.

### 3.1.9 Infrastructure

**Lot 5 in DP829137 appears to be the closest parcel of land to TransGrid's infrastructure. Any development proposed near TransGrid's infrastructure is subject to SEPP (Infrastructure) 2007, in particular regulation 45. (TransGrid)**

Springvale Coal acknowledges that any development undertaken near TransGrid owned infrastructure is subject to clause 45 of SEPP (Infrastructure) 2007.

**Lot 11 in DP1139978 is imminently close to TransGrid's Wallerawang 330KV Transmission Line Outlet Easement and the State significant infrastructure situated therein. The south west corner of this parcel of land (Lot 5 in DP1139978) is located only 2 metres from the outer edge of TransGrid's easement; approximately 26 metres from the actual transmission line catenary (even less when the transmission line is at maximum operating temperature) and within 29 metres of the transmission line stanchion (tower). Horizontal clearances apply to all TransGrid easements and infrastructure, especially near stanchions that are constructed with subterranean earthing straps that protrude at least 15 metres diagonally from each leg of the tower. Therefore, no excavation or other earth works are to be undertaken near this tower. (TransGrid)**

No excavations or earthworks will be undertaken near the TransGrid owned Wallerawang 330KV Transmission Line Outlet Easement and the State significant infrastructure situated therein or within any TransGrid owned easements without the prior written consent of TransGrid.

**The land near TransGrid's easements and infrastructure must not become vulnerable to mine subsidence. (TransGrid)**

Springvale Coal will ensure TransGrid's easements and infrastructure will not become vulnerable to mine subsidence.

**A safe working platform must be preserved along the easement and surrounding land, so maintenance can be undertaken to the transmission line and structures. As the transmission line changes direction at the location of Structure 5 (Feeder 70/71), it is particularly important to preserve a safe working platform around this structure which should be at least a 50 metre radius. (TransGrid)**

Springvale Coal will preserve a safe working platform along the easement and surrounding land, so maintenance can be undertaken to the transmission line and structures including the TransGrid Structure 5 (Feeder 70/71).

### 3.1.10 Landowner Consent

**A review by Crown Lands of the Project Application form has noted that Section 7, Landowner's consent, has not been completed. As Crown land together with a number of Crown Roads is located with the Project Boundary Application Area, the Applicant would need to seek consent from Crown Lands. (Crown Lands)**

Section 7 of the Development Application form is related to "Landowner's Consent". Landowner consent is not required as long as the applicant advertises the project within 14 days of submitting a development application in accordance with clause 8F(3) of Environmental Planning and Assessment Regulations 2000. The Springvale MEP was advertised by Springvale Coal in the Lithgow Mercury on 30 November 2014 and The Land on 5 December 2014.

### 3.1.11 Mine Design

**The Department of the Environment considers, consistent with the advice from IESC in 2012 reproduced below, for the mining of longwalls 415, 416 and 417, that there is a high risk of severe impact to Temperate Peat Highland Swamp on Sandstone (THPSS) that are directly above or laterally adjacent to the proposed longwall panel. The mitigation measures proposed by the proponent are unlikely to reduce the risk of future potential impacts to acceptable levels. The Department believes that a precautionary approach will be necessary to avoid an unacceptable risk of impacts to THPSS. (DotE)**

**Longwall mining in areas directly below known high quality sites of temperate highland peat swamps on sandstone should be restricted which may potentially reduce the risk of unacceptable impacts on the endangered ecological community, particularly if appropriate buffers that reflect the local geological characteristics are incorporated between the longwall mining panels and high quality swamps. The Interim Committee supports the proposal that this condition could be revisited if the proponent is able to demonstrate that a proven technology or engineering methodology can be used that prevents the risk of subsidence in the listed ecological community, or that would allow any subsidence related impacts to be remediated. (IESC, 2012)**

Springvale Coal has developed a reliable and detailed understanding of the environmental constraints as a result of experience from operating Springvale Mine over many years and from the environmental management and monitoring regimes. Using this knowledge, potential environmental constraints have been taken into account during the mine design process to ensure the Project is undertaken safely and in the most environmentally sensitive manner feasible.

The approach of Springvale Mine to the MEP has been to apply a best practice system of environmental management, that is, adopt a hierarchy of avoiding, minimising, mitigating and finally, offsetting residual impacts.

As mining has progressed at Springvale Mine, the alignment and dimensions of longwall panels have been developed and refined for a range of mine designs. There has been significant effort to prioritise avoidance and reduction of potential impacts and constraints of surface features and geological and geotechnical issues, while considering mine safety, feasibility and optimisation. Sensitive surface features have been avoided where Project viability was not at risk. Section 8.3.4 of the EIS describes in detail the alternative mine layouts which considered:

- Further reduction in longwall width and increase in pillar size
- Changing distribution of longwalls to avoid undermining THPSS

- Shortening longwalls to avoid undermining THPSS
- “Splitting” longwall mining blocks to avoid undermining THPSS
- Cessation of mining north of 400 panel main headings.

None of the alternate mining layouts noted above represent a viable business case for Springvale Coal.

Previous Springvale Mine’s experience at extracting longwalls of a wide range of void widths is that the narrower sub-critical longwalls had significantly less subsidence than the wider, critical longwalls that contributed to unpredicted environmental consequences above Springvale Mine. The mine design consequence is that narrower panels (261 m void width) are proven to minimise impacts on sensitive surface features. An analysis of the sensitivity of void widths at Springvale Mine identified that:

- marginal subsidence reductions would occur for longwall void widths between 150 m and 260 m and that the greatest reductions can be made from 315 m to 260 m; and
- marginal strain reduction would occur for widths between 150 m and 260 m and that the greatest reduction can be made from 315 m to 260 m.

The sensitivity analyses confirm that narrowing the longwalls to <260 m does not afford additional environmental advantages but comes at a cost to the business viability at Springvale Mine.

The following controls have been applied through the mine design process at Springvale Mine to minimise impacts to the environment.

- Proposed longwalls LW501 to LW503 have been positioned between clusters of cliffs; only one cliff lies over LW501. Previously approved LW419 to LW422 have been shortened to avoid cliffs and pagodas.
- The mine plan has been modified to avoid most of the pagodas, however pagodas exist above LW501 and LW502.
- The proposed longwalls in the Project Application Area which lie beneath Newnes Plateau Shrub Swamps (LW416 – LW432) are designed to be sub-critical panels with void widths of 261 m resulting in void width to depth of cover (W/H) ratios <1.00, and chain pillars at least 55 m wide.

The shrub swamps to be undermined are Sunnyside East, Carne West, Gang Gang South West, Gang Gang East, Pine Swamp, Pine Swamp Upper, Marrangaroo Creek, Marrangaroo Creek Upper and Paddys Creek Swamps. The longwalls beneath these swamps are sub-critical panels and not likely to cause subsidence impacts.

Carne Central, Barrier, Sunnyside and Nine Mile Swamps have been avoided in the mine design.

In 2002, Angus Place Colliery and Springvale Mine commenced intensive monitoring, investigations and research to better understand the surface environment overlying the mining areas. These investigations have included groundwater, surface water, ecological aspects and the interplay of these aspects on shrub swamps.

The data collected and analysed over the past 11 years has been critical to providing evidence that the technologies and engineering methodologies proposed for longwall mining at Angus Place Colliery and Springvale Mine will minimise impacts to sensitive surface features.

In 2008 and 2009, monitoring at Angus Place and Springvale Collieries detected impacts attributable to mining-related activities at two Temperate Highland Peat Swamps on Sandstone (THPSS), listed under the Environment Protection and Biodiversity Conservation Act 1999. These collieries have since then launched an extensive investigative program to determine the factors causing these impacts. In addition, investigations were targeted to determine the hydrogeological characteristics of THPSS. The purpose of these investigations was to ascertain the coincident characteristics which lead to THPSS formation and to understand the sensitivity of those characteristics to mine subsidence behaviour.

The results of investigations have allowed Springvale Mine and Angus Place Colliery to understand the multiple co-incident factors that have led to historical mining-related impacts and implement management practices to ensure mining impacts will be avoided in the future or can be managed appropriately. The mine design was identified as the key controllable factor and Springvale’s mine design was changed in 2011 following the investigations in order to mitigate potential impacts to THPSS on the Newnes Plateau. LW416 onwards are designed with void widths of 261 m, reduced from 315 m void widths for LW410 – LW415 and LW416 to LW432 are sub-critical.

Since the investigations were conducted, Springvale Coal has been proactive in avoiding or minimising potential subsidence impacts to the geodiversity and biodiversity of the mining area using a comprehensive multi-disciplinary risk-based approach to mine planning and mine design in conjunction with a rigorous monitoring program.

The monitoring techniques employed are wide-ranging and complementary and the combined results provide insights into roles factors such as geology, hydrogeology, topography play in THPSS formation, and the effects of mine subsidence on THPSS.

The extensive monitoring and investigation process employed by Springvale Coal, which utilised multiple lines of evidence to support the management decisions, created the foundations for an adaptive management outcome. Mine design changes (in the form of reduced longwall void width and increased chain pillar width) were implemented in 2011 and are planned in all proposed mining areas where NPSS are present.

Based on the results of the investigation and changes implemented in response to the investigation, the Department of the Environment gave approval to mine beneath THPSS under EPBC2011/5949 in October 2013.The outcome of detailed mine planning and design as discussed above is that the Springvale mine plan minimises predicted subsidence and reduces the occurrence of subsidence effects beyond predictions.

It should be noted that to avoid directly undermining shrub swamps overlying LW416 to LW432 (noted above), is not economically feasible for Springvale Mine, and is not necessary based on the predicted impacts to the swamps as a result of the mine design proposed. The same criterion has been applied at the adjoining Angus Place Colliery where the mine design has been specifically modified in the area of Tri-Star and Trail Six Swamps, with a void width reduction from 360 m to 261 m.

### 3.1.12 Mining Title

**The project area is within mining titles held by the company and extends into the company's Exploration Licence 6317. The company will submit a mining lease application for the right to mine within the exploration license area. (DRE)**

As detailed in Section 5.3.2 of the EIS, to permit the extraction of coal within the Project Application Area a new mining lease will be required over the Project Application Area under the Mining Act 1992 in the area currently covered by Exploration Licence 6974.

### 3.1.13 Monitoring/Management

**OEH considers that, given the potential for fracturing of bedrock in drainage lines, monitoring of groundwater and flows on drainage lines within 800 m of the Gardens of Stone National Park is required. (OEH)**

The Gardens of Stone National Park is located more than 7 km north of the proposed longwalls at Springvale Mine. Section 5.15 of the Subsidence Impact Assessment (Appendix D of the EIS) notes at this distance the National Park will not experience any measurable subsidence movements as a result of the extraction of the proposed LW416 to LW432 and LW501 to LW503.

**There is no appropriate monitoring of flow in streams which is capable of testing the veracity of the claims made in the EIS of no impact to flows. (OEH)**

As detailed in Section 10.1.3 of the EIS, approximately 2 km of Carne Creek is directly above the proposed longwalls LW416- LW419. Wolgan River is located to the west of the proposed longwalls, outside the mining area, above the previously extracted longwalls at the colliery. The Wolgan River is located 460 m west of LW416, at its closest point to the proposed longwalls. The total length of the Wolgan River located within a distance of 600 m from the extents of the proposed longwalls is approximately 900 m.

No significant ponding, flooding, scouring is predicted for the Wolgan River. The Wolgan River has previously experienced up to 270 mm subsidence and 330 mm closure due to previous extraction of longwalls at both Angus Place Colliery and Springvale Mine, which caused no significant fracturing or related surface water diversions. It is not predicted that any significant fracturing or water diversion will occur due to the Project.

Given that most channels in Carne Creek catchment have grades well in excess of 25 mm/m, the predicted tilt is not expected to reverse any grades nor cause significant changes in channel grade, and is unlikely to have any adverse effect. Accordingly there is no ponding or scouring predicted, apart from the potential for small sections of grade reversal where natural channel grades are very low immediately upstream of chain pillars. The predicted tilt of 0.25 mm/m, is less than the typical natural grade of Carne Creek, which ranges from 25 mm/m to 300 mm/m and therefore no significant ponding, flooding, scouring is predicted.

Impacts to watercourses have been avoided through eliminating extraction directly underneath some watercourses and through narrowing the longwall width to sub-critical voids. As a result, monitoring of impacts to watercourses will be through the underground Strata Management Plan and will be limited to the section of Carne Creek within the 26.5 degree angle of draw.

**There is no indication of what actions will be taken if monitoring indicates that mining-induced impacts occur. (OEH)**

Chapter 11 of the EIS lists the Statement of Commitments of the Project and details the management plans that will be developed or updated for the Project following the granting of Development Consent. Springvale Coal will commit to developing Trigger Action Response Plans as part of the development of these management plans which will detail the response to be taken if mining induced impacts occur. This has been included in the revised Statement of Commitments contained in **Section 5.0** of this RTS.

**The absence of any proposed monitoring for Marrangaroo Creek is considered unsatisfactory. It is considered that as a minimum, full hydrological monitoring should again be undertaken for this significant tributary of the Coxs River, and water quality monitoring also undertaken. (SCA)**

The Statement of Commitments contained within Chapter 11.0 of the EIS notes that Springvale Coal will develop a Water Management Plan for the Project within six (6) months of development consent. This Water Management Plan will be developed in consultation with relevant stakeholders including SCA. This has been included in the revised Statement of Commitments contained in **Section 5.0** of this RTS.

The Water Management Plan will include a review of the existing groundwater and surface water monitoring sites. At this time the need for new monitoring sites, both bore sites for groundwater monitoring and surface water sites for flows and water quality, will be reviewed and implemented as relevant.

**The proposed surface water and groundwater management plans should identify critical impact thresholds in groundwater levels and quality and surface water flows and water quality to enable adaptive response and management of operations within the proposed Surface and Groundwater Management Plan. A mechanism for identifying and reporting variations from predictions should be clearly stated within the Plan. (NOW)**

**To improve the coverage of baseline characterisation data, it is recommended data loggers be installed in key monitoring bores to enable continuous monitoring of groundwater levels in response to rainfall events. (NOW)**

**The expansion of the groundwater monitoring network, and the associated monitoring schedules to be updated in the Water Management Plan (WMP), should be carried out in consultation with the Office of Water. (NOW)**

**A comprehensive monitoring and management plan should be produced that takes into account the hydrological and geological context in which the swamps sit and includes:**

**i. potential geological and hydrological impacts in upstream tributaries that feed into the peat swamps and in areas laterally adjacent to peat swamps;**

**ii. potential downstream geological and hydrological impacts;**

**iii. potential lateral geological and hydrological impacts. (IESC)**

As detailed in the Statement of Commitments contained within Section 11.0 of the EIS, Springvale Coal will develop a Water Management Plan for the Project within six (6) months of development consent. Springvale Coal will develop the Water Management Plan in consultation with the NOW. This has been included in the revised Statement of Commitments contained in **Section 5.0** of this RTS.

The Water Management Plan will include a review of the existing monitoring bore data with a commitment to installing real time data loggers in key monitoring bores to enable continuous monitoring of groundwater levels in response to rainfall events. Additionally, the Water Management Plan will identify critical impact thresholds in groundwater levels, groundwater quality, surface water flows and surface water quality to enable adaptive response and management of operations and a mechanism for identifying and reporting variations from predictions, potential geological and hydrological impacts in upstream tributaries that feed into the peat swamps and in areas laterally adjacent to peat swamps, potential downstream geological and hydrological impacts and potential lateral geological and hydrological impacts.

**A minimum of 2 years of baseline data should be applied for all GDE sites within range of longwall panels. (NOW)**

Springvale Coal has committed to monitoring groundwater dependant ecosystems potentially impacted by the Project. Groundwater monitoring will be undertaken 2 years prior to, during and for 2 years following completion of mining in the adjacent longwall panel.

**Prior to construction commencing, the applicant must prepare a detailed Environmental Monitoring Program as part of a Subsidence Management Plan. This plan should include the monitoring of surface water drainage lines for subsidence impacts as well as monitoring impacts on swamps, wetlands, and water dependent ecosystems for subsidence impacts. (NSW Fisheries)**

As detailed in Section 11.0 of the EIS, a new Subsidence Management Plan will be developed as required by the Mining Act 1992. A new Subsidence Management Plan will be required as a condition of the Mining Lease; however this Plan will be consistent with the new Extraction Plan required for the Project, in accordance with ML1326 lease conditions.

The new Extraction Plan for the Project will incorporate requirements for monitoring and mitigating surface water, groundwater, landscape and ecology impacts identified in Chapter 10, Sections 10.1, 10.2 and 10.3 of the EIS.

**Fisheries NSW should be notified if monitoring detects significant impacts on 3rd order surface drainage lines (Strahler Ordering System) as a result of subsidence. (NSW Fisheries)**

Springvale Coal will commit to notify NSW Fisheries if any monitoring detects significant impacts to third order drainage lines as a result of subsidence.

**The proponent should develop a Riparian Habitat Management Plan regarding management and protection of riparian areas aimed at minimising riparian clearing and maintaining adequate riparian buffer zones as per the departments' Policy and Guidelines for Fish Habitat Conservation and Management (Update 2013). (NSW Fisheries)**

Riparian habitat management will be incorporated into the Biodiversity Management Plan to be prepared to support the Project.

### 3.1.14 Newnes Plateau Shrub Swamps/Hanging Swamps

**Having significantly damaged Newnes Plateau Shrub Swamp EECs in the past, the EISs do not provide any definitive evidence or guarantee that further NPSS will not be impacted by the current mine plan or future longwalls. (OEH)**

Springvale Coal acknowledges in Section 2.6.2.7 of the EIS the historical impacts to Shrub Swamps as a result of previous mining and mining related activities. Longwalls have been extracted directly or partially beneath 13 shrub swamps and 26 hanging swamps. Surface impacts have been observed at five swamps including Kangaroo Creek Swamp, Narrow Swamp North, Narrow Swamp South, East Wolgan Swamp and Junction Swamp. These have been investigated and where impacts have been observed, these have been identified as largely the result of mine water discharge. From early 2007 to April 2010, due to issues with the SDWTS infrastructure and management of the system, licensed emergency discharges of mine water to Narrow and East Wolgan Swamps via LDP004, LDP005 and LDP006 were required to ensure the safety of mine workers.

Chapter 2 of the EIS for both Angus Place and Springvale MEPs provides details on the investigation efforts undertaken to establish the mechanisms that could lead to a mining related impact to THPSS and associated fauna species. These investigations have concluded that there are a number of causal factors that, in combination, would result in impacts occurring. Where any one of these causal factors can be avoided, the causal linkage to impact will not be realised. These causal factors and the management controls implemented at Springvale Mine (and Angus Place Colliery) are detailed in Table 2.6 of the EIS.

Investigations have identified that erosional and flora dieback impacts at Narrow Swamp North, Narrow Swamp South, East Wolgan Swamp and Junction Swamp were caused by changes to swamp hydrology related to mine water discharge and were not related to subsidence. As a result of this finding, future mine dewatering systems have been designed to ensure that discharge of mine water to Newnes Plateau Shrub Swamps is avoided. This is discussed in Section 4.10.1 of the EIS.

Subsidence effects to aspects of swamp hydrology have been previously noted at two swamps (Kangaroo Creek Swamp and East Wolgan Swamp). In both of these cases investigations have revealed that mine design was a primary causative factor. The ratio of longwall mining void width to depth of cover over mine workings was identified to be in the critical subsidence behaviour range. Following this investigation, the mine design was modified for all future proposed mining areas in the vicinity of Newnes Plateau Shrub Swamps to ensure that the ratio of longwall mining void width to depth of cover over mine workings was in the sub-critical subsidence behaviour range. No subsidence effects to swamp hydrology or flora communities have been identified in areas where sub-critical mine design has been used in the past. The proposed longwalls LW416 to LW432 have been designed to be sub-critical panels with void widths of 261 m and chain pillars of 55 m.

From the detailed investigations conducted at Springvale Mine and Angus Place Colliery commencing in 2002, the following conclusions can be drawn.

- Detailed analysis of baseline data has shown that there is significant variability between individual THPSS (refer Corbett et al 2014).
- Discharge of mine water into THPSS caused impacts on swamp hydrology and geomorphology and flora communities.
- Longwall mining conducted within a $26.5^{o}$ angle of draw caused no measurable impacts to THPSS.

As noted above subsidence caused localised impacts on NPSS hydrology in Kangaroo Creek Swamp and East Wolgan Swamp. Investigations revealed that a combination of measurable factors was required in order to cause an impact on NPSS hydrology. These factors were consistent with those identified by researchers in the field of mine subsidence.

- The hydrology of the Burralow Formation aquifer/aquitard system has not been significantly affected by mine subsidence.

- Mine design in future planned mining areas has been informed by the results of the investigations into the causes of impacts on THPSS from mining related activities in order to prevent impacts in the future.

As mining has progressed at Springvale Mine, the alignment and dimensions of longwall panels have been developed and refined for a range of mine designs. There has been significant effort to prioritise avoidance and reduction of potential impacts and constraints of surface features and geological and geotechnical issues, while considering mine safety, feasibility and optimisation. Sensitive surface features have been avoided where Project viability was not at risk. Section 8.3.4 of the EIS describes in detail the alternative mine layouts which were considered:

- Further reduction in longwall width and increase in pillar size
- Changing distribution of longwalls to avoid undermining THPSS
- Shortening longwalls to avoid undermining THPSS
- “Splitting” longwall mining blocks to avoid undermining THPSS
- Cessation of mining north of 400 panel main headings.

None of the alternate mining layouts noted above represent a viable business case for Springvale Coal.

Previous Springvale Mine’s experience at extracting longwalls of a wide range of void widths is that the previously mined narrower sub-critical longwalls had significantly less subsidence than the wider, critical longwalls that contributed to unpredicted environmental consequences above Springvale Mine. The mine design consequence is that narrower panels (261 m void width) are proven to minimise impacts on sensitive surface features. An analysis of the sensitivity of void widths at Springvale Mine identified that:

- marginal subsidence reductions would occur for longwall void widths between 150 m and 260 m and that the greatest reductions can be made from 315 m to 260 m; and
- marginal strain reduction would occur for widths between 150 m and 260 m and that the greatest reduction can be made from 315 m to 260 m.

The sensitivity analyses confirm that narrowing the longwalls to <260 m does not afford additional environmental advantages but comes at a cost to the business viability at Springvale Mine.

The following controls have been applied through the mine design process at Springvale Mine to minimise impacts to the environment, including shrub swamps.

- Proposed longwalls LW501 to LW503 have been positioned between clusters of cliffs; only one cliff lies over LW501. Previously approved LW419 to LW422 have been shortened to avoid cliffs and pagodas.
- The mine plan has been modified to avoid most of the pagodas, however pagodas exist above LW501 and LW502.
- The proposed longwalls in the Project Application Area which lie beneath Newnes Plateau Shrub Swamps (LW416 – LW432) are designed to be sub-critical panels with void widths of 261 m resulting in void width to depth of cover (W/H) ratios <1.00, and chain pillars at least 55 m wide.

The shrub swamps to be undermined are Sunnyside East, Carne West, Gang Gang South West, Gang Gang East, Pine Swamp, Pine Swamp Upper, Marrangaroo Creek, Marrangaroo Creek Upper and Paddys Creek Swamps. The longwalls beneath these swamps are sub-critical panels and not likely to cause subsidence impacts.

Carne Central, Barrier, Sunnyside and Nine Mile Swamps have been avoided in the mine design.

**The irreversibility of impacts to EECs are a significant consideration for OEH. If the relatively impermeable base of the Newnes Plateau Shrub Swamps or Hanging Swamps is fractured, then any perched aquifer is likely to drain downwards into the fracture network, thereby altering natural groundwater levels within the swamp and leading to increased desiccation. These impacts have already been demonstrated for Centennial's longwall operations at both Springvale and Angus Place mines. They have also been well documented in the Southern Coalfield for coastal upland swamps. (OEH)**

**Longwall mining beneath THPSS may fracture the sandstone substrate and alter the swamp's water balance. The Department is unaware of any proven strategies to effectively mitigate longwall mining impacts other than avoiding impacts through changes to mine plan layout. (DotE)**

**The mitigation measures proposed by the proponent are unlikely to reduce the risk or the likelihood of the risk being realised to an acceptable level. (IESC, 2012)**

Section 2.6.2.7 of the EIS describes historical impacts to Newnes Plateau THPSS from mining related activities by Springvale Mine and Angus Place Colliery. Act.

As identified in Section 2.6.2.7 of the EIS: "Subsidence effects to aspects of swamp hydrology have been noted at two swamps (Kangaroo Creek Swamp and East Wolgan Swamp). In both of these cases investigations have revealed that mine design was a primary causative factor. The ratio of longwall mining void width to depth of cover over mine workings was identified to be in the critical subsidence behaviour range. Following this investigation, the mine design was modified for all future proposed mining areas in the vicinity of Newnes Plateau Shrub Swamps to ensure that the ratio of longwall mining void width to depth of cover over mine workings was in the sub-critical subsidence behaviour range. No subsidence effects to swamp hydrology or flora communities have been identified in areas where sub-critical mine design have been used in the past."

Kangaroo Creek Swamp is located above Angus Place LW940 and LW950 which had widths of 262 metres and 292 m, respectively. The depth of cover at this swamp varies between 265 m at the downstream end to 280 m at the upstream end. The width-to-depth ratios at this swamp, therefore, vary between 0.97 above LW940 to 1.04 above LW950.

The longwall width-to-depth ratios at Kangaroo Creek Swamp are greater than those where the proposed longwalls are located beneath Tri Star and Trail 6 Swamps at the Angus Place MEP (0.8 to 0.9) and beneath the shrub swamps at the Springvale Extension Project (0.70 to 0.75). The proposed longwalls beneath the shrub swamps in both Angus Place and Springvale mining areas are more sub-critical than LW940 and LW950 beneath Kangaroo Creek Swamps.

The mine design approach for all future longwall mining proposed in the Springvale Mine and Angus Place Colliery MEPs is consistent with that approved for longwall mining beneath THPSS by the Department of the Environment under the EPBC Act (approval EPBC2011/5949) for LW416 and LW417.

It is noted that fracturing of bedrock due to mine subsidence does not necessarily imply that there will be loss of surface or standing water. Bedrock contains natural joints and discontinuities due to erosion and weathering processes. Subsurface monitoring by Mills (2003 and 2007) and Mills and Huuskes (2004) along the Waratah Rivulet found that the fracture network beneath the stream extended to a depth of 12 m and bed separation and dilation extended to a depth of 20 m. For subcritical longwalls with sufficient depth of cover to develop a constrained zone, the diverted surface water flows are confined in the shallow network, which then re-emerge further downstream after sufficient fall of the stream bed elevation.

Rehabilitation works are currently being undertaken on the East Wolgan Swamp. As noted in Section 2.6.2.6 of the EIS, OEH approved the undertaking restoration actions at East Wolgan Swamp, and issued a certificate under Section 95 of the TSC Act on 25 November 2013.

Page 80 of the EIS briefly describes the rehabilitation works proposed for the East Wolgan Swamp and approved remediation works have been carried out since January 2014. The slumping area identified in LEG and Colong Foundation submissions dated May 2014 has now been rehabilitated as shown in the figures below.

**Figure 1 - Slumping area identified in LEG and Colong Foundation Submissions (May 2014)**

**Figure 2 - Slumping Area in Figure 1 in Process of Rehabilitation in Accordance with Section 95 Approved Remediation Plan (June 2014)**

**Figure 3 - Partly Remediated Slumping Area Shown in Figure 1 Following Further Remediation (June 2014)**

Soft engineering solutions for the remediation of minor impacts to swamps have been developed by Blue Mountains City Council and have been shown to be successful in a number of cases, discussed in detail in Section 3.1.18. For major impacts hard engineering solutions will be required. The following excerpt from Springvale Mine's EPBC Approval 2011/5949 Condition 1 Application of March 2013 specifically discusses "hard engineering" solutions which may be employed in the event of major impacts to THPSS caused by cracking of underlying rock.

### Hard Engineering Solutions

Hard engineering solutions may be required where cracking of the base of a THPSS may cause drainage of water away from the THPSS, which may have the potential to affect to the health of the system. Aquifer modelling and the groundwater and swamp health case studies presented in the EIS show that this is extremely unlikely. However, proven technologies related to other mining operations developed to remediate cracking of rock structures are now discussed. The integrity of the water retaining structure within the THPSS is restored through the implementation of these remediation strategies. The strategies have been researched and modified so as to suit the specific THPSS systems above the Springvale mining operation.

### Injection Grouting

Grouting of rock formations has been occurring since the 1800s (Heidarzadeh et al (2007)), and the technology has evolved since this time. It can be used in a range of different applications. Grouting is utilised to either stabilise rock formations or to manage the flow of groundwater and has been implemented successfully for decades in underground coal mines in Australia and overseas.

This technology has been recently adapted to seal mine subsidence related surface and subsurface cracking in rock bars in the southern coalfields of NSW.

“Injection grouting” is the process of injecting grout using pre-drilled holes into a cracked rock bar or swamp substrate. Grouting involves injecting a permanent low permeability material into cracked areas to provide a seal to control vertical or horizontal water flows. There are various types of grouts that can be used but generally they will be either cement based or polyurethane resins (PUR). The use of injection grouting for remediating subsidence cracking has been pioneered in the southern coalfields of NSW and has been used to successfully repair cracking in surface and near surface rock substrates.

Grout is pumped into the targeted area at low pressure once the grouting holes have been drilled. High viscosity grouts are used for vertical fracturing as the setting time for vertical holes needs to be shorter to optimise the use of the grout which flows faster in vertical cracks under the influence of gravity. Lower viscosity grouts would be used where horizontal cross linking of cracks is present.

A specific example of where PUR grouting has been shown to successfully repair a rock substrate can be seen at Helensburgh Coal Pty Ltd (HCPL) in the NSW Southern Coalfields. Experience at HCPL has shown that grouting using PUR can be used to successfully fill cracks ranging from small sub millimetre sized cracks to open fractures greater than 100 mm.

A trial was conducted at HCPL on the WRS4 rock bar in the *Waratah Rivulet* and was followed by a remediation report (*Waratah Rivulet Remediation Trial Activities – Completion Report (2007*)). The main findings of the remediation report were:

- PUR is non-toxic.
- PUR injection can be conducted in an environmentally acceptable fashion.
- PUR injection is suitable for sealing cracking in rocks from less than 1mm to greater than 100 mm.
- Pre and post permeability testing showed that permeability was reduced by several orders of magnitude following PUR injection.
- The PUR injection process was transferrable to other areas where cracking of rock had occurred.

The HCPL PUR grouting programs are used to seal cracking in outcropping rock bars. However, it is considered that this technology is transferrable and can be used to seal cracks in swamp bases as a swamp *base* is analogous to a rock bar, albeit one covered with peat and sand.

The use of cementitious grouts has also been used to successfully remediate subsidence induced cracking which led to water loss in watercourses in the Southern Coalfield. Injection grouting with cementitious grouts was successfully used for rock bar rehabilitation in the Georges River.

Where alluvial material overlies sandstone, injection grouting through drill rods has also been used successfully to seal void under the alluvial material (soil / peat). This technique was also used in the Georges River, where 1-2m of loose sediment was grouted through using purpose designed grouting pipes.

In the case of East Wolgan Swamp, subsidence impacts to rock underlying the swamp are very localised and allow for targeted rehabilitation.

**In contrast to the experience at Springvale and Angus Place mines, OEH notes the comparative lack of impact at Centennial's Clarence Colliery operations to NPSS which uses an alternative mining methodology. The recently approved 900 Series at Clarence Colliery are located just on the other side of the Pine Plantation from the proposed Springvale Mine longwalls and operates in similar depths of cover. Subsidence at Clarence Colliery is of the order of 100 mm compared to 1500-2000 mm at Springvale and Angus Place. (OEH)**

Clarence Colliery extracts coal from the Katoomba seam, which lies approximately 100 m above the Lithgow Seam, from which coal is extracted at Springvale Mine and Angus Place Colliery.

The depth of cover range in future mining areas at Angus Place is 270-450 m (typically 370 m). The depth of cover range in future mining areas at Springvale is 180-420 m (typically 400 m). The depth of cover range at Clarence is 130-320 m (typically 240m).

Section 8.2.1 of the EIS deals with the reasons for selection of the longwall mining method at Springvale Mine and Angus Place Colliery. More detail is provided below.

Springvale and Angus Place Mining Method

As a means of assessing alternative mining methods suitable for utilisation at Springvale Mine and Angus Place Colliery, the viability of Bord and Pillar mining with partial pillar extraction was assessed in the report "Strata Engineering Pty Ltd (2010) Report No. 03-123-AGP-33 Partial Extraction at Depths of >300 m".

Bord and Pillar mining with partial pillar extraction is often perceived as an alternative to the longwall method of mining, however it is dependent on the structural competency of the roof (strata overlying the coal seam) and the stress environment (which is a function of the depth of the coal seam below the surface).

Strata Engineering (2010) stated: "The common feature of all mines practising partial extraction is the ability to drive "extended cuts" (i.e. to reliably and consistently cut out >6 m prior to installing roof support, usually in a cyclic or "place changing" system of development. The potential to do so successfully can be assessed using the Coal Mine Roof Rating or "CMRR" system, to analyse the impact of roof competency on extended cut behaviour, in the context of the stress environment and specifically depth."

CMRR is calculated by determining a weighted average of the rock properties in the roof above the coal seam. It is based on the thickness, shear strength, compressive strength, moisture sensitivity, presence of ground water and degree of homogeneity of the roof.

The CMRR system categorises roof competency as follows:

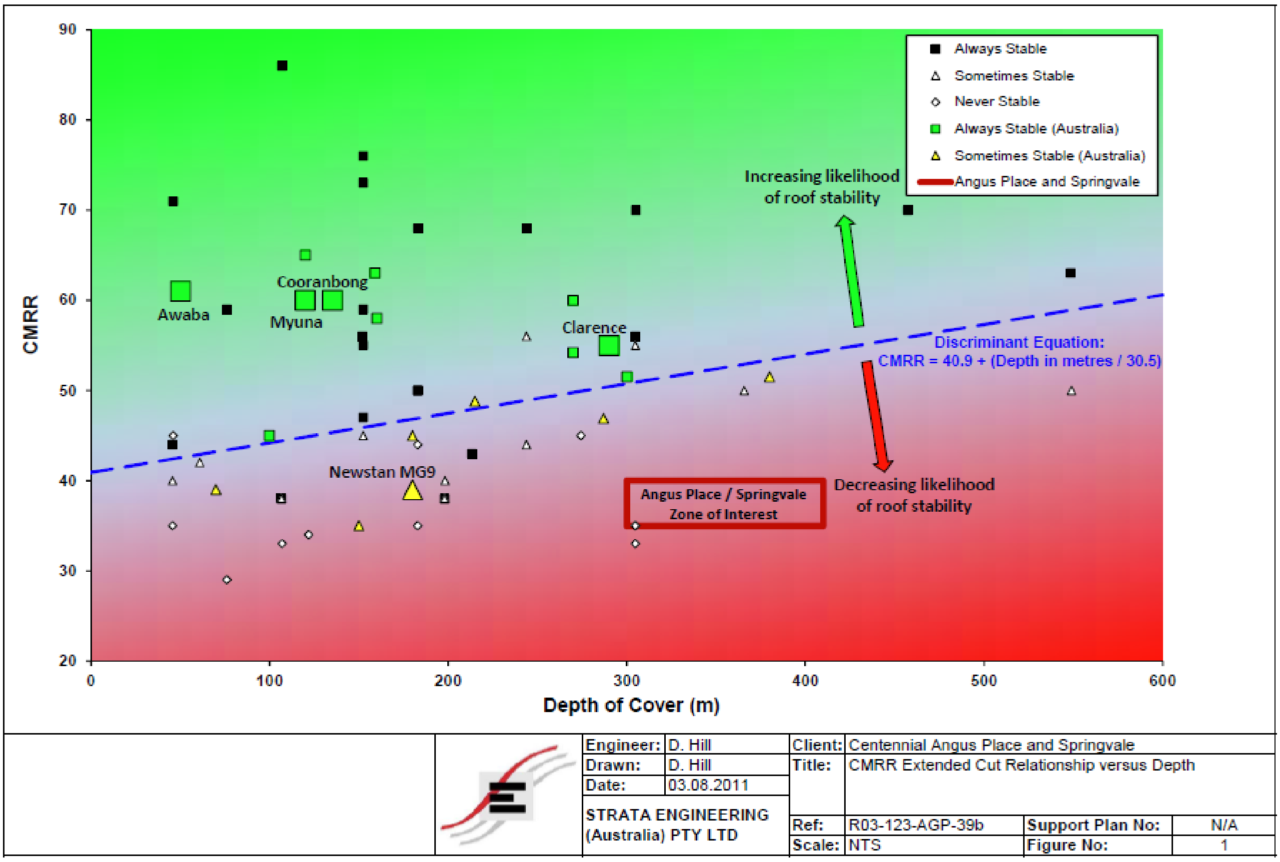
- CMRR <45 - Weak Roof
- CMRR = 45 to 65 - Moderate Roof

- CMRR >65 - Strong Roof

Published CMRR data from Springvale Mine and Angus Place Collier has been gathered from a number of locations and ranges from 31 – 35. The roof at Springvale Mine is classed as weak under the CMRR system.

The Depth of Cover at Springvale Mine in the area of LW416-418 ranges from 350 m to 420 m.

**Figure 4** is a graph of 18 Australian case studies and 44 case studies from the US database. The dashed blue line is the discriminant equation, which is the relationship that best separates the 'always stable' from the 'sometimes' and 'never stable' cases. The Australian 'always stable' cases are generally characterised by CMRRs of >50 and depths of ≤ 300 m. The Springvale data is expressed as a regime defined by the CMRR range of 35 to 40 and a depth range of 300 m to 400 m (i.e. within the red box in the figure).



| | | | | | | |
|---|---|---|---|---|---|---|
| Engineer: | D. Hill | Client: | Centennial Angus Place and Springvale | | | |
| Drawn: | D. Hill | Title: | CMRR Extended Cut Relationship versus Depth | | | |
| Date: | 03.08.2011 | | | | | |
| STRATA ENGINEERING (Australia) PTY LTD | | Ref: | R03-123-AGP-39b | Support Plan No: | N/A | |
| | | Scale: | NTS | Figure No: | 1 | |

Figure 4 - Coal Mine Roof Rating versus Depth of Cover

Strata Engineering (2010) stated: "With regard to the Angus Place / Springvale 'regime', the data all lies below the discriminant equation line, with adverse implications for the stability of extended cut stability. The available precedents suggest that failure is almost certain at a depth of >200 m."

Strata Engineering (2010) concluded: "There is no known precedent, in Australia at least, for a safe and viable partial extraction operation in the geotechnical environment under consideration. The primary issue is that it is considered unlikely that the increased roadway width of around 5.5 m required for any partial extraction operation could be safely, consistently and economically driven with the current level of roof and rib support technology."

As a result of the findings of the Strata Engineering Pty Ltd report, the Bord and Pillar and partial pillar extraction mining method is not considered viable as an alternative to longwall mining in the proposed mining areas at Angus Place Colliery and Springvale Mine.

OEH has referred to the bord and pillar / partial extraction mining system at Clarence Colliery. Clarence Colliery mines the Katoomba Seam at depths of cover of typically 100 to 290 m, with a generally strong sandstone roof (CMRR 50-60). All of the Clarence Colliery data lies above the discriminant equation line in **Figure 4** (i.e. in the "always stable" classification). The Angus Place and Springvale situations cannot be compared to Clarence Colliery.

A number of alternate mining layouts were investigated for Springvale Mine and are discussed in Section 8.3.2 of the EIS. The evolution of mine design at Springvale Mine, including different mine plans options considered, is discussed in Section 8.3.3 of the EIS.

The alternate mining layouts considered at Springvale Mine, included:

- Further Reduction in Longwall Width and Increase in Pillar Size.
- Changing Distribution of Longwalls to Avoid Undermining THPSS.
- Shortening Longwalls to Avoid Undermining THPSS.
- "Splitting" Longwall Mining Blocks to Avoid Undermining THPSS.
- Cessation of Mining North of 400 Panel Main Headings.

As noted in Section 3.1.11, none of the alternate mining layouts represent a viable business case for Springvale Coal.

**The History of Mining Beneath Swamps section of the Subsidence Impact Assessments fails to discuss the interaction of geological structures and swamp impacts. (OEH)**

The section on the history of mining beneath swamps in the Subsidence Impact Assessment (Appendix D of the EIS) provides background information and was intended that it be read in conjunction with the background information provided by other specialist consultants. These specialist consultants provide further and more detailed information on historical observations including the effects of mining on groundwater, surface water and ecology.

Non-conventional movements are often observed within valleys due to combinations of valley related movements and the presence of surface lineaments. The predicted closure movements across the valleys (including the influence of the surface lineaments) were determined using the method outlined in 2002 ACARP Research Project C9067. The reliability of this method was reviewed in Section 3.8 of the Subsidence Impact Assessment report, based on ground monitoring data from Angus Place and Springvale Collieries, and it was found that the "observed closure movements along these monitoring lines were less than those predicted using the 2002 ACARP method".

**The frequency of subsidence impacts (caused by longwall mining) on swamps appears to be low but when such impacts occur they are likely to have a high impact on the ecological functioning of individual swamps. (DotE)**

Section 2.6.2.7 of the EIS describes historical impacts to Newnes Plateau THPSS and acknowledges "Subsidence effects to aspects of swamp hydrology have been noted at two swamps (Kangaroo Creek

Swamp and East Wolgan Swamp)". Case studies of both of these swamps are included in Section 2.6.2.6 of the EIS.

In the case of Kangaroo Creek Swamp, changes to standing water levels as measured by KC1 swamp piezometer were recorded following mining. Swamp hydration from a spring upstream of the swamp and valley wall seepage associated with the Burralow Formation geology has not been significantly affected by longwall mining. Vegetation monitoring at Kangaroo Creek Swamp has not demonstrated changes to the flora community within the swamp.

In the case of East Wolgan Swamp, Goldney et al (2010), an independent report commissioned by DEWHA (now Department of the Environment), concluded the following with regard to East Wolgan Swamp: "Site 10 (East Wolgan Samples a and b): There has been a significant and catastrophic impact on this swamp, where ecological and geomorphic thresholds have been exceeded. Shrub components had disappeared, a significant thickness of peat had been washed away and a heavy deposit of patchy sand of unknown origin was deposited over what remains of the swamp bed. We attributed this swamp's destruction principally to mine water discharge. However, we are unable to determine the role of longwall mining as a contributing factor since mine water discharge impacts have very likely masked the longwall mining impacts. We have determined that these impacts were very likely significant.

Mine design changes have now been implemented to prevent future subsidence impacts to Newnes Plateau Shrub Swamps.

Following extensive investigations to determine impact causes to THPSS on the Newnes Plateau, the following actions have been completed to prevent impacts to swamps on the Newnes Plateau.

Mine Re-Design to Reduce Subsidence

Major design changes have been made to the Springvale mine plan in order to reduce subsidence from longwall mining. These changes are based on the following dimensional changes:

- Void width reduced from 315 m to 261 m for LW416 onwards
- Pillar width increased from 45 m to 58 m.

These changes have been made specifically to reduce the environmental impacts of longwall mining under the Newnes Plateau, and demonstrate Springvale Coal's commitment to sustainable mining practices. The changes have been made in good faith and at significant cost to the business at a time when there was no guarantee of approval for ongoing mining activities.

Section 1.3.2 of this RTS discusses the history of the mine water management at both Springvale Mine and Angus Place Colliery. As noted in that section the SDWTS was constructed in 2006 in consultation with EPA to transfer mine water to Wallerawang Power Station (formerly owned by Delta Electricity, now Energy Australia) for use in their cooling towers. The construction of the SDWTS was in response to a Pollution Reduction Program and eliminated the need to discharge mine water inflows into East Wolgan Swamp on Newnes Plateau.

Springvale Mine and Angus Place Colliery mine water management system on the Newnes Plateau has been modified through the following management measures to eliminate mine water impacts to Newnes Plateau swamps.

- There have been no mine water discharges to Newnes Plateau Swamps since April 2010.
- Dewatering bore facilities are located downstream of swamps (e.g. Springvale Bore 8 facility is located downstream from Sunnyside East Swamp and Carne West Swamp).
- Re-design of Angus Place Colliery's mine dewatering infrastructure underground to allow storage of emergency discharges in the Angus Place 900 Area Water Storage.

- Angus Place Colliery's emergency discharge point (LDP006) was relinquished on 29 July 2013 following a variation to EPL467.
- Springvale Mine's emergency discharge points, LDP004 and LDP005 will be relinquished as part of the Springvale MEP, as discussed in Section 4.10.1 of the EIS. It is planned to re-inject any future emergency discharges underground into the Angus Place 900 Area Water Storage. Prior to relinquishment, the following processes must be completed:
    - Development Consent for Angus Place and Springvale MEPs
    - Aquifer Injection Licence to allow re-injection into mine workings voids.
    - Testing of current infrastructure and design / build of additional required infrastructure for mine water management.

Studies to Understand Swamp Formation and Interactions with Mine Subsidence

Studies have been conducted by Springvale Mine and Angus Place Colliery in the following areas to improve understanding of swamp formation and interactions with mine subsidence:

- Geology and hydrogeology
- Swamp hydrology
- Mine design and subsidence.

These studies have been used to inform mine design in order to prevent future impacts to Newnes Plateau THPSS. The mine design approach for all future longwall mining under shrub swamps in the proposed Springvale and Angus Place mining areas is consistent with that approved for longwall mining beneath THPSS by the Department of the Environment under EPBC2011/5949 for LW416 and LW417.

**The Subsidence Impact Assessment predicts values for subsidence, upsidence, tilts, curvatures, hogging and sagging that if realised would, according to the EIS, have minimal impacts on the swamps. Similar estimates have been made for projects on the Newnes Plateau in the past (Springvale and Angus Place). In these cases it has been documented that longwall mining (conducted under EPBC approval 2011/5952- Angus Place Colliery) resulted in major impacts on East Wolgan Swamp (subsidence and cracking) and significant impacts on Kangaroo Creek Swamp (undermined, with water losses from the ecosystem). (DotE)**

Centennial Angus Place refutes the claim that longwall mining conducted under EPBC approval 2011/5952 (Angus Place Colliery) has resulted in major impacts on East Wolgan Swamp (subsidence and cracking) and significant impacts on Kangaroo Creek Swamp (undermined, with water losses from the ecosystem). EPBC approval 2011/5952 was granted in April 2012 and relates specifically to mining under Angus Place LW900W (extraction commenced in April 2014) and LW910 (not yet extracted). No THPSS overlie these longwalls (refer to Figure 10.1 of the Angus Place MEP EIS) and no impacts to any THPSS in the vicinity have been predicted or have occurred.

As discussed below subsidence related impacts to East Wolgan Swamp and Kangaroo Creek Swamp were recorded in 2008 and the then Commonwealth Department of, Environment, Water, Heritage and the Arts (DEWHA) commissioned an independent investigation into the impacts in 2010; the results of which are reported in Goldney et al (2010). The impacts to East Wolgan Swamp and Kangaroo Creek Swamp occurred well before the grant of EPBC approval 2011/5952.

Centennial Angus Place and Springvale Coal contest Department of the Environment's claim that water losses from the Kangaroo Creek Swamp ecosystem have occurred due to longwall mining. Photo monitoring has been undertaken at three locations along the Kangaroo Creek at locations and periods indicated below. The monitoring photos and additional details are provided in **Appendix 11**.

- **Kangaroo Creek Dam** – overlies Springvale Mine's previously mine LW401 (refer Figure 3.1 of the Springvale EIS), which was undermined in 1996. The site is downstream from the Kangaroo Creek Swamp South (refer Figure 2.2 of the Angus Place EIS and Figure 2.7 of the Springvale EIS) and upstream from the Kangaroo Creek Waterhole location (see below). Photo monitoring conducted in the period 30 December 2009 to 8 June 2012 (refer **Appendix 11**) at this location shows that the dam has contained water on 22 out of 24 monitoring occasions (conducted monthly or bi-monthly).

- **Kangaroo Creek Waterhole** – this is the location within the Kangaroo Creek Swamp and two piezometers at downstream (KC1) and upstream (KC2) locations have been monitoring groundwater levels since July 2005 and end 2008, respectively. Groundwater levels at KC1 appear to have been affected by the longwall mining of Angus Place Colliery's LW940 resulting in a sudden reduction in groundwater levels in June 2008, unrelated to rainfall. In the five years of photographic monitoring since the measured reduction in groundwater levels in 2008, only three monitoring events out of 41 monthly or bi-monthly monitoring events showed no water in the waterhole (February 2014, June 2014 and August 2014), and these events show strong correlation to deficit in rainfall in the period.

- **Kangaroo Creek Downstream** – overlies Angus Place Colliery's LW910 (not mined as yet) and downstream from the Kangaroo Creek Waterhole (see above). Photo monitoring at this location over the period 30 August 2012 to 18 September 2013 shows presence of water at the location on all monitoring occasions confirming no water has been lost from the Kangaroo Creek ecosystem.

It is noted that Kangaroo Creek Swamp South was undermined by Springvale Mine's LW401. An aerial assessment of the Newnes Plateau Shrub Swamps by Blue Mountains City Council as 'Caring for Country Save Our Swamps 2010 Project' has noted the overall condition of the Kangaroo Creek Swamp South as 'Good', which is the highest category in the assessment report.

**The current EIS fails to acknowledge the failure of past predictions and that longwall mining below the swamps could result in further irreparable damage to THPSS. (DotE)**

**Neither EIS provides convincing evidence that THPSS will be immune from similar impacts to those that damaged the ecological community in the past. The reduction in longwall widths to 261m provides no reassurance that THPSS will not be impacted by bed rock fracturing as some of the previous impacts (Kangaroo Creek Swamp) occurred with 262m wide longwalls (longwall 940). (DotE)**

**There appears to be a high risk of severe impact to the EPBC Act listed (endangered) Temperate Highland Peat Swamps on Sandstone that is present directly above or laterally adjacent to the proposed longwall panels associated with the Centennial Coal mining proposal; with this risk being greater for the proposed Springvale Colliery than the Angus Place Colliery. (DotE)**

**The evidence that longwall mining under the Newnes Plateau may have at least partially contributed to previous damage to the listed endangered ecological community in that area suggests that the likelihood of the risk being realised is also high. (DotE)**

Centennial Angus Place and Springvale Coal have had significant experience in undermining swamp systems. Angus Place Colliery and the neighbouring Springvale Mine have together directly or partially undermined 13 shrub swamps and 26 hanging swamps. Surface impacts have been observed at four of these swamps (Narrow Swamp North, Narrow Swamp South, East Wolgan Swamp and Junction Swamp).

An independent investigation by Goldney et al (2010) undertaken on behalf of the then Commonwealth Department of, Environment, Water, Heritage and the Arts (DEWHA) found that the major cause of most of the impacts at Narrow Swamp North and Narrow Swamp South was mine water discharge and not subsidence related ground movements. Impacts at East Wolgan Swamp and Kangaroo Creek Swamp appear to have been caused by a combination of subsidence-related ground movements, mine water discharge and erosion, with the particular contribution of subsidence impacts unable to be quantified.

The chronology below illustrates when the impacts to East Wolgan Swamp and Kangaroo Creek Swamp occurred and the subsequent investigation process, action plan implementation and granting of EPBC 2011/5952 approval.

Chronology of THPSS Impacts from Longwall Mining and Subsequent Actions

- Impacts to East Wolgan Swamp hydrology were recorded in 2008.
- Impacts to Kangaroo Creek Swamp hydrology were recorded in May 2008.
- Investigations of the incidents and reporting to NSW Government agencies were conducted in 2009.
- DEWHA investigations / reporting were conducted in 2010 (Goldney et al 2010).
- Implementation of actions by Centennial Angus Place and Springvale Coal to cease mine water discharge to swamps and modify mine design to reduce longwall void width and increase chain pillar width occurred in 2010 / 2011.
- Enforceable Undertaking under Section 486DA of the EPBC Act by the Federal Minister for the then Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) on 12 October 2011.
- Angus Place Colliery’s Referral under the EPBC Act for Longwalls 900W and 910N lodged with SEWPaC in May 2011.
- Angus Place EPBC 2011/5952 approval for Longwalls 900W and 910N issued in April 2012.
- Longwall mining under EPBC 2011/5952 commenced in Longwall 900W in April 2014.

Section 2.6.2.7 of the EIS acknowledges historical impacts to Newnes Plateau THPSS from mining related activities by Springvale Mine and Angus Place Colliery and identifies the major causes of impacts to Newnes Plateau THPSS from mining related activities as mine water discharge and mine subsidence.

Section 2.6.2.7 of the EIS further summarises the changes to mine water management on the Newnes Plateau and mine design changes implemented to prevent future impacts to THPSS.

Chapter 8 of the EIS details the changes to mine design which occurred following the investigation into subsidence impacts at East Wolgan Swamp and Kangaroo Creek Swamp.

Actions taken by Springvale Mine and Angus Place Collieries to prevent impacts to Newnes Plateau THPSS are summarised below.

Mine Re-Design to Reduce Subsidence

Major design changes have been made to the Springvale mine plan in order to reduce subsidence from longwall mining. These changes are based on the following dimensional changes:

- Void width reduced from 315 m to 261 m
- Pillar width increased from 45 m to 58 m.

These changes have been made specifically to reduce the environmental impacts of longwall mining under the Newnes Plateau, and demonstrate Springvale Coal's commitment to sustainable mining practices. The changes have been made in good faith and at significant cost to the business at a time when there was no guarantee of approval for ongoing mining activities.

Springvale Coal accepts that impacts at Kangaroo Creek Swamp and East Wolgan Swamp have occurred, and in the case of Kangaroo Creek Swamp the subsidence related impacted occurred with 262 m wide longwall. Kangaroo Creek Swamp is located above Angus Place LW940 and LW950 which had widths of 262 metres and 292 m, respectively. The depth of cover at this swamp varies between 265 m at the downstream end to 280 m at the upstream end. The width-to-depth ratios at this swamp, therefore, vary between 0.97 above LW940 to 1.04 above LW950 and fall in the critical behaviour range.

The longwall width-to-depth ratios at Kangaroo Creek Swamp and East Wolgan Swamp are greater than those where the proposed longwalls are located beneath Tri Star and Trail 6 Swamps at the Angus Place MEP (0.8 to 0.9) and beneath the shrub swamps at the Springvale Extension Project (0.70 to 0.75). The proposed longwalls beneath the shrub swamps in both Angus Place and Springvale mining areas are more sub-critical than the critical LW940 and LW950 beneath Kangaroo Creek Swamps.

No Further Mine Water Discharges to Swamps

Springvale Mine and Angus Place Colliery's mine water management system on the Newnes Plateau has been modified through the following management measures to eliminate mine water impacts to Newnes Plateau swamps.

- There have been no mine water discharges to Newnes Plateau Swamps since April 2010.
- Dewatering bore facilities are located downstream of swamps (e.g. Springvale Bore 8 facility is located downstream from Sunnyside East Swamp and Carne West Swamp).
- Re-design of Angus Place Colliery's mine dewatering infrastructure underground to allow storage of emergency discharges in the Angus Place 900 Area Water Storage.
- Angus Place Colliery's emergency discharge point (LDP006) was relinquished on 29 July 2013 following a variation to EPL467.
- Springvale Mine's emergency discharge points, LDP004 and LDP005 will be relinquished as part of the Springvale MEP, as discussed in Section 4.10.1 of the EIS. It is planned to re-inject any future emergency discharges underground into the Angus Place 900 Area Water Storage. Prior to relinquishment, the following processes must be completed:
- Aquifer Injection Licence to allow re-injection into mine workings voids.
- Testing of current infrastructure and design / build of additional required infrastructure for mine water management.

Studies to Understand Swamp Formation and Interactions With Mine Subsidence

Studies have been conducted by Centennial in the following areas to improve understanding of swamp formation and interactions with mine subsidence:

- Geology and hydrogeology
- Swamp hydrology
- Mine design and subsidence.

These studies have been used to inform mine design in order to prevent future impacts to Newnes Plateau THPSS. The mine design approach for all future longwall mining in the Springvale and Angus Place MEP areas is consistent with that approved for longwall mining beneath THPSS by the Department of the Environment under EPBC2011/5949 approval.

As indicated in section 2.6.2.6 of the EIS, OEH approved the undertaking restoration actions at East Wolgan Swamp, and issued a certificate under Section 95 of the TSC Act on 25 November 2013. Approved remediation works have been carried out since January 2014.

**The hydrological requirements of the peat swamps are not well enough understood to accurately predict the cumulative impacts of longwall mining. (DotE)**

Section 2.6.2 of the EIS summarises the findings of studies conducted on the geology, hydrogeology and hydrology of THPSS on the Newnes Plateau. It further relates specific groundwater response of swamps and surrounding aquifers to longwall mining.

**The proponent has not characterised existing surface water, groundwater and ecological conditions for the majority of THPSS within the proposed project area. Seasonal surface water flow and an assessment, or estimation, of the baseflow component of the Coxs River are not provided and are needed to enable the prediction of impacts to seasonal flows within, and interactions between, surface water and groundwater systems, including those associated with THPSS. This information would also improve predictions of discharge and baseflow losses within the Coxs River and the potential for downstream impacts to occur. (DotE)**

A detailed response has been provided in Section 2.1 of **Appendix 16**.

**Does the EIS, and in particular the groundwater model and the treatment of subsidence and fracturing predictions, provide a reasonable assessment of the likelihood, extent and significance of impacts on overlying adjacent swamps? (DotE)**

**The EIS, including the groundwater model, does not provide a reasonable assessment of impacts to THPSS. Confidence in the groundwater model's capacity to predict site specific impacts to individual THPSS is low. In particular the model scale is not appropriate to predict impacts to THPSS, and a number of THPSS are not included within the groundwater model and therefore groundwater related impacts to these swamps cannot be predicted. (DotE)**

A detailed response has been provided in Section 2.2 of **Appendix 16**.

**Impacts to undermined THPSS have historically been severe, resulting in changes to the hydrological and hydrogeological regimes, vegetation composition and structure, and large reductions in THPSS extent. These changes have been significant and are considered to be beyond the ability of the ecological community to recover naturally. As yet, there is no scientific evidence or industry based results to indicate that such impacts to THPSS can be remediated successfully. (DotE)**

**The subsidence related impacts affecting overlying and adjacent THPSS would be expected to include fracturing of underlying bedrock, a water storage capacity increase within the bedrock fracture network, a decrease in surface water flow provision from upstream tributaries and a corresponding decrease in standing surface water level. (DotE)**

**Due to the low level of confidence in the groundwater model's capacity to predict hydrological impacts to individual THPSS, the likelihood, extent and significance of groundwater impacts to swamps cannot be determined with certainty. Swamps that are directly undermined or overlie structural lineaments are more likely to be severely impacted due to the instability of underlying strata and locally increased subsidence effects. Given the temporal variability and time lags with which impacts are observed in THPSS, the significance of groundwater impacts may not be readily determined for some time. (DotE)**

**The EIS states that fracturing up to 50 mm wide is predicted to occur within the shallow bedrock of THPSS wherever they are undermined. Impacts to THPSS are considerably more likely to occur where swamps are directly undermined. Fracturing to further THPSS and their upstream tributaries would be expected to occur where compressive and tensile strains exceed 0.5 mm/m and 2 mm/m respectively. Strain is caused by the horizontal movement of the ground surface relative to two fixed points. Tensile strain occurs where the distance between two points increases and compressive strain occurs where the distance between two points decreases. (DotE)**

A detailed response has been provided in Section 2.2 of **Appendix 16**.

**Avoidance of undermining and locating longwalls such that compressive and tensile strains are below 0.5 mm/m and 2 mm/m respectively at THPSS sites are considered the most effective ways to manage the potential impacts to THPSS. This strategy should also be applied to any upstream tributaries that provide a significant proportion of surface flow to THPSS. (DotE)**

**The proponent has stated that cracks are predicted to form within the sandstone substrate underlying many swamps within the project area. The proponent states that these cracks will naturally fill with soil and peat (self-ameliorate), and therefore impacts related to these bedrock fractures are "considered unlikely". However, THPSS are exceptionally slow to self-heal or self-ameliorate. Examples of lowland swamps from the Southern Coalfields of New South Wales show that without attempted rehabilitation, self-amelioration is not evident within two lowland swamps over a 25 to 30 year period5. Based on a lack of supporting evidence and available literature, self-amelioration is not considered to be a reliable or effective remediation method. (DotE)**

A detailed response has been provided in Section 2.2 of **Appendix 16**.

**The only known strategy to reduce the risk of impact to THPSS ecological communities within the project area would be to alter the mine layout such that swamps are not undermined by longwall panels and longwalls are sufficiently removed from THPSS such that tensile and compressive strains at THPSS sites are below 0.5 mm/m and 2 mm/m respectively5. This avoidance strategy should also be applied to any upstream tributaries that provide a significant proportion of surface flow to THPSS. This approach is the most likely to prevent impacts to THPSS given the potential severity of impacts, difficulties in the accurate and confident prediction of impacts, and the ineffectiveness of other mitigation and management measures. (DotE)**

A detailed response has been provided in Section 2.2 of **Appendix 16**.

### 3.1.15 Noise

**Noise monitoring and management should be implemented where possible. (Lithgow City Council)**

**There is increasing evidence that exposure to noise is associated with health effects. We recommend that the noise mitigation strategies listed in the application become part of the conditions of approval to ensure there are minimal impacts on the local community from noise. (NSW Health)**

A Noise Impact Assessment was prepared by SLR Consulting to support the Project and provided as Appendix L to the EIS.

The Noise Impact Assessment predicts the following.

- The predicted construction noise levels are significantly below the construction noise goals at the nearest sensitive receiver and therefore the potential construction noise impacts of the Project are negligible.
- Noise modelling has indicated that noise emissions associated with the Project are predicted to exceed the project specific intrusive and amenity noise levels by up to 4 dBA during the night-time period under adverse meteorological conditions.

Noise modelling has indicated that with the implementation of noise control measures, it is feasible to reduce noise emissions from the existing Springvale pit top to be compliant with the project specific intrusive and amenity noise levels at the nearest affected receivers. As such, the following mitigation measures have been identified and detailed in Section 10.6.6 of the EIS.

**Front end loader and dozer alarms**

- Replace beepers with modulated quackers
- Replace alarms with flashing lights at night

**Stockpile dozer**

- Attenuate exhaust and radiator

- Restrict to first gear when reversing

**Conveyor drives**

- Clad southern wall of ROM conveyor building; or
- Construction of noise barrier on southern side of ROM building

**Processing plant**

- Close all three southern doors at night; or
- Construct noise wall adjacent to southern wall

**Drift conveyor**

- Weekly inspection of idlers and prompt replacement if damaged or highly worn

**Compressor house**

- Re-orient exhaust fan away from receivers

**Pump houses**

- Keep doors closed

In addition to the specific controls listed in Table 10.30 of the EIS, the following measures will be undertaken:

- workers will be regularly trained (i.e., toolbox talks) to use the equipment in ways that minimise noise;
- mobile plant will be operated in a quiet, efficient manner;
- plant and equipment will be well maintained including regular inspection and maintenance;
- for equipment with enclosures (i.e. compressor rooms) it will be ensured that doors and seals are well maintained and kept closed when in use ;
- noise monitoring on site and within the community will be continued in accordance with the Noise Monitoring Program ;
- onsite noise mitigation measures and plant operating procedures will be refined where practical;
- clear signage will be provided including relevant contact numbers for community enquiries; and
- community issues of concern will be addressed promptly.
- Noise from the Springvale Mine would continue to be monitored quarterly with operator attended noise monitoring at relevant nearest potentially affected receiver locations (namely S1 to S2, located on Springvale Lane).

### 3.1.16 Physical Impacts

**The Department notes that the proposed project footprint borders the Greater Blue Mountains World Heritage Area (Gardens of Stone National Park) and that surface impacts resulting from longwall mining may impact on the values of this Area. (DotE)**

As detailed in Section 10.1.4 of the EIS, the 15,100 ha Gardens of Stone National Park is approximately 6 kilometres north of the Project Application Area, The nearest conservation reserve, the Gardens of Stone National Park (part of the larger National Heritage Place and World Heritage Area) will not experience any measurable subsidence movements as a result of the Project. As no measurable subsidence movements have been predicted for the Gardens of Stone National Park or other reserves, there will be no consequences to conservation values of the area.

### 3.1.17 Planning Agreement/Contributions

**Council would like the opportunity to enter into a Voluntary Planning Agreement for both projects. Council also has a Section 94A Contributions Plan which imposes a 1% Contribution on all developments over $200,000. Should the proponent not enter into a Voluntary Planning Agreement for the proposal then a condition should be placed on the consent requiring payment of a contribution in accordance with Council's Section 94A Contributions Plan. (Lithgow City Council)**

As detailed in Section 6.2.2 of the EIS, NSW Planning and Environment has determined that the appropriate planning authority to determine if a Voluntary Planning Agreement (VPA) or S94 contribution is applicable to Lithgow City Council. Discussions between the Centennial Coal and Lithgow City Council are underway with a VPA to be finalised prior to determination of the Project. Springvale Coal will continue working with Lithgow City Council regarding these arrangements.

### 3.1.18 Rehabilitation

**The Proponent shall rehabilitate the site to the satisfaction of the Secretary of the Department of Trade and Investment, or his delegate. Rehabilitation must be substantially consistent with the Rehabilitation Objectives described in the EIS and the Statement of Commitments in Chapter 11 of the EIS. (DRE)**

Springvale Coal will rehabilitate the site to the satisfaction of the Secretary of the NSW Department of Trade and Investment, or his delegate. Rehabilitation will be substantially consistent with the rehabilitation objectives described in Section 10.11.1 of the EIS, the Decommissioning and Rehabilitation Strategy provided as Appendix P, and Statement of Commitments included in Chapter 11 of the EIS.

**The Proponent must prepare and implement a Rehabilitation Plan. (DRE)**

**A Rehabilitation Management Plan is to be prepared in consultation with Lithgow City Council and implemented for the project. (Lithgow City Council)**

**The existing Mining Operations Plan (MOP) will need to be replaced by a new MOP. (DRE)**

Section 5.3.2 of the EIS identifies that it is expected that the conditions of the new mining lease and SSD consent will require a new Mining Operations Plan (MOP) to be prepared for the Project. The new MOP will include a detailed Rehabilitation Plan. In accordance with Section 1.4 of the ESG3: Mining Operations Plan (MOP) Guidelines, September 2013 (DRE), consultation with relevant landholders, community groups and government agencies (including the Lithgow City Council) will be undertaken in the development of the MOP.

**It is noted that the final sentence on Page 456 states the final landform will comprise the domains of Woodland, Grassland and a Water Management Area. However, in the previous section 'Rehabilitation Outcomes', Grassland has now been removed from the post mining rehabilitation outcomes. It is unclear why the grassland rehabilitation outcome has been removed as it would appear to have been an appropriate final land cover for sections of the pit top site. (DRE)**

The final landform will comprise the domains of Woodland and a Water Management Area, as noted in Section 10.11.2 and Table 10.48, and shown in Figure 10.28 of the EIS. The final sentence on page 456 of the EIS should not have stated Grassland as one of the domains proposed in the final landform as no grassland domain is proposed.

Grassland was proposed as one of the secondary domains covering the Springvale Mine pit top area in the adequacy version of the EIS. The then Department of Planning and Infrastructure noted the EIS did not adequately justify returning the Springvale Pit Top area to grassland as part of post closure rehabilitation, as distinct from other land use or ecological outcomes. It was also noted the EIS did not nominate a final land use for all parts of the proposed development, having regard to any relevant strategic land use planning or resource management plans or policies, as required by the DGRs.

In addressing the adequacy comments a review of the final land use options analyses and justification was undertaken. An outcome of this review was that Woodland as the final land use will be consistent with the surrounding land use of forestry in the Newnes State Forest, and will become the ‘environmental protection works’. Additionally this final land use aligns with the:

- the current Lithgow Local Environmental Plan 1994
- the Draft Lithgow Local Environmental Plan 2013
- Draft Lithgow Land Use Strategy 2010 – 2030.

Further information on the above summary is available in Section 6.3 of the Decommissioning and Rehabilitation Strategy for the Project provided as Appendix P of the EIS.

**Domain 2 in Table 10.49 indicates Domain 2 as a Water Management Area, while previously this has been referred to as Domain 3. (DRE)**

The Water Management Area is Domain 3, as noted in Section 10.11.2 and Table 10.48, and shown in Figure 10.27 of the EIS. Reference to the Water Management Area as Domain 2 in Table 10.49 of the EIS is a typographical error.

**Remediation strategies in areas affected by longwall mining are primarily designed to restore flows and the hydrological regime. Other remediation strategies have been focused on sealing fracture networks on cracked stream beds and have not addressed fractures occurring beneath peat sediments. The Department is unaware of any examples of THPSS impacted by longwall mining that have been successfully remediated. (DotE)**

**There is little evidence that the suite of remediation measures proposed would be effective in repairing damage to the endangered ecological community if the proposed longwall mining did lead to impacts such as fracturing of a peat swamp basin. Previous experience with implementation of such remediation measures has shown little or no success. (IESC)**

The Blue Mountains City Council's Upland Swamp Rehabilitation Program was commenced in 2006 after Blue Mountains Swamps were listed as part of the Temperate Highland Peat Swamps on Sandstone endangered ecological community, with the aim of protecting and restoring Blue Mountains Swamp across the local government area (LGA).

In August 2008 Blue Mountains City Council and Lithgow City Councils formed a partnership to deliver the ‘Save our Swamps’ (S.O.S) project to restore Temperate Highland Peat Swamps on Sandstone across both LGAs supported by grant funding of $250,000 over 3 years from the Urban Sustainability program of the NSW Environmental Trust.

The ‘Save our Swamps”’ project has been assisting in the management and conservation of the nationally threatened Temperate Highland Peat Swamps on Sandstone (THPSS) ecological community across the Blue Mountain and Lithgow LGAs.

In 2009 the ‘Save our Swamps’ project received a $400,000 federal ‘Caring for Country’ grant to expand the program to incorporate Wingecarribee Shire Council and Gosford City Council.

The innovative integrated and landscape scale approach to the management of THPSS has resulted in the ‘Save our Swamps ‘project receiving four awards including:

- National Governments Local Government Award for Innovation in Natural Resource Management 2010;
- United Nations World Environment Day Award for Excellence in Overall Environmental Management 2011 (Special Commendation);
- NSW Sustainable Cities award for Biodiversity Conservation 2010; and
- National Keep Australia Beautiful (Tidy Town award) for Biodiversity Conservation 2011.

As part of a collaborative approach to information and skill sharing the practical knowledge and lessons learnt from the Save Our Swamps project, BMCC has developed a practical set of guidelines entitled "Soft engineering solutions for swamp remediation - a 'how-to' guide". The guide was created by Blue Mountains City Council with the assistance of Lithgow City Council, Gosford City Council, Wingecaribee Shire Council. This publication comprehensively covers soft engineering swamp rehabilitation applications, techniques and materials. It also covers background information on swamp geomorphology, threats and impacts to Temperate Highland Peat Swamps on Sandstone swamps.

The ‘How to guide’ includes case studies on successful implementation of remediation to THPSS comprising:

- Braeside Swamp located in the Blue Mountains LGA;
- Marmion Swamp located in the Blue Mountains LGA;

- Wentworth Falls Swamp located in the Blue Mountains LGA;
- Happy Valley Swamp located in the Lithgow LGA;
- Ellem Gully Swamp located in the Gosford LGA; and
- Paddys River Swamp located in the Wingecarribee LGA.

Section 2.6.2.7 of the EIS describes historical impacts to Newnes Plateau THPSS from mining related activities by Springvale Mine and Angus Place Colliery and notes that subsidence effects to aspects of swamp hydrology have been noted at two swamps, namely Kangaroo Creek Swamp and East Wolgan Swamp. In both of these cases investigations have revealed that mine design was a primary causative factor. In response to these impacts and to avoid any future subsidence-related impacts Springvale Mine and Angus Place Colliery have re-designed the proposed longwalls beneath THPSS to be sub-critical with void widths of 261 m. No subsidence effects to swamp hydrology or flora communities have been identified in areas where sub-critical mine design have been used in the past.

It should be noted the mine design approach proposed for longwall mining under the THPSS in the proposed Springvale and Angus Place mining areas is consistent with that approved for longwall mining beneath THPSS by the Department of the Environment under EPBC2011/5949 approval for LW416 and LW417.

Rehabilitation works at the East Wolgan Swamp are currently being undertaken under an approved rehabilitation management strategy. Subsidence impacts to rock underlying the swamp are very localised and allow for targeted rehabilitation. Rehabilitation works use the soft engineering techniques developed by BMCC discussed above, and hard engineering technique proposed and approved under Springvale Mine's EPBC Approval 2011/5949 Condition 1 Application (March 2013). The hard engineering technique is to be used for the repair of major impacts to THPSS caused by cracking of underlying rock. Details of the technique are discussed above in Section 3.1.14. The progress made to date on the rehabilitation works is provided in **Figure 3**.

### 3.1.19 Stygofauna

**It is important to note that stygofauna (and potential stygofauna) were actually found. Since this was the first survey of its kind for stygofauna in the area, there is the potential for the species collected to be unique. Unfortunately the taxonomic level of identification is currently inadequate to investigate whether these animals are new to science, and the implications of potential impacts from longwall mining affecting groundwater aquifers in which the stygofauna exist cannot be ascertained. (OEH)**

Springvale Coal acknowledges that the aquatic ecology assessment undertaken for the Project identified the presence of stygofauna.

Additionally, Springvale Coal will commit to undertaking a regional stygofauna assessment which will:

- Collate existing available information on groundwater bores, water quality and characteristics in Centennial Coal's areas of operations throughout the Western Coalfield.
- Use this information to form a prioritisation list of likely areas for GDEs to occur.
- Use the prioritisation protocol to identify bores that can be sampled to provide data on the presence and significance of fauna both within and outside mine areas.

- Identify any stygofauna found to a minimum of Family level.
- Advise on the significance of the findings.
- Examine relationship between bore characteristics and presence of stygofauna.

The Statement of Commitments contained in **Section 5.0** of this RTS has been updated to include this commitment.

### 3.1.20 Subsidence

**MSEC has provided no data, statistical analysis or graphics to support the factor of 10x maximum curvature used in their stress calculations. the derived maximum strains and levels of stress obtained by the DgS (2014) methodology should be used for subsidence predictions rather than the 10x maximum curvature calculation. (OEH)**

**The potential for impacts generally result from differential movements (i.e. curvature and strain), rather than from vertical subsidence. It is expected that the compressive strains at the lineaments above the proposed LW1001 to LW1019 will be similar to those observed above the previously extracted longwalls at Angus Place and Springvale Collieries, which were typically between 5 mm/m and 15 mm/m. (OEH)**

**Information should be provided on the height of fracturing that has occurred as a result of earlier Springvale and Angus Place mining operations. (OEH)**

**OEH has concerns regarding predictions for stress, upsidence and valley closure. (OEH)**

Strain

The "10 times" factor is used to provide predictions for conventional strain, which are the normal levels of strain which occur when the ground subsides conventionally and, therefore, do not include the localised non-conventional (i.e. anomalous or valley related) strains. Hence, these strains represent typical or likely values rather than the maximum or peak values. The purpose of providing predictions for conventional strains is to allow the comparison of the typical movements from location to location across the mining area.

It is highlighted in Section 4.3 of the subsidence report, that "there can be considerable variation from the linear relationship, resulting from non-conventional movements or from the normal scatters which are observed in strain profiles". For this reason statistical analyses of strain has been undertaken which provides the predictions for strain including both conventional and non-conventional movements. The results of the statistical analysis are provided in Sections 4.3.1 to 4.3.3 of the subsidence report, which are based on the measured strains at Angus Place and Springvale Collieries.

The impact assessments for the natural and built features have been based on the outcomes from the statistical analyses (i.e. based on the peak strains which include non-conventional movements), rather than on the conventional strains (i.e. typical or average movements).

The predicted conventional strains have been provided for each feature in Chapters 5 and 6 of the MSEC report, to allow a comparison of the typical movements expected from location to location. It is stated each time that "Non-conventional movements can also occur as a result of, amongst other things, anomalous movements" and then refers the reader to the statistical analyses provided in Chapter 4 for the peak or maximum strains. The impact assessments are based on the statistical analysis (i.e. peak strains) rather than the conventional (average) strains.

The linear factor is dependent on the overburden geology and the depth of cover and, therefore, varies from Coalfield to Coalfield. Hence, a factor of 15 is used in the Southern Coalfield and a factor of 10 is used in the Newcastle, Hunter and Western Coalfields. No data or statistical analyses were provided to justify the 10 factor, as the predicted conventional strains were not used for the impact assessments, but for comparative purposes only. The impact assessments were based on the statistical analyses of strain provided in Chapter 4 which used to local and site specific monitoring data from Angus Place and Springfield Collieries.

Closure

The use of 200 mm predicted closure for the Bulli Seam Operations Part 3A Application was to assess the potential for impacts on rock bar controlled streams in the Southern Coalfield. This value was adopted by Illawarra Coal as it represented a low probability of impact on the standing water pool levels upstream of rockbars.

In that application, the use of 200 mm predicted closure in relation to swamps was only considered to assess the potential for fracturing of bedrock and rock bars (i.e. the subsidence effects) rather than to assess the consequences (i.e. impacts on vegetation, water levels and swamp health). MSEC does not support the use of 200 mm predicted closure as a threshold for potential environmental consequences (i.e. impacts) on swamps.

Lineaments and Swamps

The statement that the “compressive strains at the lineaments above the proposed LW1001 to LW1019 will be similar to those observed above the previously extracted longwalls” was intended to refer to (but was not specifically stated) the locations where the mining geometry (i.e. width-to-depth ratios) are similar to the previous longwalls. The compressive strains will be less where the longwall width-to-depth ratios are less than the previously extracted longwalls.

Tri-star swamp is the only swamp located above the proposed LW1001 to LW1019 that is coincident with a Type 1 or 2 lineament. In this location the longwalls have been narrowed to 261 metres and the width-to-depth ratio varies between 0.80 and 0.90. There is no Type 1 or 2 lineaments identified beneath either Twin Gully Swamp (which is also outside of the longwalls) or Trail 6 Swamp (which is above the narrower longwalls).

The strains across the lineaments above the previously extracted longwalls were measured at monitoring lines where the width-to-depth ratios varied up to 1.1. The compressive strains at the swamps coincident with Type 1 and 2 lineaments above the proposed longwalls, therefore, are expected to be less than the maxima previously measured.

Kangaroo Creek Swamp is located above Angus Place LW940 and 950 which had widths of 262 metres and 292 metres, respectively. The depth of cover at this swamp varies between 265 metres at the downstream end to 280 metres at the upstream end. The width-to-depth ratios at this swamp, therefore, vary between 0.97 above LW940 to 1.04 above LW950.

The longwall width-to-depth ratios at Kangaroo Creek Swamp are greater than those where the proposed longwalls are located beneath Tri Star and Trail 6 Swamps at the Angus Place Extension Project (0.8 to 0.9) and beneath the shrub swamps at the Springvale Extension Project (0.70 to 0.75).

Two piezometers (KC1 and KC2) were installed near Kangaroo Creek Swamp, with the monitoring results presented in Section 2.6.2.6 of the EIS written report. Piezometer KC2 showed a sudden drop in groundwater level in June 2008, which was unrelated to rainfall, during the extraction of LW940. Piezometer KC1 still shows strong correlation to rainfall indicating that the groundwater levels in this location have not been affected by mining.

An assessment of the effects on subsidence on the swamps at Angus Place and Springvale Collieries by Fletcher et al (2013) found that “Kangaroo Creek and West Wolgan swamps have not shown significant trajectories towards non-swamp vegetation community type, sustained degradation of structural species condition or increases in weedy species richness".

Also as described in the EIS written report that "Flora monitoring at Kangaroo Creek Shrub Swamp indicated no trend of decreasing condition and that species abundance is not declining. The available evidence indicates that underground mining has not resulted in any negative effects on Kangaroo Creek Shrub Swamp".

It is considered that the impact of mining on the groundwater level at Kangaroo Creek Swamps was the result of the high longwall width-to-depth ratio (up to 1.04) in combination with the presence of near surface geological structure.

Height of Fracturing

Information on the height of fracturing based on extensometer and piezometer data from LW411 and LW412 was presented in Section 2.6.2.6 of the EIS (Figure 2.22). The monitoring "indicates that the height of continuous fracturing above longwall mining areas in the Lithgow Seam is truncated at 132 m height above the workings at the interface of the Burra-Moko Head Sandstone". Discontinuous fracturing and strata dilation continued a further 124 m, into the Banks Wall Sandstone, to a height of 99 m below the surface above LW411.

Microseismic monitoring was also undertaken between the 01 July 2010 and 31 December 2010 in the vicinity of LW413. The data indicated that the majority of the seismic events (which were associated with shear failure mechanisms) occurred below the Mount York Claystone. The interpretation of this data is that the height of the continuous fracture zone is within the Burra-Moko Head Sandstone (refer Table 2.5 of the EISs).

The discussion provided in Section 4.6 of the Subsidence Impact Assessment report (Appendix D) provides a guide on the height of fracturing (both continuous and discontinuous) based on the mining geometry alone. The height of connective cracking is not only dependant on the mining geometry (i.e. panel width) but also other important factors including: the site specific geology of the overburden; the presence of massive spanning strata units (which can reduce the overall height of fracturing); and the presence of aquitards (which can reduce the height of continuous or connective fracturing).

The overburden contains a number of aquitards, including the Mount York Claystone and the claystone layers YS1 to YS6 (refer Table 2.5 and Figure 2.12 in the EIS). The detailed numerical groundwater modelling by CSIRO (EIS Appendix E) assesses the changes in permeability of the overburden (i.e. height of continuous fracturing) which includes the influence of these claystone units.

In addition to using the CSIRO groundwater numerical model noted above, an empirical model has been developed as part of the Response to Submissions to characterise changes to groundwater systems caused by longwall mining throughout the overburden lithology. This empirical model, prepared by Ditton Geotechnical Services Pty Ltd (DgS), is provided in **Appendix 6** and described briefly below. The response provided below should be read in conjunction with the report entitled "Subsurface Fracture Zone Assessment above the Proposed Springvale and Angus Place Mine Extension Project Area Longwalls", DgS Report No. SPV 003/7b, dated 10 September 2014, and

"Peer Review of Mine Subsidence Induced Height of Fracturing Issues for Angus Place and Springvale Collieries", D Kay, MSEC, 20 September 2014.

It is recognised that longwall mining results in surface and sub-surface subsidence displacements and it creates new fractures and opens up or widens pre-existing bedding planes and natural joints within the overburden. The location of and the impacts from these mining induced fractures within the overburden depend on both the mining geometry and the geology and lithology of the strata (refer MSEC report in **Appendix 7**).

The opening of existing joints and bedding planes and the creation of new mining induced cracks within the overburden over a mined panel increases the permeability of the existing strata layers. The height at which new mining induced fractures (height of fracturing (HoF)) may form above a mined panel has been measured to be up to 1 to 1.5 times the panel width, depending on the spanning capacity of the overlying strata and the bulking of the goafed strata. However, the creation of these new fractures, which while has the effect of increasing horizontal permeability, does not necessarily imply that a direct hydraulic connection will exist vertically up through the strata layers to each fracture.

Significant volumes of mine inflow only occur from the height where the fractures form a connected continuous path or a conductive network towards the mined opening. The height of the connected fracturing zone (HoCF) is defined as the height of a zone above the seam that mining induced connected or continuous fractures can transmit water from the overlying strata to the mined void, or, the height of a zone above the seam from which water would flow freely into the mine. The HoCF above the extracted longwalls, is commonly much lower than the HoF, depending on many factors listed below:

- widths of extraction
- heights of extraction
- depths of cover
- presence and proximity of previous workings, if any, near the current extractions
- presence of pre-existing natural joints within each strata layer
- thickness, geology and geo-mechanical properties of each strata layer
- angle of break of each strata layer
- spanning capacity of each strata layer, particularly those layers immediately above the collapsed and fractured zones
- bulking ratios of each strata layer within the collapsed zone
- groundwater factors such as the presence of and the head in aquiclude or aquitard zones within the overburden and the permeability of each strata layer.

In this Response to Submissions the height of continuous fracturing (HoCF) has been assessed for all longwalls in the proposed Project Application Areas for the Angus Place and Springvale projects using the DgS and Hydrosimulations Geology Pi-Term model. This new methodology is co-authored by Steve Ditton (DgS) and Noel Merrick (Hydrosimulations) and was presented at the Australian Earth Sciences Convention in July 2014.

The Pi-Term empirical model for the determination of HoCF by DgS is based on an extensive database of 34 case studies from all NSW and Queensland Coalfields. The new methodology recognises the key fracture height driving parameters of panel width (W), cover depth (H), mining thickness (T), and local geology factors (t'), which represents the effective thickness of strata at height of A-Zone to estimate the A-Zone and B-Zone horizons above a given longwall panel. The effective delineation of A- B- and C-Zones is critical to understanding effects to groundwater in the overburden and these subsidence zones are defined in **Appendix 6** as follows:

- A-Zone – Continuous fracture zone (unconstrained) with Caved zone included in this zone
- B-Zone – Discontinuous fracture zone (dilated bedding and constrained)
- C-Zone – Elastic deformation zone (dilated bedding and constrained)

The Geology Pi-Term model presented in **Appendix 6** has also been calibrated against Springvale Mine and Angus Place Colliery data from a number of multi-level extensometers, multi-level vibrating wire piezometers and groundwater level monitoring bores.

The process by which the Pi-Term empirical model was calibrated to the geological and hydrogeological conditions and then used to model subsidence zones in future mining areas at Angus Place Colliery and Springvale Mine was through:

- Measuring subsidence zones using extensometers
- Measuring groundwater effects within different subsidence zones using vibrating wire piezometers AND water level monitoring piezometers (changes in storage though minor bed separation may change pressures without measurable changes in water level)
- Modelling of subsidence zones using the Pi-Term Model (calibrated to site measured data)
- Use of historical piezometric response within the measured subsidence zones to approximate future groundwater response in the overburden (modelled subsidence zones) throughout the mine extension areas.

The Geology Pi-Term model has been used to predict the A-Zone and B-Zone fracture heights above:

- Springvale Mine's LW415 to LW423 – refer to Table 7A and Figures 8a to 8c in DgS report in **Appendix 6** for the predicted fractures heights for the A- and B-horizons
- Springvale Mine's LW424 to LW432, LW501 to LW503 – refer to Table 7B and Figures 9a to 9e in DgS report in **Appendix 6** for the predicted fractures heights for the A- and B-horizons
- Angus Place Colliery's LW1001 to LW1019 – refer to Table 7C and Figures 10a to 10d in DgS report in **Appendix 6** for the predicted fractures heights for the A- and B-horizons.

The predicted sub-surface fracture height outcomes for the proposed mining layouts in the Angus Place and Springvale Mine Extension Projects, based on the Geology Pi-Term Model, are summarised in Section 8.0 of the DgS report in **Appendix 6**. The predictions indicate that the A-Zone for the proposed longwalls is likely to occur up to the Upper Caley Sandstone with the B-Zone developing in the Burra-Moko Head and Banks Walls Sandstone.

It should be noted that the microseismic data (refer Section 4.3.8 and Figure 7 of the DgS report) from overburden monitoring at Springvale Mine's LW413 appears to support the modelled height of the A-Zone.

It is certainly the case that significant claystone aquitards are present in the overburden lithology and that these have a significant effect on groundwater behaviour in response to longwall mining. The Mount York Claystone (analogous to the Bald Hill Claystone in the Southern Coalfield) is a major claystone unit (average 22 m thick and laterally continuous across the historical and proposed mining areas of the Angus Place and Springvale Mine Extension Project Application Areas) and lies approximately 200 m above the Lithgow Seam. Measurement with multi-level vibrating wire piezometers in 26 different boreholes over up to a 12 year monitoring period indicates that desaturation of the AQ3 aquifer (refer Table 2.5 of the EISs) which underlies the Mount York Claystone is very significant, compared to a relatively minor response in the AQ4 aquifer which overlies the Mount York Claystone.

The Geology Pi-Term model is superior to the existing models for the determination of HoCF as it does recognise geology from a geotechnical perspective. The Geology Pi-Term model was peer reviewed by Don Kay from MSEC and the peer review report is included in **Appendix 6**. This peer review was undertaken in conjunction with the reviews of two ACARP reports:

- CSIRO, Guo, Adhikary & Gaveva, (2007), ACARP C14033, "Hydrogeological Response to Longwall Mining",

- SCT, Gale, (2008), ACARP C13013 "Aquifer Inflow Prediction above Longwall Panels".

MSEC (Don Kay) has noted the following in respect of the Geology Pi-Term model developed for the Angus Place and Springvale Mine Extension Projects:

MSEC has reviewed the above referenced CSIRO and DgS Reports and found that they provide detailed information on the existing environment, the groundwater systems, the overburden and the presence of layers of low permeability for this Western Coalfields area. The selection and use of both numerical and empirical models which have been calibrated to site data over many years and used for the Angus Place and Springvale Mine Extension Projects, are believed to represent the current "industry best practice".

MSEC has reviewed these reports and, in our opinion, we consider the assessments of the HoCF for the proposed longwalls at Angus Place and Springvale Collieries that are included in these reports are reasonable for this particular geological region.

It is noted that these reports have provided geologically adjusted and calibrated predictions and assessments of the likely HoCF over the proposed longwalls at Angus Place and Springvale Collieries, which, in our opinion, appear to be appropriate for this geological region and, hence, should provide a satisfactory estimate for the impact assessments on the groundwater systems from the proposed mining for this particular geological region.

**MSEC provide no scientific evidence that diverted surface water re-emerges in the catchment. (OEH)**

**The assessment of potential subsidence impacts to streams in the EIS is does not include a specific assessment of 3rd order streams. (OEH)**

**It is likely that fracturing of bedrock under the swamps and drainage of perched aquifers will also lead to a loss of flow in these 3rd order streams. (OEH)**

Fracturing of bedrock due to mine subsidence does not necessarily imply that there will be loss of surface or standing water. Bedrock contains natural joints and discontinuities due to erosion and weathering processes.

Subsurface monitoring by Mills (2003 and 2007) and Mills and Huuskes (2004) along the Waratah Rivulet found that the fracture network beneath the stream extended to a depth of 12 m and bed separation and dilation extended to a depth of 20 m. For subcritical longwalls with sufficient depth of cover to develop a constrained zone, the diverted surface water flows are confined in the shallow network which then re-emerges further downstream after sufficient fall of the stream bed elevation.

Examples of this include the Bargo River above Tahmoor LW14 to LW19 and the Waratah Rivulet at Metropolitan Colliery, where the surface water flows which were diverted into the fracture networks beneath these streams re-emerged further downstream of the impact site.

Southern Coalfield Inquiry (DoP, 2008) stated that there is "No evidence was presented to the Panel to support the view that subsidence impacts on rivers and significant streams, valley infill or headwater swamps, or shallow or deep aquifers have resulted in any measurable reduction in runoff to the water supply system operated by the Sydney Catchment Authority or to otherwise represent a threat to the water supply of Sydney or the Illawarra region. However, this does not discount the possibility that a reduction in runoff may be realised under certain conditions, including downwards leakage to mining operations, especially where a shallow depth of cover prevails or a structural feature provides a conduit for flow".

The third order streams are located within and downstream of Tri Star, Twin Gully, Gang Gang and Marrangaroo Creek Swamps over the Springvale and Angus Place proposed mining areas. The potential for impacts on the sections of these streams within the swamps are assessed as part of the swamps. The sections of these streams located downstream of Tri Star Swamp and Twin Gully Swamp are located outside the extents of the proposed longwalls and adverse impacts are not anticipated.

There are short sections of the third order streams located downstream of Gang Gang and Marrangaroo Creek Swamps which are located directly above the longwalls at Springvale proposed mining area. The potential impacts for these are the same as those assessed for the drainage lines.

**OEH does not support the definitions of cliff and minor cliff presented the Subsidence Impact Assessments (OEH)**

The definitions of a "cliff" and a "minor cliff" in the subsidence report are consistent with the definitions provided in the NSW Department of Planning and Environment Standard and Model Conditions for Underground Mining (DoP, 2012) as follows:

- "Cliff - Continuous rock face, including overhangs, having a minimum length of 20 m, a minimum height of 10 metres and a minimum slope of 2 to 1 (>63.4º).
- Minor Cliff - A continuous rock face, including overhangs, having a minimum length of 20 m, heights between 5 m and 10 m and a minimum slope of 2 to 1 (>63.4º); or a rock face having a maximum length of 20 m and a minimum height of 10 m".

The detailed management strategies, monitoring programs and actions for the sensitive features will be developed as part of the Extraction Plan process.

**On page 5 of the Springvale Subsidence Impact Assessment it is stated that diversion of surface water flows beneath the swamps could occur due to valley related upsidence movements, however, the likely impacts are likely to be low because the drainage lines upstream of the swamps are generally ephemeral and therefore surface water flows occur during and shortly after rainfall events. The EIS fails to identify a key concern that should diversion occur, the swamps will no longer have access to this water, which could have significant impacts on their long term survival. Many Australian ecosystems rely solely or mainly on ephemeral surface water flows. (DotE)**

It was stated in Section 5.4.3 of the Subsidence Impact Assessment (Appendix D of the EIS) report that:

"Centennial has previously extracted longwalls beneath more than 40 km of creeks and drainages lines at Angus Place and Springvale Collieries. Changes in surface water flows and a decline in the piezometric surface at an adjacent monitoring bore were observed along Kangaroo Creek after the extraction of Angus Place LW940. A letter by Centennial (2008) to the then Department of Primary Industries stated that "Following rainfall during the last week, surface flow has resumed over the Longwall 940 surface area of Kangaroo Creek and water level in the bore has returned to within 50 mm of the previous level", which indicates that these impacts appear to be transient. Elsewhere, there has been no reported loss of surface water flows or adverse impacts on the drainage lines for the previous mining at these collieries".

If adverse impacts were observed as a result of surface cracking in the ephemeral drainage lines, these could be remediated by "infilling with soil or other suitable materials, or by locally regrading and recompacting the surface".

**Page 82 of the Angus Place Subsidence Report states that fracturing could occur in the top most bedrock in swamps directly above the proposed longwalls. The Report also states that the shrub swamps comprise significant quantities of sediment and fracturing of shallow bedrock beneath these swamps is likely to be filled with soil during subsequent flow events along the drainage lines. Examples of where this has been known to occur should be provided. (DotE)**

Southern Coalfield Inquiry (DoP, 2008) stated that "There are a number of examples of natural processes of remediation in the Southern Coalfield. Stream bed cracking, surface water drainage to the subsurface and ferruginous springs, which occurred in the Upper Bargo River in 2002, is now barely evident. In the lower Cataract River (where subsidence caused severe stream bed cracking between 1993 and 1997 and a simultaneous period of historically low water flows led collectively to a loss of flow, drainage of pools, loss of fish life and significant water quality changes), exposed stream bed cracks have subsequently been colonised by various biota. Water quality is now sufficient to support aquatic macrophytes and small fish."

Tahmoor Colliery reported that there was "sporadic cracking of the river bed and the drying out of some ponds at the time of mining. Subsequently, the fracture network in the Upper Bargo River appears to have largely self healed, surface water levels have returned to their pre-mining steady state, and there are no obvious impacts on ecology" (DoP, 2008).

**The incremental profile method utilised in the EIS provides reasonable predictions of subsidence likely to occur as a result of the proposed longwall design. However, there is a lower degree of confidence in subsidence predictions proximal to "type 1" and "type 2" lineaments, which are the shallow manifestations of deep, underlying faults. As a result, the EIS subsidence and flora impact assessments based on the subsidence predictions do not adequately consider the potential site specific subsidence impacts to overlying individual THPSS. (DotE)**

**A series of lineaments (shallow manifestations of deep, underlying faults) have been identified within the geological strata of the project area and are, in some areas, several hundred metres wide. Four lineament types were identified, and two of these types ("type 1" and "type 2") are considered important in determining the structural stability of the underground mining areas add the overlying geological strata. These lineament zones increase the risk and severity of subsidence in their vicinity. (DotE)**

The reliability of the predictions obtained using the Incremental Profile Method (IPM) in the locations of the Type 1 and 2 surface lineaments was reviewed in Section 3.6.2 of the Subsidence Impact Assessment report appended as Appendix D in the Angus Place and Springvale EISs. The review of the ground monitoring data from the mines found that locally increased vertical subsidence occurs where the longwalls had been extracted beneath the surface lineaments, for example, the maximum vertical subsidence exceeded the predictions obtained using the standard IPM by 27% above the eastern end of Angus Place Colliery's LW940 and by 5 to 10 % above the eastern ends of LW950 and LW960. As stated in Section 3.6.2 of the Subsidence Impact Assessment report "the subsidence predictions have been increased by 25% in the locations of these surface lineaments directly above the proposed longwalls" to account for the effect of the Type 1 and 2 structures. However it should be then noted, that the potential for impacts do not result from absolute vertical movement, but rather from differential horizontal movements (i.e. closure and strain), which are discussed below.

The predicted valley related movements were determined using the empirical method outlined in ACARP Research Project No. C9067 (ACARP, 2002). The reliability of this method for use at Angus Place and Springvale Collieries based on the local mining conditions and in the locations of the Type 1 and 2 surface lineaments was reviewed in Section 3.8 of the Subsidence Impact Assessment reports. The monitoring data was reviewed where previously extracted longwalls at the mine had extracted beneath surface lineaments, including the: A-Line, C-Line, E-Line and F-Line at Angus Place Colliery; and the B-Line, EWS-Line and M-Line at Springvale Colliery. It was found that "the observed closures were less than those predicted using the 2002 ACARP method" and that there was "a large variation between the observed and predicted closures at each location, with the ratios varying between 0.31 and 0.89 (i.e. 31% and 89%)".

The large variation between observed and predicted movements was due to: the closure and conventional movements being additive directly above the extracted longwalls; and the closure movements being reduced by the conventional movements above the chain pillars. It was stated in Section 3.8 of the Subsidence Impact Assessment report that the closure movements are expected to be: "typically in the order of 60% to 90% of that predicted using the 2002 ACARP method" in the locations directly above the proposed longwalls; and "in the order of 30% and 60% of that predicted using the 2002 ACARP method" in the locations directly above the chain pillars.

**While the incremental profile method applied within the subsidence assessment generally provides reasonable predictions of subsidence parameters, there is low confidence in the approach of increasing subsidence predictions by 25 per cent in the vicinity of "type 1" and "type 2"structural lineaments. The EIS states, (Appendix D, p. 33), observed subsidence effects in the vicinity of these lineaments at the existing operations are highly variable and are, in places, up to eight times greater than predictions derived using this approach. Subsidence over previously mined longwall panels, in proximity to "type 1" and "type 2" structural lineaments, at the existing Angus Place operations contributed to severe impacts to overlying THPSS. (DotE)**

The predicted vertical subsidence obtained using the IPM was increased in the locations of the Type 1 and 2 surface lineaments by: using a percentage increase directly above the longwalls where the magnitudes of the predicted movements are the greatest; and using an absolute value for the increased subsidence in the locations outside the longwalls where the magnitudes of the predicted subsidence are small.

The review of IPM in the locations of the Type 1 and 2 surface lineaments using the monitoring data from the mine found that the vertical subsidence exceeded the standard model by between 5 and 27% in locations directly above the extracted longwalls. It was therefore considered appropriate to increase the predicted vertical subsidence by +25% where the surface lineaments were located directly above the proposed longwalls.

It was recognised in the Subsidence Impact Assessment report, that the observed movements could exceed the predictions from the standard IPM by much greater percentages where the surface lineaments were located outside and immediately adjacent to the longwalls, since the magnitudes of the predicted movements are much lower. It was considered more appropriate to adopt an absolute value for the increased subsidence in the locations outside the longwalls, rather than to adopt a percentage increase because of the lower predicted magnitudes. This was outlined in Section 3.6 of the Subsidence Impact Assessment report which stated that "As the observed subsidence could exceed the predictions by more than +25% outside and adjacent to the proposed longwalls, the natural and built features in these locations have been assessed for potential impacts resulting in localised subsidence up to 800 mm". The value of 800 mm was adopted based on the maximum vertical subsidence observed at the surface lineaments located outside and adjacent to the longwalls, which occurred to the east of Angus Place Colliery's LW960.

The potential for impact on features located near the bases of valleys is not dependent on the vertical subsidence, but rather the differential horizontal movements, i.e. closure movements and the associated compressive strains. The valley closure movements were determined using the method outlined in ACARP Research Project No. C9067 (ACARP, 2002) and the reliability of this method at Angus Place and Springvale Collieries and in the locations of the Type 1 and 2 surface lineaments is discussed previously in this RTS.

**Based on the documentation provided in the EIS nine THPSS (including groups or swamp clusters) are located within the potential subsidence impact zone, and a number of these, such as Trail 6 Swamp and Tri Star Swamp, are proposed to be undermined. The EIS (p. 274) states that fracturing up to 50 mm wide is predicted to occur within the shallow bedrock of THPSS wherever they are undermined. Impacts to THPSS, such as those identified in paragraph 16, are considerably more likely to occur where swamps are directly undermined. Fracturing to further THPSS and their upstream tributaries would be expected to occur where compressive and tensile strains exceed 0.5 mm/m and 2 mm/m respectively. Strain is caused by the horizontal movement of the ground surface relative to two fixed points. Tensile strain occurs where the distance between two points increases and compressive strain occurs where the distance between two points decreases. (DotE)**

**The risk and potential severity of impacts is higher for Tri Star Swamp and Trail 6 Swamp. These swamps are both proposed to be undermined with the resulting conventional subsidence predicted to be 1.9 and 0.95 m, respectively. Additionally, Tri Star Swamp is situated above a "type 2" structural lineament and longwall panels below Trail 6 Swamp are, in places, critical in width (longwall width to depth of cover ratio of 0.96). (DotE)**

**Critical panel widths and structural lineaments were factors resulting in severe impacts to East Wolgan Swamp and Narrow Swamp, which were previously undermined on the Newnes Plateau. Impacts to East Wolgan Swamp and Narrow Swamp have been identified in literature and also described within the EIS (Appendix D, p. 77). Impacts included rapid decline of groundwater, peat desiccation and associated slumping, loss of natural surface flows through swamp channels and almost complete decline of THPSS flora species. Surface flows were found to be flowing into the subsidence induced bedrock fracture network and not resurfacing downstream. At East Wolgan Swamp, it was later identified that this water was pooling within bedding separation of strata approximately 60 to 70 m underneath the swamp. (DotE)**

The impacts on East Wolgan Swamp and Narrow Swamp were due to combinations of: surface related activities (i.e. mine water discharge), higher longwall width-to-depth ratios; and the presence and surface lineaments.

The report by Goldney et al (2010) stated that the impacts on: East Wolgan Swamp "are likely due to synergisms between subsidence induced impacts and mine water discharge"; Narrow Swamp North "are very likely due to flow releases from Springvale Mine. Any adverse impacts due to LWM [Longwall Mining] and mine subsidence per se, if present, are likely to be completely masked by the major impacts described"; and Narrow Swamp South that the "potential impacts from mine water discharge are a very likely explanation along with possible direct impacts from LWM. Any impacts from LWM are likely masked by the possible significant impacts of mine water discharge."

The impacts to East Wolgan Swamp were investigated by the University of Queensland (Fletcher and Erskine, 2014) which found that "The primary cause for vegetation loss appears to be the flow path of mine discharge water through the studied shrub swamp community. This conclusion is supported by the presence of shrub swamp species surrounding impacted areas caused by discharge events which ended in March 2010."

East Wolgan Swamp was located above Springvale LW411 (315 m wide) and Angus Place LW960 and LW970 (both 293 m wide), as well as the barrier pillar between these longwalls. The swamp was also coincident with a Type 1 surface lineament. The depth of cover beneath this swamp varies between 290 m at the downstream end (above the longwall commencing end) to 330 m at the upstream end. The width-to-depth ratios at this swamp, therefore, vary between 0.9 above LW960 and LW970 to 1.1 above LW411. The impacts on this swamp were the result of the combination of: mine water discharge, higher longwall width-to-depth ratios; and the presence and the surface lineament. The impacts on Narrow Swamps North and South appear to be primarily the result of mine water discharge, with the effects of mine subsidence 'masked' by these impacts.

Tri-star Swamp is the only swamp located above the proposed longwalls in the Angus Place Mine Extension Project that is coincident with a Type 1 or 2 lineament. In this location the longwalls have been narrowed to 261 m and the width-to-depth ratio varies between 0.80 and 0.90. There are no Type 1 or 2 lineaments identified beneath either Twin Gully Swamp (which is also outside of the longwalls) or Trail 6 Swamp (which is above the narrower longwalls).

In the Springvale Mine Extension Project Sunnyside and Carne West Swamps are coincident with Type 1 lineaments and Gang Gang South West, Gang Gang East and Marrangaroo Creek Swamps are coincidence with Type 2 lineaments. The depths of cover beneath these swamps are typically between 340 m and 370 m and the width-to-depth ratios vary between 0.70 and 0.75.

The longwall width-to-depth ratios at East Wolgan Swamp are greater than those where the proposed longwalls are located beneath the shrub swamps at the Angus Place (Tri Star and Trail 6 Swamps) and the Springvale Mine Extension Projects (Sunnyside, Carne West, Gang Gang South West, Gang Gang East and Marrangaroo Creek Swamps). Centennial Angus Place and Springvale Coal have also developed management plans to minimise the potential for future impacts resulting from mining related surface activities, including mine water discharge and activity on nearby roads.

**Avoidance of undermining and locating longwalls such that tensile and compressive strains are below 0.5 mm/m and 2 mm/m respectively at THPSS sites are considered the most effective ways to manage the potential impacts to THPSS5. This strategy should also be applied to any upstream tributaries that provide a significant proportion of surface flow to THPSS. (DotE)**

**The proponent has designed the longwall mine layout to avoid some THPSS (Twin Gully Swamp and several unnamed swamps), and to minimise subsidence through narrowing of several longwalls and increasing chain pillar widths. However, a number of THPSS remain overlying or within the potential subsidence impact zone of the proposed longwalls. Fracturing in the bedrock below these swamps is expected to occur where tensile and compressive strains caused by conventional subsidence exceed 0.5 mm/m and 2 mm/m respectively5. Fracturing within the bedrock of tributaries upstream of THPSS is also predicted to occur. The risk of bedrock fracturing is reduced by minimising the exposure of bedrock to strain. Ensuring that tensile and compressive strains are below 0.5 mm/m and 2 mm/m respectively at THPSS sites is the only measure known to prevent impacts to THPSS5. To avoid impacts to the surface water hydrological regime of THPSS, this avoidance strategy would also need be applied to upstream tributaries that provide a significant proportion of surface water flows to downstream THPSS. (DotE)**

**The only known strategy to reduce the risk of impact to THPSS ecological communities within the project area would be to alter the mine layout such that swamps are not undermined by longwall panels and longwalls are sufficiently removed from THPSS such that tensile and compressive strains at THPSS sites are below 0.5 mm/m and 2 mm/m respectively. This avoidance strategy should also be applied to any upstream tributaries that provide a significant proportion of surface flow to THPSS. This approach is the most likely to prevent impacts to THPSS given the potential severity of impacts, difficulties in the accurate and confident prediction of impacts, and the ineffectiveness of other mitigation and management measures. Further, there is no currently available scientific evidence to demonstrate that remediation activities are able to successfully restore the ecological and hydraulic functions of these threatened ecological communities to pre-impact condition. (DotE)**

The magnitudes of 0.5 mm/m tensile and 2 mm/m compressive are guides to the potential for fracturing in bedrock due to conventional subsidence movements. The basis for these values is that fracturing is rarely seen in the Southern Coalfield as a result of conventional subsidence movements, i.e. away from valley bases, where the maximum ground strains are typically in this order. These strain values should not be used as an indicator of the potential for environmental consequence (i.e. impact) on surface features, as fractures at these magnitudes tend to be minor and isolated. This is supported by the PAC review (2010) for the Bulli Seam Operations which stated that “As already noted, it is based on MSEC’s advice that fracturing of sandstone has generally been observed in the Southern Coalfield once systematic compressive strain has exceeded 2 mm/m. This concurs with the Panel’s experience. However, based on the Panel’s own inquiries, field inspections and experience, total diversion of surface flow into a subsidence-induced subsurface fracture system requires higher total compressive strains that are very dependent on geological factors such as strata composition, thickness and bedding laminations. Limited measurements suggest a threshold total compressive strain[156] value for total diversion of flow in sandstone environments of the order of 7 mm/m, however the database is too small to be reliable at this point in time.”

**The proponent has stated that cracks are predicted to form within the sandstone substrate underlying many swamps within the project area. The proponent states that these cracks will naturally fill with soil and peat (self-ameliorate), and therefore impacts related to these bedrock fractures are “considered unlikely”. However, THPSS are exceptionally slow to self-heal or self-ameliorate. Examples of lowland swamps from the Southern Coalfields of New South Wales show that without attempted rehabilitation, self-amelioration is not evident within two lowland swamps over a 25 to 30 year period. Based on a lack of supporting evidence and available literature, self-amelioration is not considered to be a reliable or effective remediation method. (DotE)**

The two lowland swamps cited appear to refer to Drillhole and Flat Rock Swamps. Investigations of these swamps identified that impacts had developed at these swamps prior to mine subsidence and that they were also affected by physical disturbances. Tomkins and Humphreys (2006) were engaged by the Sydney Catchment Authority to assess the erosion in swamps on the Woronora Plateau, including Flat Rock and Drill Hole Swamps, and concluded that:

“Human disturbance in the catchment, particularly direct physical disturbance such as at Drillhole Swamp has been found to be an important trigger of erosion of swamps. The impact of mine subsidence, however is less clear. Both Swamp 18 and Flat Rock Swamp featured scour pools and gully erosion well before any direct effects of mining were observed. It may be likely that dewatering of swamps due to mining increases the sensitivity of swamps to other influences such as wildfires.”;

and that

"The impacts of mining on erosion of Swamp 18 and Flat Rock Swamp is less clear as both swamps were already in the process of erosion prior to the commencement of known mining and ground subsidence."

The findings were supported by the Southern Coalfields Inquiry (DP&I, 2008) which stated that:-

"Most impacted swamps that the Panel was made aware of were valley infill swamps (e.g. Flatrock Swamp and Swamps 18 and 19). However, at all sites inspected by the Panel, there had been a range of other environmental factors in play, including evidence of pre-existing scour pools, previous initiation of erosion, concurrent drought, and subsequent heavy rainfall and/or severe bushfires. The sequence of events was not clear in relation to the swamp impacts (drying, erosion and scouring, water table drop, burning, vegetation succession, etc).";

and that in relation to Drill Hole Swamp:

"gully erosion was not directly caused by mining subsidence, per se. Significant site disturbance took place as a result of site clearing, soil disturbance and erosion associated with the drilling of a stratigraphic drillhole in 1976 for the Reynolds Inquiry. Tomkins and Humphreys conclude that the cause of the gully erosion was this site disturbance, coupled with an extreme rainfall event."

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

**After reviewing the EIS, DRE is of the view that risks of mine subsidence related to the above-mentioned subsidence issues are similar to those at the mine's current mining operation and should be manageable through the Extraction Plan process. (DRE)**

As detailed in Section 5.3.2 of the EIS, it is expected that the conditions of the new mining lease and SSD consent will require an Extraction Plan to be prepared and approved for the Project.

### 3.1.21 Surface Disturbance

**The proponent shall carry out all surface disturbing activities in a manner that, as far is reasonably practicable, minimises potential for dust emissions and shall carry out rehabilitation of disturbed areas progressively, as soon as reasonably practicable, to the satisfaction of the Secretary or his delegate. (DRE)**

As detailed in Section 10.7.5 of the EIS, potential air quality impacts can be mitigated through the continued implementation of existing management measures such as water spraying, minimisation of exposed areas and ceasing work during adverse weather conditions.

Section 10.11.4.1 of the EIS details potential progressive rehabilitation implementation. Surface infrastructure proposed on the Newnes Plateau will require the disturbance of areas peripheral to operational areas. For example, the SDWTS duplication and the installation of buried connecting pipelines and power lines to dewatering boreholes will require the clearing of a corridor approximately 10 m wide, but half of this will be rehabilitated on installation of the services.

As surface infrastructure becomes surplus to requirements, the facility (eg. dewatering facility) will be decommissioned and the sites progressively rehabilitated. Any exploration drill holes will be rehabilitated on completion.

Progressive rehabilitation is not feasible at the pit top, as the entire area and contained facilities are required until the cessation of mining, at which time a staged rehabilitation process will commence.

All rehabilitation will be undertaken to the satisfaction of the Secretary or his delegate.

### 3.1.22 Traffic Management

**The intersection of Mine Access Road with the Castlereagh Highway should be upgraded to a Channelised Right Turn in accordance with Part 4A Austroads Guide to Road Design 2010. The intersection upgrade is to be completed prior to 2017, or when the Castlereagh Highway peak traffic volume exceeds 400 vehicles per hour should that occur earlier than 2017. RMS)**

**The intersection upgrade is located on a state road and the developer will be required to undertake private financing and construction of works on a road in which Roads and Maritime has a statutory interest. A formal agreement in the form of a Works Authorisation Deed (WAD) is required between the developer and Roads and Maritime prior to works commencing. (RMS)**

As detailed in Section 10.5.5 of the EIS and the Traffic Impact Assessment (Appendix J of the EIS), ARC Traffic + Transport assessed the current and predicted future traffic flows along the Castlereagh Highway at the intersection with Mine Access Road. It was found that, while the existing situation provides an adequate level of service, by 2017, predicted traffic flows on the highway (not due to the Project) will trigger AustRoads warrants for an upgrade of the highway to Mine Access Road right turn movement. This situation is not as a result of the Project, which will not generate additional flows, and is merely due to predicted regional traffic growth.

**A Traffic Management Plan be prepared in consultation with Lithgow City Council and implemented for the duration of the operational phase at each project site. (Lithgow City Council)**

As detailed in Section 10.5.4 of the EIS, operationally there will be no additional traffic generated at the Springvale pit top with no significant impact on the Castlereagh Highway or local access roads as a result of the Project. Coal is transported from the pit top on the conveyor system and the pit top provides on-site parking to accommodate the unchanged peak staff demand. The sub-regional road access network provides significant spare capacity and the Project will not change this.

As detailed in Section 10.5.5, a Construction Traffic Management Plan will be prepared in consultation with the Forestry Corporation of NSW; however will be restricted to construction activities only. No traffic management plan is considered required for the operation of the Project due to there being no additional consequences on the capacity, efficiency and safety of the local road network.

**All construction heavy vehicle trips to/from the Newnes State Forest sites be undertaken during daylight hours, which would generally require them to occur between 6.00am and 6.00pm. (Lithgow City Council)**

As detailed in Section 10.5.5 of the EIS, all heavy vehicle trips within the Newnes State Forest will be undertaken during daylight hours to maximise safety. These heavy vehicle movements will generally be between the hours of 6 am and 6 pm.

### 3.1.23 Water Flows

**The monitoring of flows at the NSW Office of Water (NOW) gauging station on the Coxs River upstream of Lake Wallerawang indicate that median flow in the Coxs River at this point is approximately 13.3 ML/day. The proposed discharge from LDP009 (30 ML/day rising to 50 ML/day if both mine projects are approved) means that the discharge is approximately twice the median flow in the Coxs River at this point and is projected to increase to almost 4 times the median flow in the Coxs River at this point. Further, some of the flows measured at the NOW gauge actually already include discharges from Centennial's other operations in the Upper Coxs River catchment (i.e. Angus Place). (NOW)**

The Regional Water Quality Impact Assessment (**Appendix 2**) presents calibration and prediction simulations including all catchment runoff processes as well as groundwater discharge. Prediction simulations include the scenario whereby there is nil demand from Wallerawang Power Station. The Regional Water Quality Impact Assessment quantifies the impact (water quality and water quantity) of the proposed discharge from both Angus Place and Springvale MEPs on the Coxs River catchment, including Lake Burragorang.

### 3.1.24 Water Licensing

**The take of surface water requires further assessment. Assessment should consider:**

- **Capture of surface run off from dams**
- **Indirect losses or reduction in surface water flows due to impacts from underground mining**
- **Reduction of storages of swamps due to impacts from underground mining. (NOW)**

**The EIS does not include details of any unregulated category licences held by the proponent or any discussion on how they are planning to comply with the WMA requirements. The proponent must identify licensable take and hold unregulated category access licences from the relevant water source of the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011. (NOW)**

The containment ponds at the site are exempt from harvestable right calculations for dam sizes as they are used “for the capture, containment and recirculation of drainage” and are required for the prevention of contamination of nearby water sources (NSW Office of Water). As such, no water extraction licences are held for the site.

The incidental take of surface water from swamps and rivers has been assessed and reported in both the Angus Place and Springvale Mine Groundwater Impact Assessments (Appendix E in each EIS).

For both Springvale and Angus Place MEPs Section 8.2 of the Groundwater Impact Assessment details the surface water licensing requirements, which are presented for the individual swamps in Table 8.5 and summarised per Management Zone in Table 8.7 of the Groundwater Impact Assessment.

For Angus Place Colliery, the maximum total annual licensing requirement due to baseflow reduction is 73.8 ML/yr for the Wywandy River Management Zone and 321.8 ML/yr for the Colo River management Zone.

For Springvale Mine, the total annual licensing requirement due to baseflow reduction is 65.9 ML/yr for the Wywandy River Management Zone and 129.7 ML/yr for the Colo River Management Zone.

Centennial Coal met with the NSW Office of Water on 13 June 2014 to discuss the water licensing requirements for the Project. Centennial's western operations as a whole are not predicted to require additional water entitlements until 2018. Centennial acknowledges that it is legally obligated to hold the necessary entitlements to undertake its operations. Centennial acknowledges that a review of recharge studies may not result in a change to the licensing requirements for Springvale and Angus Place's future water need. Centennial acknowledges that this may present a compliance risk beyond 2020.

The following strategy will be adopted by Centennial Coal to secure water licenses required for the Angus Place and Springvale MEPs.

- Trade, within the constraints of the relevant Water Sharing Plan, with other Centennial Coal water license holders.

- Obtain, when available through controlled allocation orders under the relevant Water Sharing Plan, additional allocations.

- Review the hydrogeological model and predicted water inflows for the Project on a 6 monthly basis to ensure adequate accounting for water take and license requirements.

- Contribute to the 2016 Water Sharing Plan review process, as agreed with the NSW Office of Water.

The Statement of Commitments contained in **Section 5.0** of this RTS has been updated to include this commitment.

**Any ongoing take of water post-closure of the mine will need to be accounted for by holding or maintaining licences. (NOW)**

Springvale Coal will maintain water licences for the on-going take of water post closure of the mine.

**The proponent must maintain records of annual water take from water sources impacted by the development and reported in the annual environmental report. (NOW)**

Springvale Coal will commit to maintain records of annual water take from water sources impacted by the Project and report these in the Annual Review, to be provided to the NOW.

**It is not clear from the EIA/GIA documentation that the losses of surface baseflow have been included in the total estimate of groundwater take. This should be clarified during licensing. (NOW)**

The losses of surface baseflow have been included in the total estimate of surface water take rather than groundwater take as it comprises a net reduction in contribution to a surface water feature.

Section 8.2 of the Groundwater Impact Assessment Angus Place and Springvale MEPs details the surface water licensing requirements, which are presented for the individual swamps on Table 8.5 and summarised per Management Zone in Table 8.7 of the Groundwater Impact Assessment.

For Angus Place Colliery, the maximum total annual licensing requirement due to baseflow reduction is 73.8 ML/yr for the Wywandy River Management Zone and 321.8 ML/yr for the Colo River management Zone.

For Springvale Mine, the total annual licensing requirement due to baseflow reduction is 65.9 ML/yr for the Wywandy River Management Zone and 129.7 ML/yr for the Colo River Management Zone.

### 3.1.25 Water Management

**The discharge limits that have been applied to mine water discharges (LDP001 and LDP009) to the Coxs River by the EPA, were established on an interim basis to enable the mines to continue to operate while undertaking works identified in pollution reduction programs (PRPs) attached to both licences to identify and implement a solution to the mine water discharge quality. The PRPs have required either the development of options to cease water discharges (such as redirecting mine water at Angus Place backed into old underground workings) or to develop options to treat mine water to ensure any discharge can meet the ANZECC (2000) trigger value for upland rivers of 350 μS/cm. (EPA)**

An assessment of site specific trigger values (SSTV) has been undertaken for Angus Place LDP001 and Springvale LDP009. The only analytes whose median concentrations were found to exceed the ANZECC guidelines for protection of aquatic ecosystems were Salinity, as EC, Copper (Springvale LDP009 only) and Zinc. At both Angus Place LDP001 and Springvale LDP009, Copper and Zinc are also found to be elevated in the upstream sampling points.

Further discussion with regard to these analytes is provided in the SSTV analysis attached as **Appendix 3** to this RTS.

Following public exhibition of the EIS, a review of the EPA Direct Toxicity Assessment on Springvale's LDP009 discharge was undertaken by GHD (**Appendix 9** to this RTS). Following the review, an additional Direct Toxicity Assessment, provided as **Appendix 10** to this RTS, was carried out on discharge water from LDP001 at Angus Place and LDP009 at Springvale. The methodology for the Direct Toxicity Assessment was approved by the EPA in August 2014. The results of the Direct Toxicity Assessment show that there is no toxicity associated with the Discharge water from LDP001. Although toxicity has been observed at LDP009, it has been demonstrated that neither the EC or bicarbonate concentrations have any effect on the toxicity of the water. Lowering the EC may have a detrimental effect on the system as shown by the high toxicity at sites upstream of LDP001. The chemistry of water quality discharged through LDP009 does not point to any source in particular that is leading to the toxicity being observed. As such, Centennial proposes to undertake further investigations into the toxicity of LDP009 water discharge to identify the cause of the toxicity. Without knowing what is causing the toxicity, the application of a treatment system is premature as you won't know what you are treating for. As such, no additional treatment of mine water is considered necessary at this stage.

**Mine water until recently was only transferred to the Wallerawang Power Station via the dedicated mine water transfer pipeline SDWTS. As the SDWTS does not continue on to Mount Piper, mine water cannot be transferred directly to Mount Piper Power Station. In addition, the EPA understands that Energy Australia has expressed no interest at present in utilising the mine water and no interest in extending the SDWTS to the Mount Piper Power Station. With Wallerawang Power Station currently not operating the SDWTS is now no longer being utilised and most mine water (all Springvale and a portion of Angus Place) is now currently discharged through the Springvale Colliery licensed discharge point LDP009 (up to approximately 30 ML/day) to the Coxs River catchment with a very low level of treatment (i.e. for suspended solids). (EPA)**

Noted.

**Much of the proponent's reasoning for discharging the large volumes of untreated mine water is based on a stated demand for mine water which currently does not exist, and any future use is subject to changes to the operation of the nearby power stations. (EPA)**

**The recent situation of Wallerawang Power Station, with one electricity generation unit being closed permanently and the other one mothballed until further notice, has resulted in about a halving of the demand for water usage by Energy Australia for use by this power station. The 40 ML/day requirement for Mount Piper is less than the daily maximum volume of mine water to be produced by the proposed mine expansion. (EPA)**

**The EISs can be considered to be highly misleading because the overwhelming bulk of the water impact assessment assumes the SDWTS is operating when it currently is not, and its future is dependent on the operational capacity of Wallerawang Power Station. Both the Angus Place and Springvale EISs have sections detailing water balance and salt balance modelling for mine water discharges. However, since both models have assumed that there are transfers via the SDWTS which is either not happening or based on changed circumstances at Wallerawang Power Station, the modelling and subsequent conclusions are flawed. Water and salt balances for the Coxs River catchment need to be redone under the real proposed scenario which is direct discharge of 30ML/day (rising to 50ML/day if both mine projects are approved) of poorly treated, high salinity mine water into the Coxs River catchment. (EPA)**

Despite the shelving of the Wallerawang Power Station, there is still significant demand for water from heavy industry in the Coxs River catchment, namely from the Mount Piper Power Station. The predicted impact to flow and quality downstream of Lake Lyell are addressed in the regional water quality impact assessment, which is attached to this RTS as **Appendix 2**. The regional water quality impact assessment addresses scenarios whereby water is discharged directly at Springvale LDP009 rather than being utilised by the Wallerawang Power Station.

As presented in the conceptual hydrogeological model in the EISs, the regional groundwater flow direction is to the northeast, at a similar gradient to the dip of the coal seams. Groundwater that is currently being extracted from the coal seams, and in the future, received recharge from the Coxs River in the past. This is due to the Coxs River having eroded the landscape over geological time to the extent that the coal seams were exposed on the valley floor. These surface exposures of coal have, essentially, already been mined via past operations of Centennial and others.

The classification of the proposed groundwater discharge as “high salinity” is, in itself, misleading.

The median salinity at Angus Place LDP001 was reported in the EIS for Angus Place, Table 10.4a, to be 1010 µS/cm (n=33) to the end of July 2012. The water quality dataset has now been updated through to 30 June 2014 and the updated median is 1050 µS/cm (n=83). Summary statistics of the updated water quality dataset is presented in the SSTV Assessment presented as **Appendix 3** to this RTS. The median salinity at Springvale LDP009 was reported in the EIS for Springvale, Table 10.4a, to be 1055 µS/cm (n=8). The water quality dataset at Springvale has now been updated through to 29 May 2014 and the updated median is 1060 µS/cm (n=95). It is noted that the frequency of monitoring at both Angus Place LDP001 and Springvale LDP009 has been increased.

If a conversion factor of 0.67 is assumed between salinity (as EC, µS/cm) and TDS concentration (mg/L), an EC of 1050 µS/cm is equivalent to a TDS of 704 mg/L and an EC of 1060 µS/cm is equivalent to 710 mg/L. Water of this quality is not of high salinity and is classified as fresh and within the acceptable range for drinking water. The ADWG (NHMRC, 2011) classifies a TDS of <600 mg/L, based on aesthetic and not health, to be good quality drinking water and a range between 600 to 900 mg/L to be fair quality. This is equivalent to the guidance adopted by the World Health Organisation (WHO, 2011) where a TDS of <600 mg/L is generally considered to be good, with an upper limit on palatability of 1000 mg/L. A summary of relevant water quality objectives is presented below.

The resulting impact of discharging water of this quality at Angus Place LDP001 and Springvale LDP009 will be neutral or beneficial in that future discharges are expected to be of equivalent water quality to the currently approved discharge. Direct toxicity assessments of the relevant Angus Place Colliery and Springvale Mine water discharge locations have been undertaken and the results are provided as **Appendix 10**.

**To date no option(s) to cease or treat the mine water has been developed by Centennial Coal. Centennial's approach to mine water is to continue and to increase the discharge from LDP001 and LDP009 to the environment for the next 3 decades without treating the mine water to an appropriate standard. The EPA's ongoing programs are not based on the continuation of the discharging of high volumes of potentially toxic, saline mine water often containing high (relative to ANZECC) levels of metal contaminants to the receiving environment of the Upper Coxs River catchment. Furthermore, it is misleading to suggest that a discharge of this magnitude and poor quality directly into Coxs River tributary streams will have a neutral or beneficial effect on water quality in Sydney's drinking water catchment or the upper Coxs River and its tributaries in terms of hydrology and aquatic health. (EPA)**

As presented in the EIS, mine water make at Springvale Mine is expected to cease in February 2025 and at Angus Place Colliery in December 2032, a period of 19 years. These dates presume the MEPs at both mines commenced in July 2014. The statement that there will be discharge to the environment for the next three decades is not correct.

As previously discussed in the EIS, the discharge mine water quality from Angus Place Colliery and Springvale Mine is not considered to be saline, in fact the median water quality, of approximately 700 mg/L total dissolved solids concentration (TDS), is classified as fresh and within the acceptable range for good quality drinking water with respect to TDS. Drever (1997) classifies fresh waters are sufficiently dilute to be potable, that is, less than about 1,000 mg/L TDS. Brackish waters are too saline to be potable, but are significantly less saline than seawater, the range is approximately 1,000 mg/L to 20,000 mg/L TDS. Saline waters have salinities similar to or greater than that of seawater (35,000 mg/L TDS) and brines are waters significantly more saline than seawater.

An assessment of site specific trigger values (SSTV) has been undertaken for Angus Place Colliery's LDP001 and Springvale Mine's LDP009. The only analytes whose median concentrations were found to exceed the ANZECC guidelines for protection of aquatic ecosystems were salinity, as EC, copper

(Springvale LDP009 only) and zinc concentrations. At both Angus Place LDP001 and Springvale LDP009, copper and zinc concentrations are also found to be elevated in the upstream sampling points.

Further discussion with regard to these analytes is provided in the SSTV analysis attached as **Appendix 3** to this RTS.

As presented in the EIS, Section 10.2.4, relevant NSW Water Quality Objectives (WQOs) include:

- Aquatic Ecosystems
- Visual Amenity
- Drinking Water – Groundwater
- Industrial Water Supplies.

Relevant NSW River Flow Objectives, presented in Section 10.2.4 of the EIS, include:

- Protection of Natural Dry Pools in Dry Times
- Protect Natural Low Flows
- Maintain Wetland and Floodplain Inundation
- Maintain Natural Flow Variability
- Manage Groundwater for Ecosystems.

A regional water quality impact assessment is presented as **Appendix 2** to this RTS. The model is a daily rainfall/runoff model based on the AWBM, implemented within GoldSIM. Pertinent results are presented below.

There are two Water Management Strategies proposed with respect to the Angus Place and Springvale MEPs:

- Water Strategy WS1 – Angus Place discharging all mine water make at Angus Place via Angus Place LDP001 (up to 30.8 ML/d) and Springvale discharging all mine water make at Springvale via Springvale LDP009 (up to 18.8 ML/d).
- Water Strategy WS2a – Angus Place discharging to Springvale LDP009 (up to 30.0 ML/d) via the existing SDWTS pipeline, to the extent available, with excess discharged through Angus Place LDP001 (up to 15.5 ML/d).
- Water Strategy WS2b – Angus Place discharging to Springvale LDP009 (up to 43.4 ML/d), with upgrade of the SDWTS pipeline to 50 ML/d when combined mine water make exceeds 30 ML/d), with excess discharged through Angus Place LDP001 (2.0 ML/d).

It is noted that for the purpose of modelling the null case consists of both Angus Place and Springvale ceasing discharge at the end of the calibration period on 30 June 2014.

Kangaroo Creek / Coxs River above Wangcol Creek/Blue Lagoon

The layout of the water quality model in this vicinity is presented below (**Figure 5**) and show the relevant sub-catchments modelled.

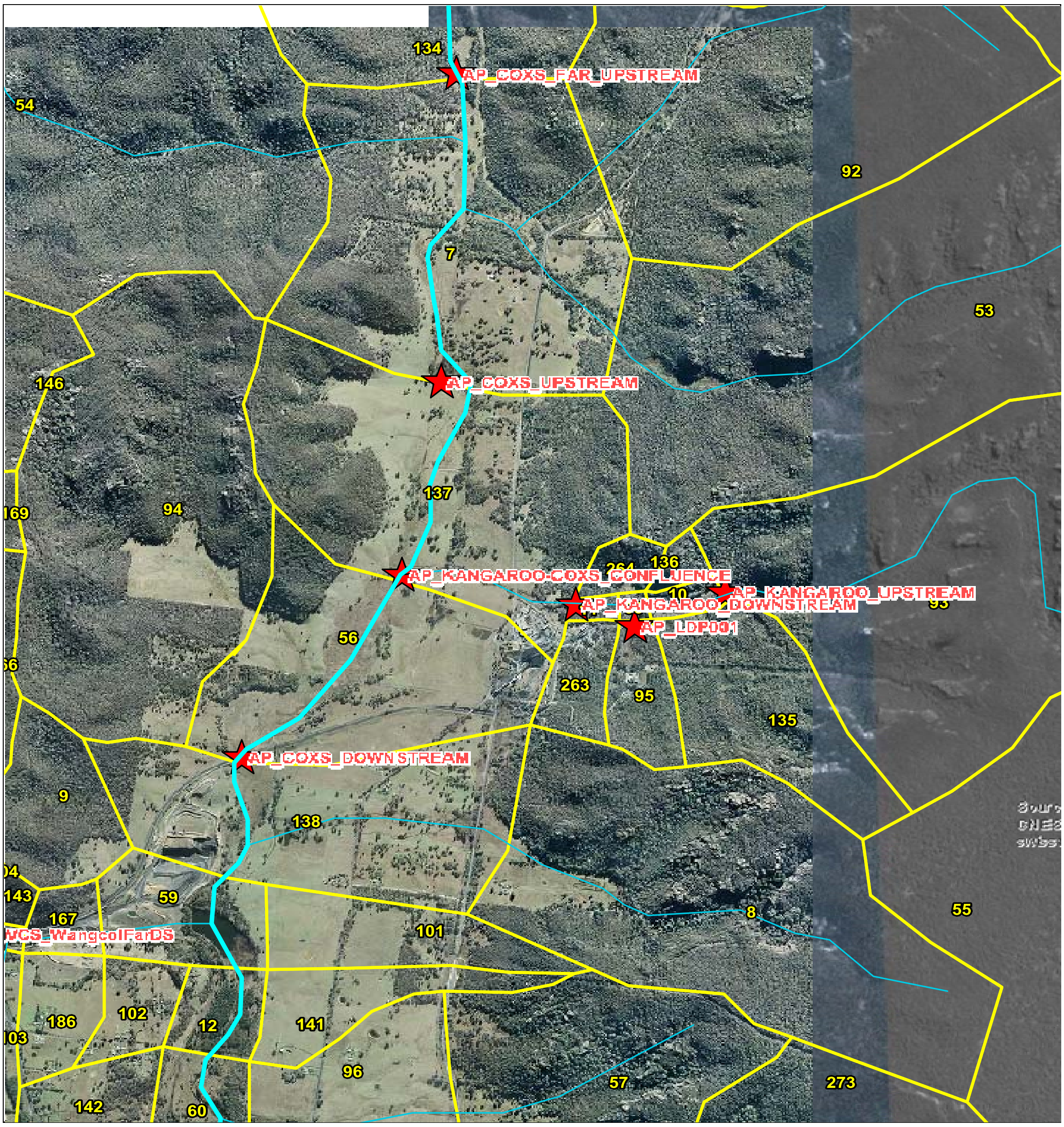


Figure 5 - Layout of the Water Quality model at Kangaroo Creek

Water quality modelling indicates that historical discharge at Angus Place LDP001 accounts for observed increase in salinity in Kangaroo Creek and the Upper Coxs River above Blue Lagoon. The calibration simulation is presented below at monitoring station AP_KANGAROO_DOWNSTREAM (#011).

Modelling assumes water quality upstream of point of discharge of Angus Place LDP001 to Kangaroo Creek (#010 and above) is 50 mg/L TDS. Modelled water quality at monitoring station AP_COXS_FAR_UPSTREAM (#134) is also 50 mg/L TDS.

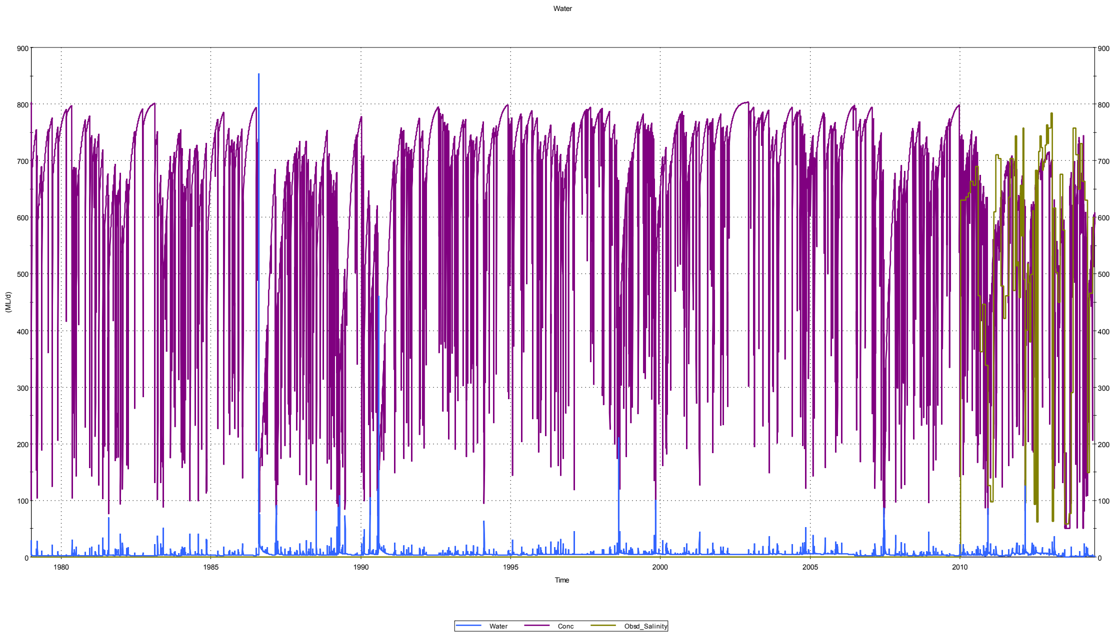


Figure 6 - Historical Daily Flow (ML/d) and Salinity (mg/L) at Sub-Catchment #011

The calibrated model assumes historical discharge from Angus Place LDP001 at 2 ML/d from 1979, increasing linearly to 5 ML/d prior to activation of the SDWTS in June 2006, however, this is a conservative assumption.

Monitoring location AP_COXS_DOWNSTREAM (#056) corresponds with historical monitoring in the AWT (1992) study at their site, E005. At that location, salinity ranged between 40 mg/L in 1980 and 335 mg/L in 1989. Current salinity at that location, from monitoring at AP_COXS_DOWNSTREAM on 5 March 2014, is 610 mg/L.

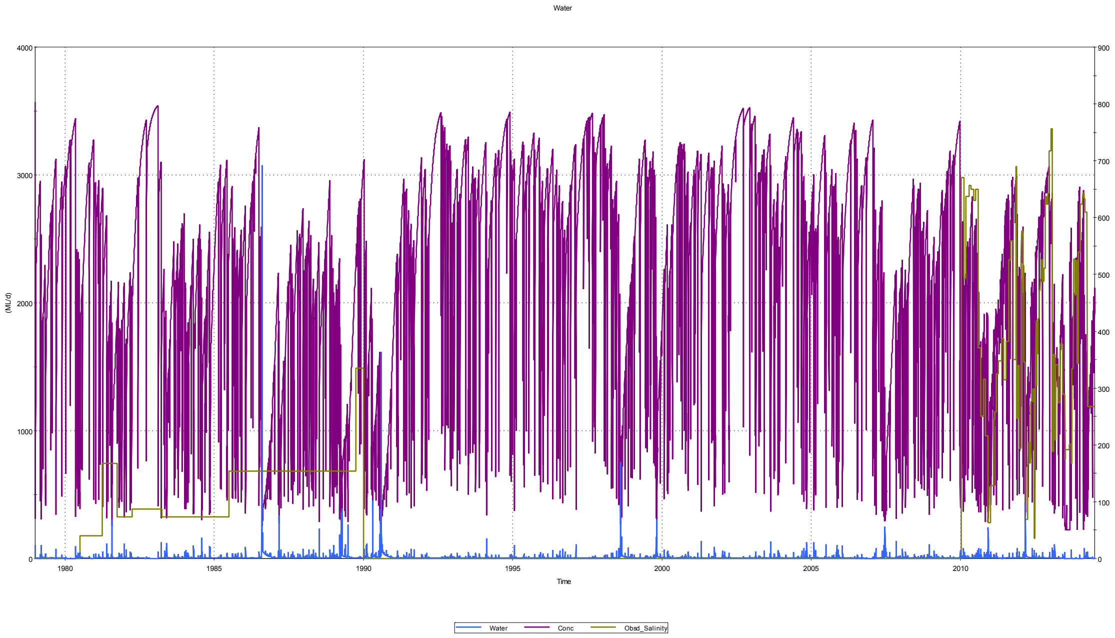


Figure 7 - Historical Daily Flow (ML/d) and Salinity (mg/L) at Sub-Catchment #056

Review of simulated daily flows in Kangaroo Creek at point of discharge of Angus Place LDP001 (#011) during historical discharge indicates that River Flow Objective – Maintain Natural Flow Variability has been met in the past. During prediction simulation of WS1 and WS2a, there is increased discharge (on a continuous basis); however, variability of flow is still evident but mine water discharge does dominate flows in Kangaroo Creek. During prediction simulation of WS2b, discharge at Angus Place LDP001 remains at 2 ML/d. Under this condition, flow variability at point of discharge to Kangaroo Creek is consistent with historical and the River Flow Objective is satisfactorily met.

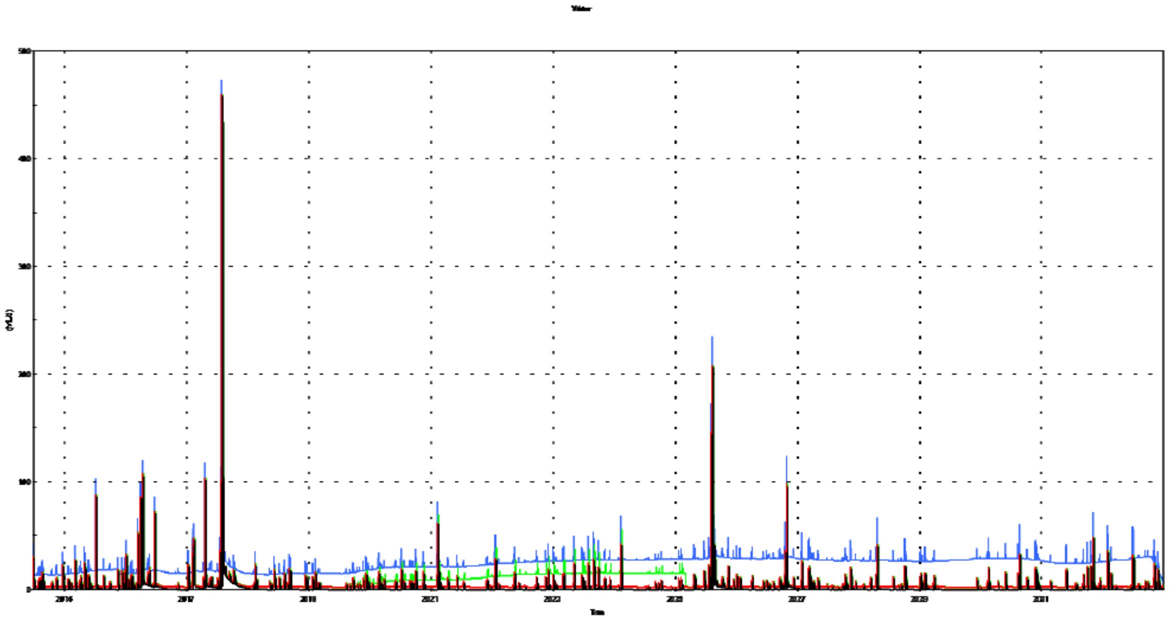


Figure 8 - Predicted Daily Flow (ML/d) at Sub-Catchment #011
Blue is WS1, Green is WS2a, Red is WS2b and Black is Null

Flow statistics of prediction simulated flow at this location are tabulated below (**Table 4**), including for the prediction null case.

**Table 4 - Predicted Daily Flow Statistics (ML/d) at Sub-Catchment #011**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 0.1 | 0.0 | 5.4 | 2.0 | 2.0 |
| 5% | 2.2 | 0.1 | 14.5 | 2.1 | 2.1 |
| 10% | 2.4 | 0.1 | 14.9 | 2.2 | 2.1 |
| 20% | 2.9 | 0.2 | 17.1 | 2.3 | 2.2 |
| 50% | 4.1 | 0.5 | 26.1 | 2.9 | 2.5 |
| 80% | 5.3 | 1.2 | 28.8 | 12.1 | 0.8 |
| 90% | 6.7 | 2.9 | 29.4 | 15.1 | 4.9 |
| 95% | 9.6 | 6.4 | 30.9 | 15.7 | 8.4 |
| Maximum | 853.8 | 458.4 | 473.5 | 460.4 | 460.4 |

Predicted salinity at #011 is presented below (**Figure 9**) and summary statistics are tabulated (**Table 5**).

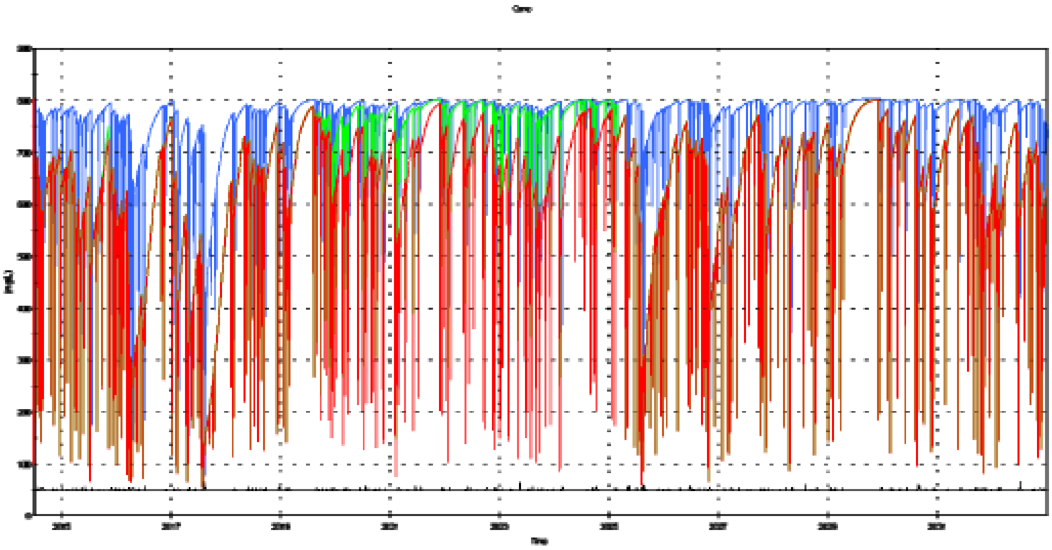


**Figure 9 - Predicted Daily Salinity (mg/L) at Sub-Catchment #011**
**Blue is WS1, Green is WS2a, Red is WS2b and Black is Null**

**Table 5 - Predicted Daily Salinity (mg/L) at Sub-Catchment #011**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 50 | 50 | 75 | 55 | 55 |
| 5% | 277 | 50 | 614 | 266 | 232 |
| 10% | 429 | 50 | 703 | 388 | 356 |
| 20% | 573 | 50 | 760 | 548 | 524 |
| 50% | 704 | 50 | 789 | 698 | 664 |
| 80% | 762 | 51 | 798 | 776 | 733 |
| 90% | 780 | 52 | 800 | 790 | 759 |
| 95% | 790 | 54 | 802 | 797 | 775 |
| Maximum | 804 | 68 | 804 | 804 | 804 |

From the above, predicted salinity in Kangaroo Creek is 804 mg/L at maximum at #011. This is consistent with assumed salinity of mine water make at Angus Place. Salinity ranges between 100 mg/L and 804 mg/L at #011, with median being 789 mg/L during WS1.

Review of predicted salinity against historical observation indicates the proposed condition is consistent with historical impact of mine water discharge. As noted above, assumed water quality of Kangaroo Creek, upstream of point of discharge is 50 mg/L.

Predicted daily flows at #056 are presented graphically below (**Figure 10**) as well as summary statistics in tabular format (**Table 6**).

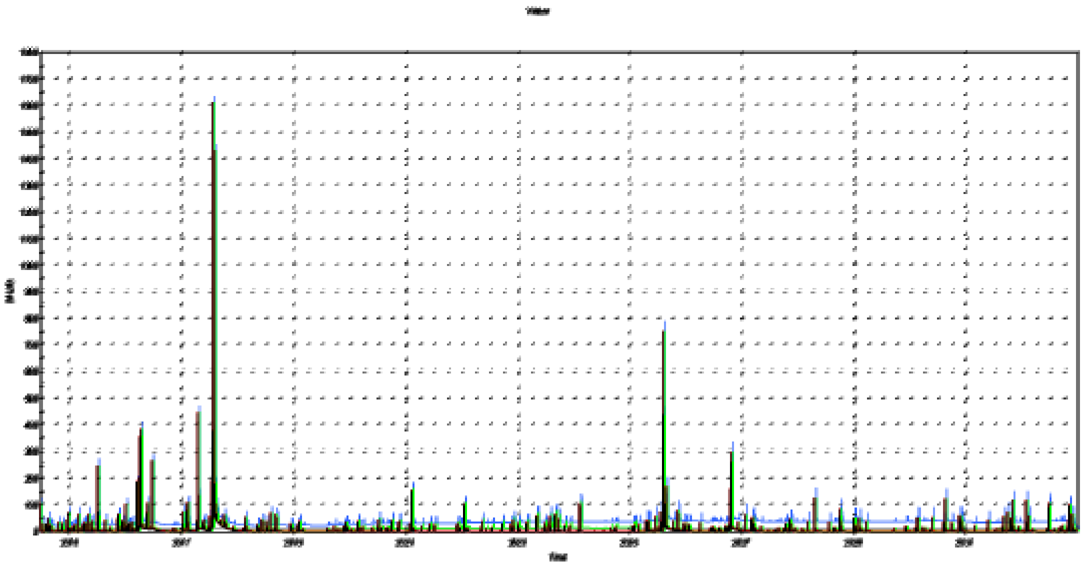


Figure 10 - Predicted Daily Flow (ML/d) at #056
Blue is WS1, Green is WS2a, Red is WS2b and Black is Null

Table 6 - Predicted Daily Flow Statistics (ML/d) at Sub-Catchment #056

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 0.3 | 0.0 | 6.9 | 2.0 | 2.0 |
| 5% | 2.5 | 0.2 | 15.3 | 2.4 | 2.2 |
| 10% | 3.0 | 0.4 | 16.2 | 2.6 | 2.4 |
| 20% | 3.8 | 0.6 | 19.8 | 3.0 | 2.6 |
| 50% | 5.1 | 1.4 | 27.4 | 5.1 | 3.4 |
| 80% | 8.0 | 4.4 | 30.1 | 15.1 | 6.4 |
| 90% | 14.4 | 11.4 | 34.8 | 16.9 | 13.4 |
| 95% | 26.6 | 22.9 | 44.8 | 26.9 | 24.9 |
| Maximum | 3076.6 | 1613.7 | 1628.8 | 1615.7 | 1615.7 |

Review of simulated daily flow in Coxs River at monitoring location AP_COXS_DOWNSTREAM indicates River Flow Objective – Natural Flow Variability has been met in the past. During prediction simulation, there is increased contribution from Kangaroo Creek to this location in WS1 and WS2a. During prediction simulation of WS2b, the impact of mine water discharge to Kangaroo Creek on flow variability at this location is small.

Predicted salinity at #056 is presented below (**Figure 11**), together with summary statistics (**Table 7**).

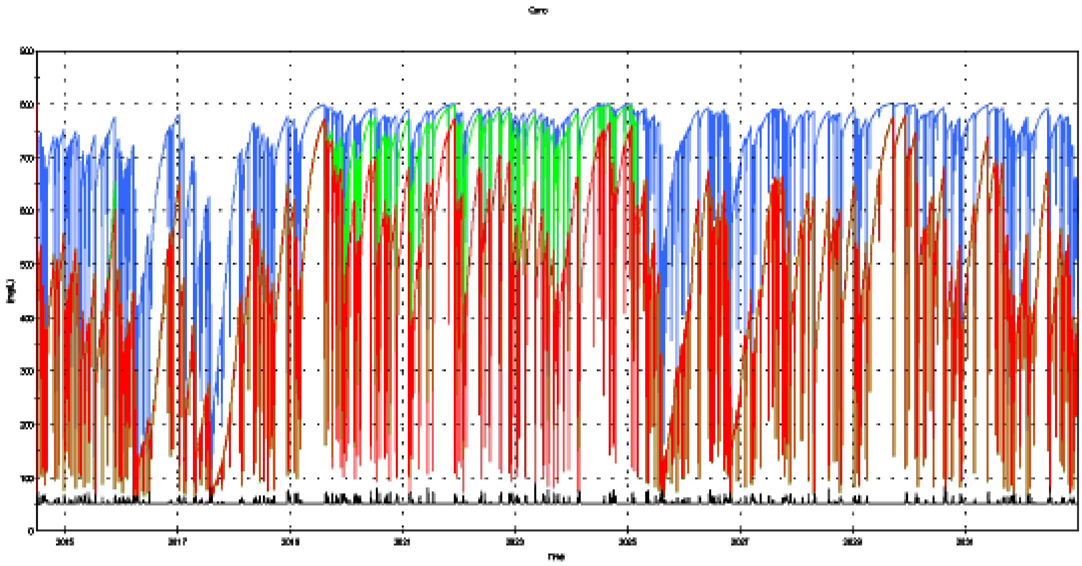


Figure 11 - Predicted Daily Flow (ML/d) at Sub-Catchment #056
Blue is WS1, Green is WS2a, Red is WS2b and Black is Null

Table 7 - Predicted Daily Salinity (mg/L) at Sub-Catchment #056

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 50 | 50 | 63 | 57 | 57 |
| 5% | 136 | 50 | 402 | 127 | 118 |
| 10% | 211 | 50 | 525 | 183 | 168 |
| 20% | 339 | 50 | 666 | 317 | 289 |
| 50% | 556 | 50 | 761 | 538 | 498 |
| 80% | 684 | 55 | 786 | 738 | 626 |
| 90% | 728 | 60 | 792 | 767 | 683 |
| 95% | 759 | 64 | 798 | 780 | 732 |
| Maximum | 804 | 89 | 804 | 804 | 804 |

Predicted salinity in the Coxs River ranges between 100 mg/L and 804 mg/L, with median being 761 mg/L during WS1.

Review of predicted salinity against historical observation indicates proposed condition is consistent with historical impact of discharge at Angus Place. As indicated above, salinity range of natural condition is between 50 mg/L (assumed minimum) and 89 mg/L, with median of 50 mg/L.

<u>Sawyers Swamp Creek / Sawyers Swamp Creek above Coxs River</u>

The layout of the water quality model is presented below in **Figure 12**.

It is noted that the blue/black drainage line in the below was obtained from the 250,000 scale vector dataset and therefore is approximate. As presented in the **Appendix 2**, sub-catchments were delineated based on high resolution topographic data.

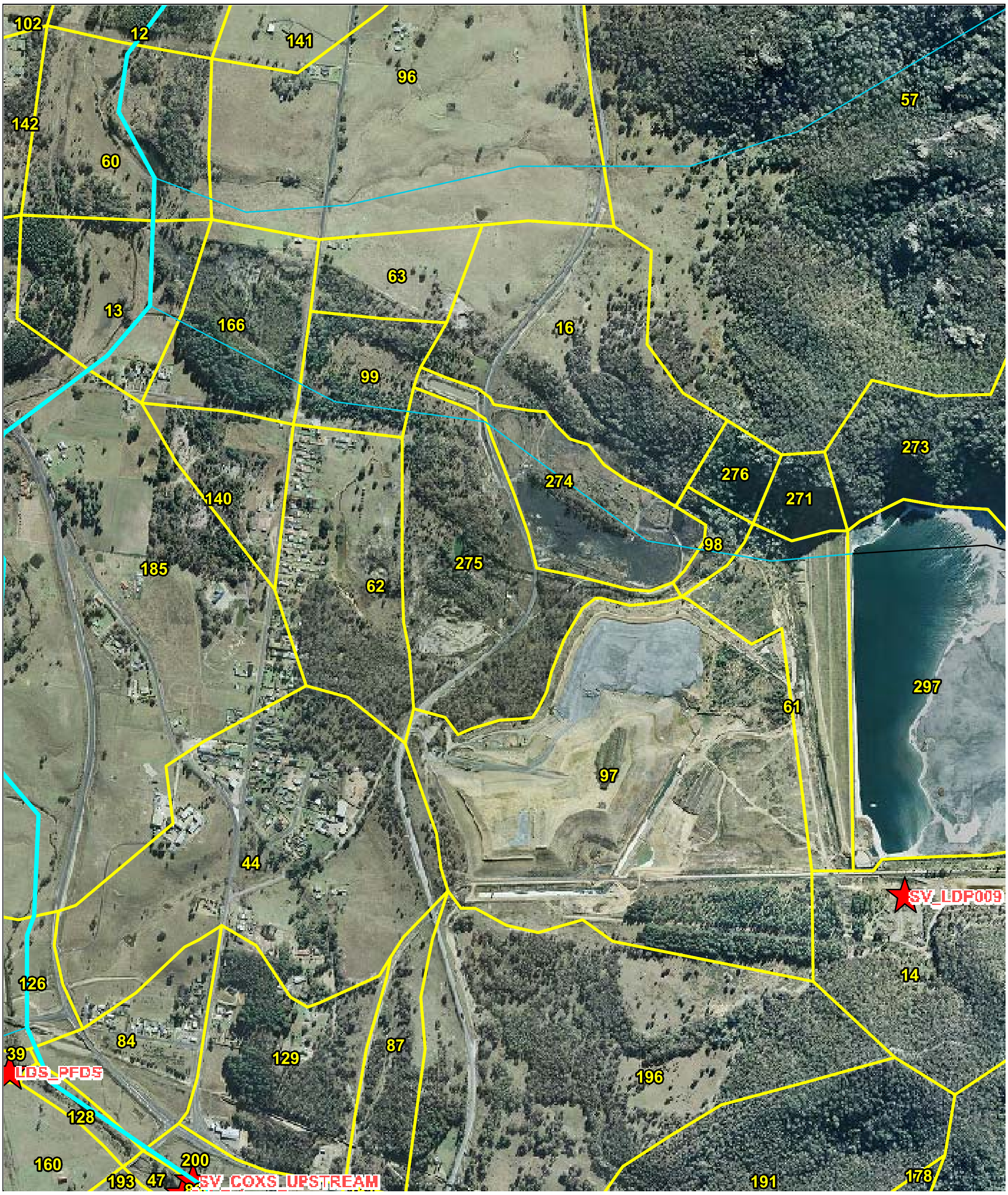


**Figure 12 - Layout of the Water Quality Model at Sawyers Swamp Creek**

Sawyers Swamp Creek is diverted around the Sawyers Swamp Creek Ash Dam and is transmitted from #014, inclusive of point of discharge from Springvale LDP009, to #061, #098, #275, #09 and #166 before entering the Coxs River.

Water quality modelling implies increased salinity observed in Sawyers Swamp Creek above Coxs River is associated with mine water discharge at Springvale LDP009, however, as presented above, the Sawyers Swamp Creek catchment is in a highly disturbed state and there are multiple potential sources of salinity and other contaminants both presently and in the past.

Monitoring location WCS_LDP003_DOWNSTREAM (#166) is located on Sawyers Swamp Creek immediately above the Coxs River. The calibration simulation is presented below (**Figure 13**).

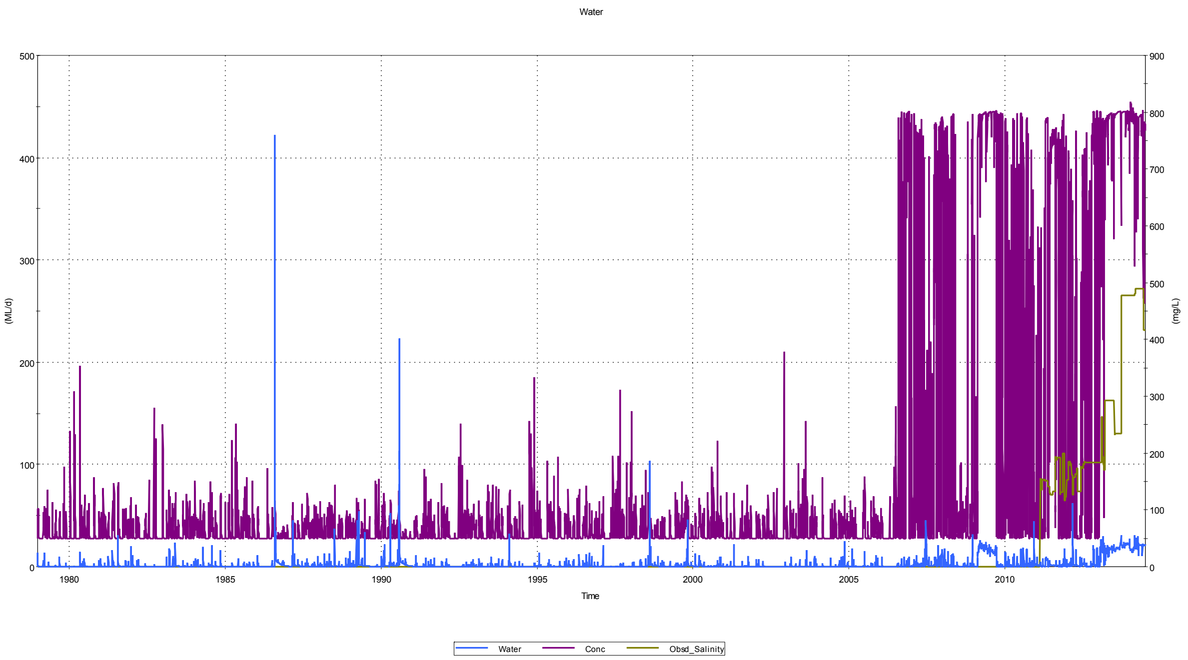


**Figure 13 - Historical Flow (ML/d) and Salinity (mg/L) at Sub-Catchment #166**

From the above, the calibration model over-predicts the observed salinity at WCS_LDP003_DOWNSTREAM. It is noted that discharge at Springvale LDP009 commenced in August 2012 and prior to this was associated with Energy Australia LDP020 from June 2006. The location of LDP020 changed in the past, however was still within sub-catchment #014.

During the prediction simulation, under scenarios WS1, WS2a and WS2b, there is discharge to Springvale LDP009. Predicted daily flow (**Figure 14**) and salinity (**Figure 15**) at sub-catchment #014 is presented below. The associated statistics for the daily flows and salinity at sub-catchment #014 are provided in **Table 8** and **Table 9**, respectively.

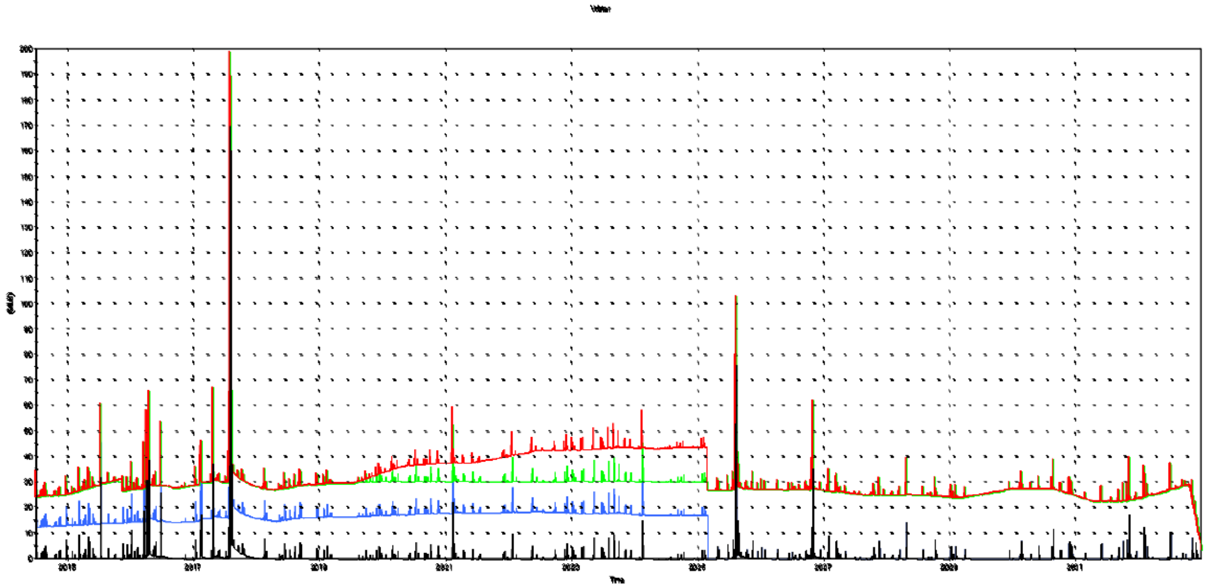


**Figure 14 - Predicted Flow (ML/d) at Sub-Catchment #014**
**Blue is WS1, Green is WS2a, Red is WS2b and Black is Null**

**Table 8 - Predicted Daily Flow Statistics (ML/d) at Sub-Catchment #014**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 0.0 | 0.0 | 0.0 | 3.0 | 3.0 |
| 5% | 0.0 | 0.0 | 0.0 | 23.3 | 23.3 |
| 10% | 0.0 | 0.0 | 0.1 | 24.4 | 24.4 |
| 20% | 0.1 | 0.1 | 0.1 | 25.1 | 25.1 |
| 50% | 0.2 | 0.2 | 14.4 | 28.0 | 28.0 |
| 80% | 1.0 | 0.4 | 17.9 | 30.1 | 38.1 |
| 90% | 4.1 | 1.1 | 18.3 | 30.3 | 42.7 |
| 95% | 16.1 | 2.3 | 18.7 | 30.8 | 43.2 |
| Maximum | 314.7 | 169.9 | 185.7 | 198.9 | 198.9 |

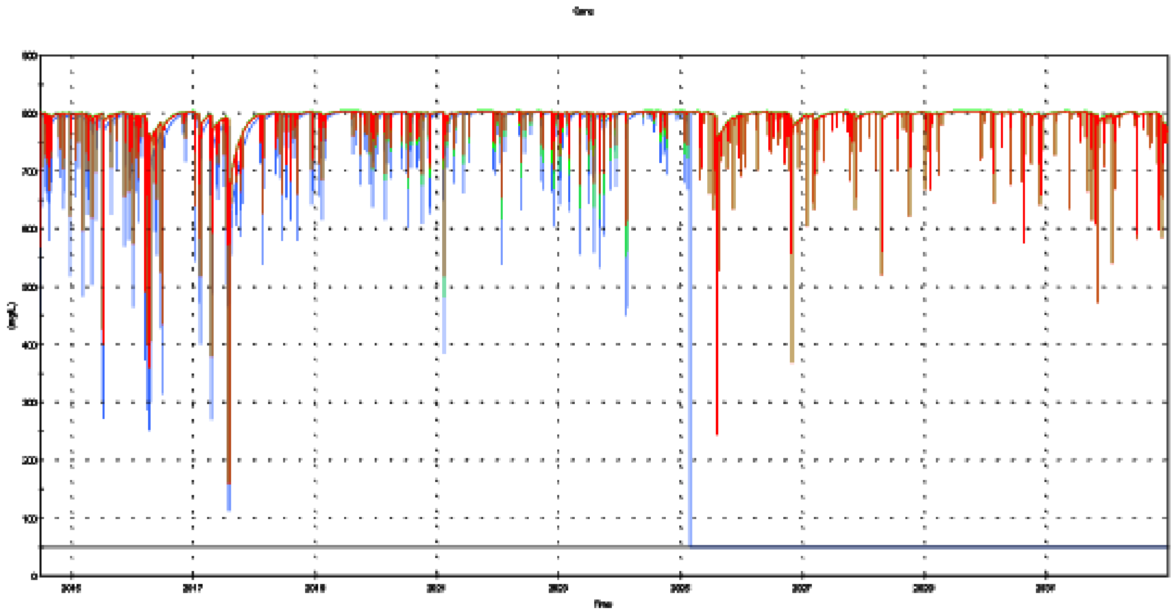


Figure 15 - Predicted Salinity (mg/L) at Sub-Catchment #014
Blue is WS1, Green is WS2a, Red is WS2b and Black is Null

**Table 9 - Predicted Daily Salinity Statistics (mg/L) at Sub-catchment #014**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 50 | 50 | 50 | 160 | 160 |
| 5% | 50 | 50 | 50 | 743 | 747 |
| 10% | 50 | 50 | 50 | 774 | 775 |
| 20% | 50 | 50 | 50 | 792 | 792 |
| 50% | 50 | 50 | 761 | 799 | 780 |
| 80% | 50 | 50 | 798 | 802 | 802 |
| 90% | 634 | 50 | 801 | 803 | 803 |
| 95% | 790 | 50 | 802 | 803 | 803 |
| Maximum | 819 | 50 | 804 | 804 | 804 |

Predicted daily flow and salinity is also presented at #166 in **Figure 16**, the associated summary statistics are provided in **Table 10**.

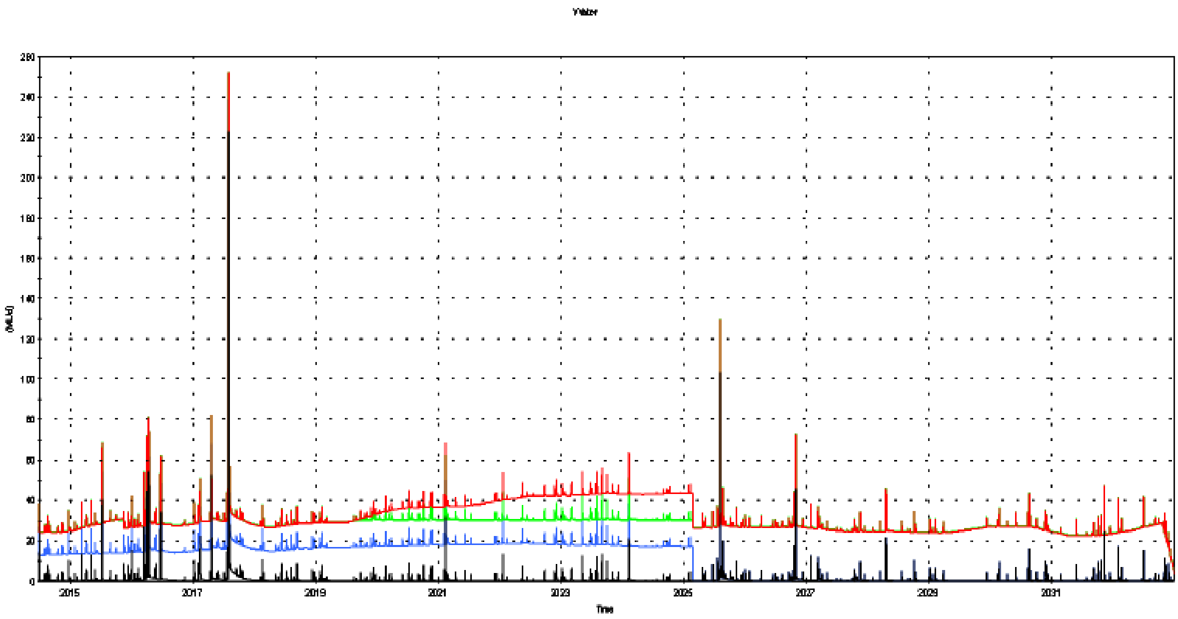


**Figure 16 - Predicted Flow (ML/d) at #166**
**Blue is WS1, Green is WS2a, Red is WS2b and Black is Null**

**Table 10 - Predicted Daily Salinity Statistics (mg/L) at #166**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 50 | 50 | 50 | 154 | 154 |
| 5% | 50 | 50 | 50 | 724 | 729 |
| 10% | 50 | 50 | 50 | 766 | 767 |
| 20% | 50 | 50 | 51 | 788 | 789 |
| 50% | 53 | 51 | 751 | 799 | 799 |
| 80% | 90 | 77 | 798 | 802 | 802 |
| 90% | 605 | 90 | 800 | 803 | 803 |
| 95% | 788 | 103 | 802 | 803 | 803 |
| Maximum | 818 | 379 | 804 | 804 | 804 |

From the above, predicted salinity at #014 and #166 is 804 mg/L a maximum, consistent with assumed salinity of mine water make at Springvale Mine and Angus Place Colliery. The catchment upstream of point of discharge, Springvale LDP009, is relatively small, therefore the predicted median salinity is similar to the assumed salinity of mine water make. As indicated, despite the relatively small contributing catchment, there is variability in concentration at #166. Predicted median salinity at #166 of 751 mg/L is within the range of modelled salinity at monitoring station WCS_LDP003_DOWNSTREAM during the calibration period.

Downstream Impacts - Coxs River / Lake Wallace / Lake Lyell / Thompsons Creek Reservoir and Lake Burragorang

Flow gauging at downstream end of Sawyers Swamp Creek is not available, however, there is a NSW Office of Water station on the Coxs River above Lake Wallace. The tributaries contributing to the Coxs River at this location include Wangcol Creek, Sawyers Swamp Creek and Pipers Flat Creek. The calibration simulation at this location is presented below.

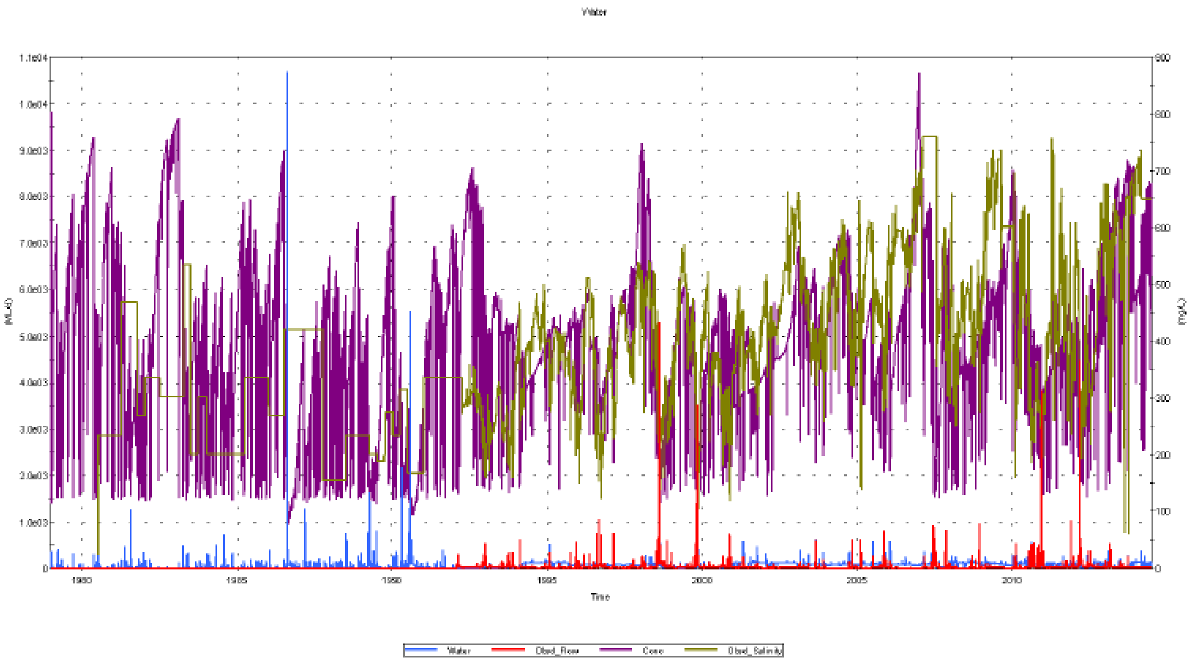


Figure 17 - Historical Flow (ML/d) and Salinity (mg/L) at #047

From **Figure 17** there is a reasonable fit between observed and modelled flow as well as observed and modelled salinity.

The layout of the water quality model in this vicinity is presented below in **Figure 18**.

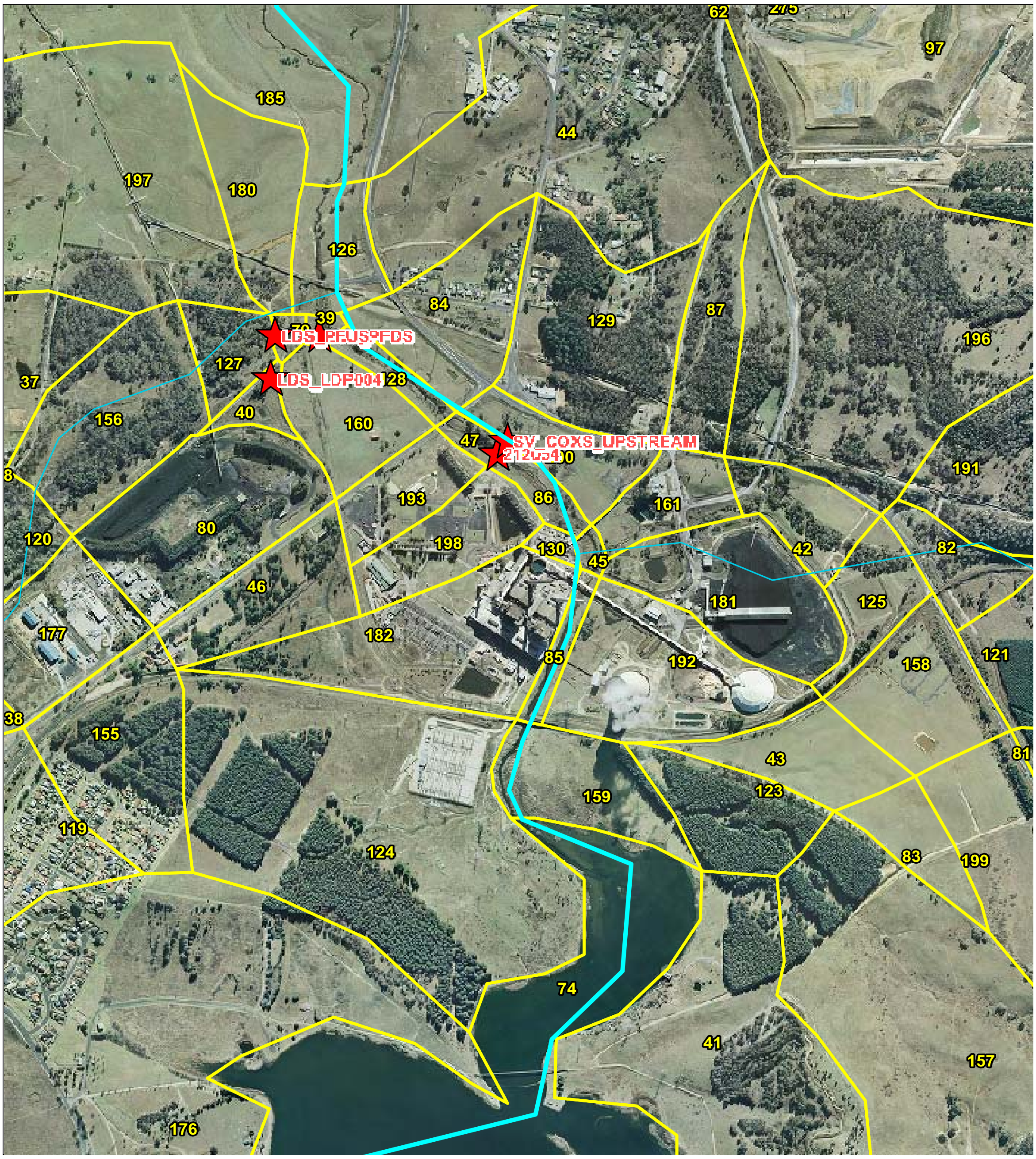


Figure 18 - Layout of the Water Quality model at Lake Wallace

Predicted daily flow (**Figure 19**) and salinity (**Figure 20**) at this location is presented below together with summary statistics for daily flow (**Table 11**) and salinity (**Table 12**). It is noted that WS1, WS2a and WS2b have identical daily flows at this location.

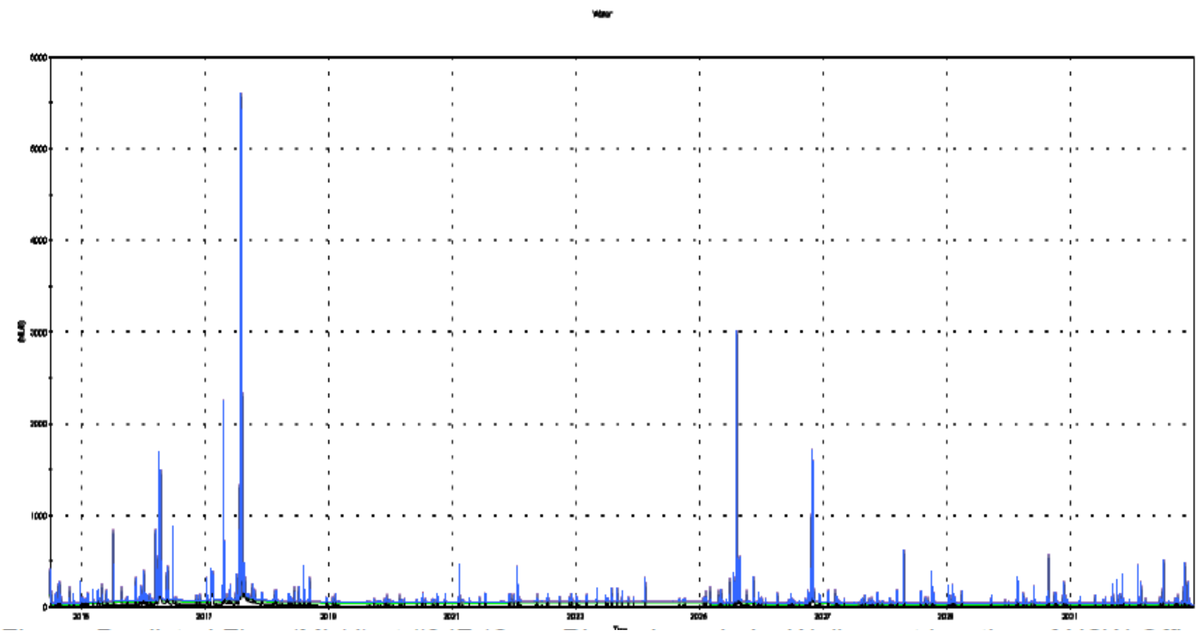


Figure 19 - Predicted Flow (ML/d) at #047

### Table 11 - Predicted Daily Flow Statistics (ML/d) at #047

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 2.0 | 4.4 | 13.3 | 13.3 | 13.3 |
| 5% | 3.4 | 6.2 | 33.0 | 33.0 | 33.0 |
| 10% | 4.5 | 6.7 | 35.1 | 35.1 | 35.1 |
| 20% | 6.6 | 7.5 | 36.8 | 36.8 | 36.8 |
| 50% | 41.8 | 10.3 | 47.9 | 47.9 | 47.9 |
| 80% | 105.4 | 30.4 | 60.9 | 60.9 | 60.9 |
| 90% | 112.2 | 51.5 | 81.9 | 81.9 | 81.9 |
| 95% | 131.2 | 95.3 | 126.1 | 126.1 | 126.1 |
| Maximum | 10694.0 | 5576.5 | 5607.4 | 5607.5 | 5607.5 |

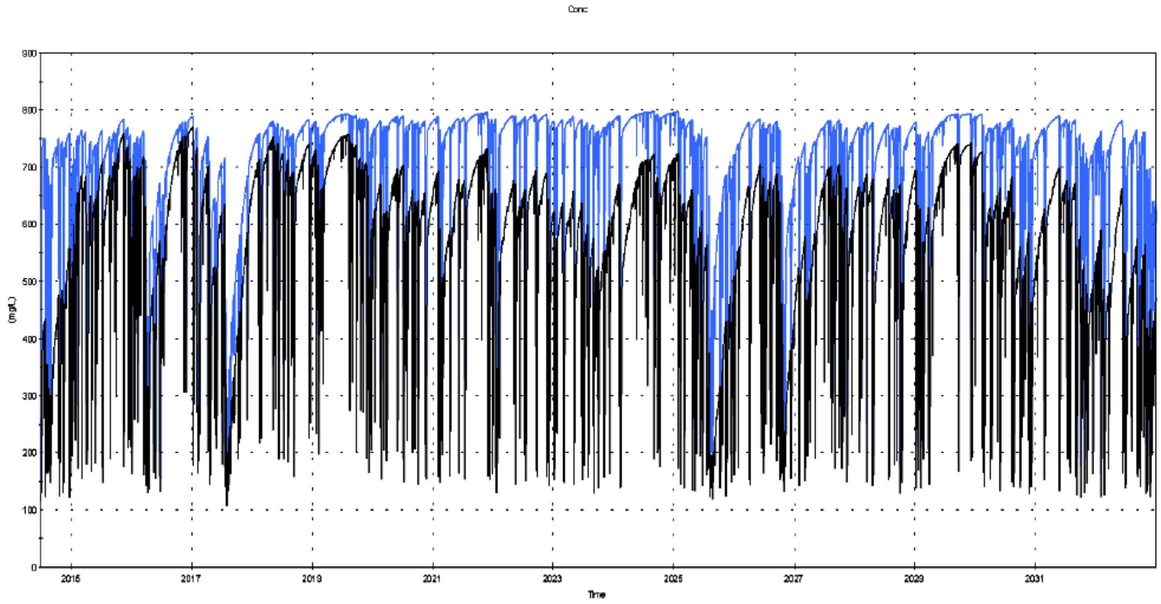


**Figure 20 - Predicted Salinity (mg/L) at #047**
**Blue is WS1 and Black is Null. It is noted that predicted salinity in WS1 is identical at this location to WS2a and WS2b.**

**Table 12 - Predicted Daily Salinity (mg/L) at #047**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 79 | 107 | 111 | 111 | 111 |
| 5% | 156 | 191 | 358 | 358 | 358 |
| 10% | 195 | 254 | 484 | 484 | 484 |
| 20% | 284 | 397 | 639 | 639 | 639 |
| 50% | 402 | 599 | 755 | 755 | 755 |
| 80% | 514 | 681 | 780 | 780 | 780 |
| 90% | 599 | 713 | 787 | 787 | 787 |
| 95% | 665 | 731 | 791 | 791 | 791 |
| Maximum | 874 | 771 | 797 | 797 | 797 |

From the above, the predicted salinity at this location is comparable to historical salinity under the proposed water management strategy.

The modelled salinity in Lake Wallace is presented below. When operational, Wallerawang Power Station, discharged some Cooling Tower blowdown water to the Coxs River above Lake Wallace (Energy Australia, LDP001 and LDP021), however, the majority was discharged below Lake Wallace (Energy Australia, LDP004). ‘Bleed-off’ from Sawyers Swamp Creek Ash Dam (SSCAD) was discharged to Lake Wallace (Energy Australia, LDP003) and whilst included in the water quality model, there was insufficient data of wet ash deposition (prior to 2002) and historical water level response in the dam to improve this component. During the prediction simulation, there was no ‘bleed-off’ from the SSCAD since evaporation from the surface of SSCAD exceeds direct rainfall on the dam surface and local catchment runoff. As such, the cumulative impact assessment is conservative because there is no contribution from SSCAD via Energy Australia LDP003.

**Figure 21 - Historical Volume (ML) and Salinity (mg/L) at #074 (Lake Wallace)**

From the above, the historical salinity in Lake Wallace is reasonably matched by the water quality model.

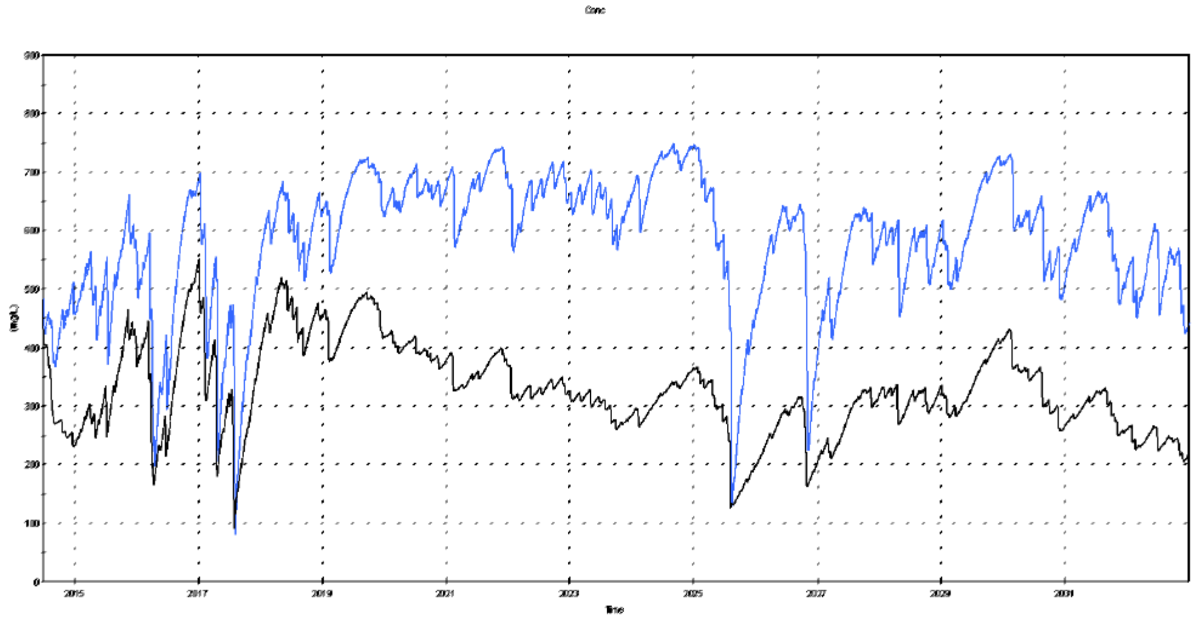


**Figure 22 - Predicted Salinity (mg/L) at #074 (Lake Wallace)**
**Blue is WS1 and Black is Null. It is noted that predicted salinity in WS1 is identical at this location to WS2a and WS2b.**

**Table 13 - Predicted Daily Salinity Statistics (mg/L) at #074 (Lake Wallace).**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 100 | 91 | 79 | 79 | 79 |
| 5% | 164 | 207 | 369 | 369 | 369 |
| 10% | 197 | 235 | 436 | 436 | 436 |
| 20% | 226 | 265 | 499 | 499 | 499 |
| 50% | 309 | 321 | 604 | 604 | 604 |
| 80% | 408 | 393 | 673 | 673 | 673 |
| 90% | 470 | 433 | 704 | 704 | 704 |
| 95% | 516 | 470 | 720 | 720 | 720 |
| Maximum | 725 | 552 | 747 | 747 | 747 |

From the above, the predicted salinity in Lake Wallace is up to 747 mg/L under the proposed water management strategy. Comparison of predicted salinity against historical observation indicates predicted salinity is within the range experienced in the past and variability in salinity is also comparable. Median salinity, however, is higher at 604 mg/L under WS1, WS2a and WS2b conditions compared to the calibration period at 309 mg/L and prediction null case of 321mg/L.

There are two monitoring locations between Lake Wallace and Lake Lyell that are of interest. The first station, #154, corresponds with NSW Office of Water Flow Gauge No. 212058. The second station, #035, corresponds with Energy Australia water quality monitoring location COX5 (Delta Electricity (2009)).

The layout of the water quality model between Lake Wallace and Lake Lyell is presented below (**Figure 23**).

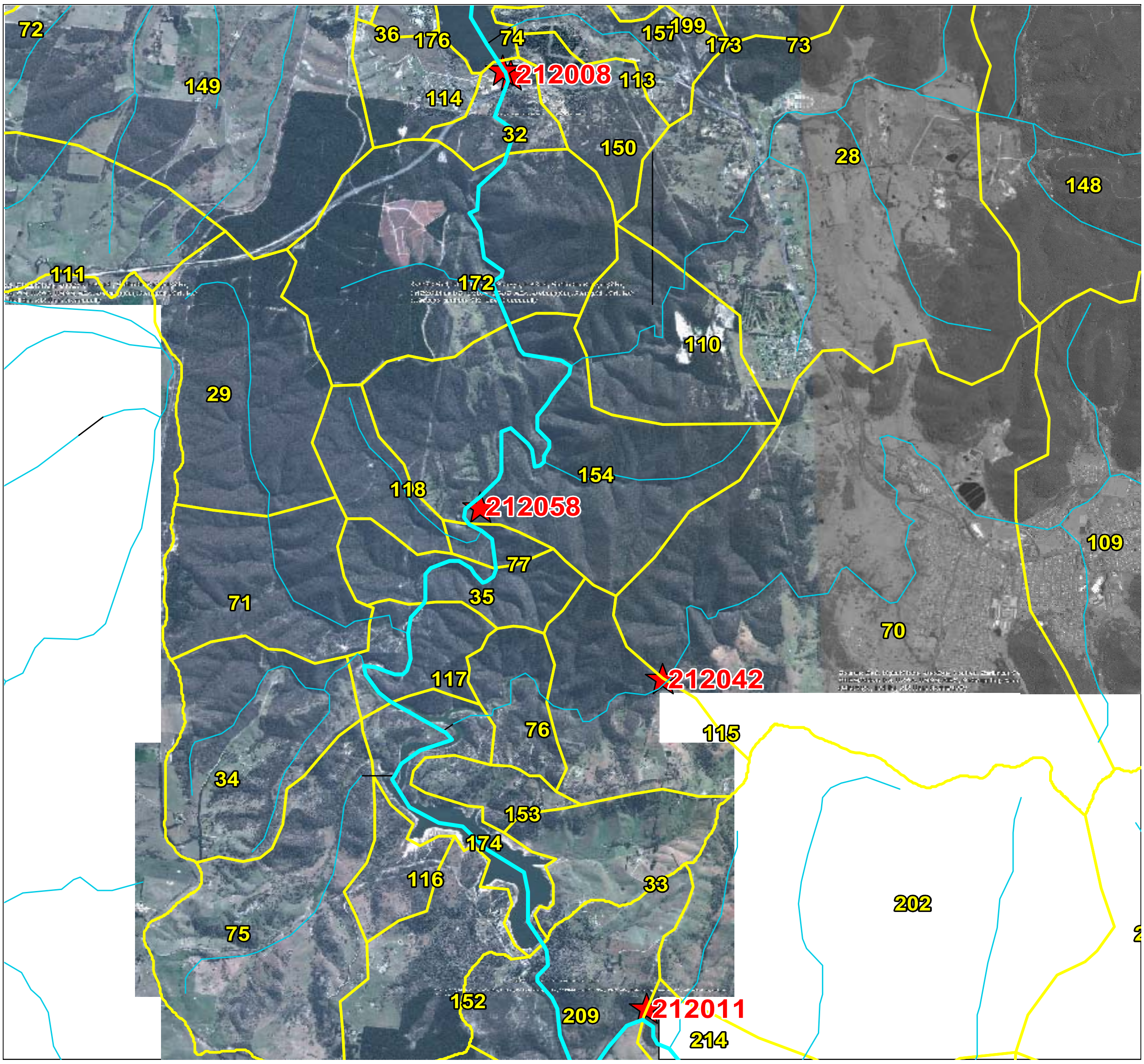


**Figure 23 - Layout of the Water Quality model between Lake Wallace and Lake Lyell**

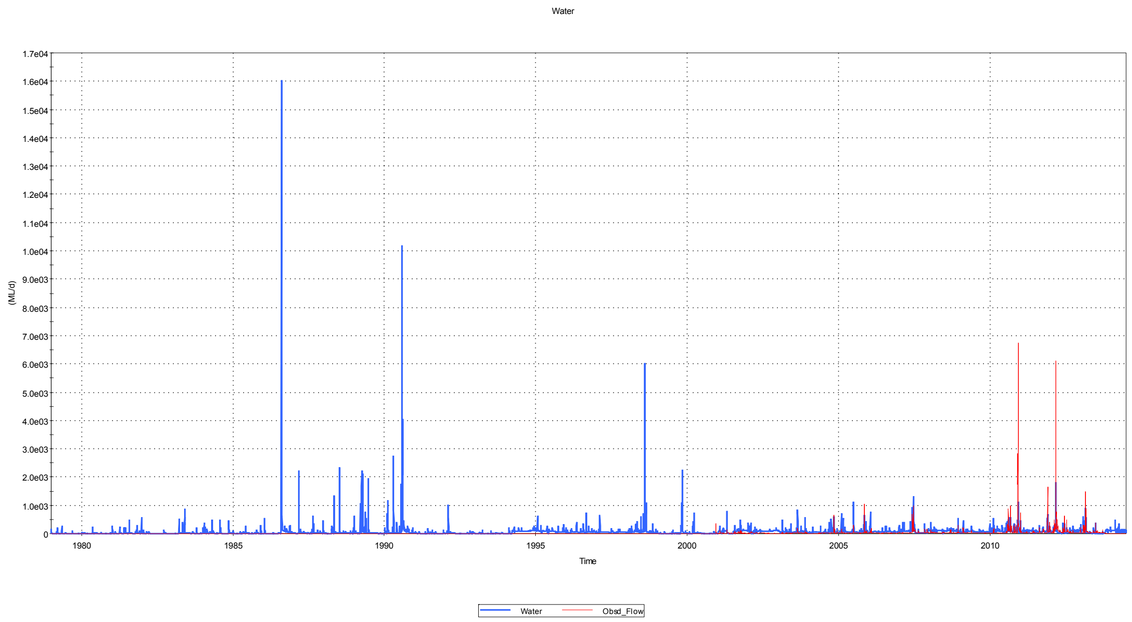


Figure 24 - Historical Flow (ML/d) at #154

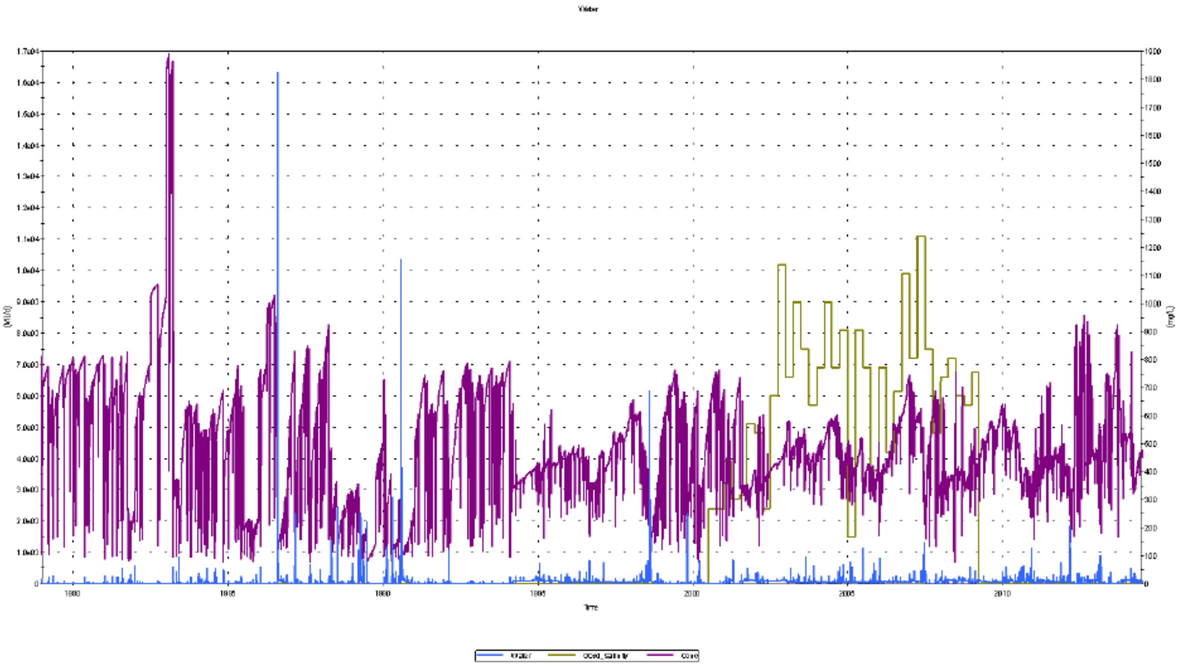


Figure 25 - Historical Flow (ML/d) and Salinity (mg/L) at #035

Prediction simulations (flow and salinity) at these locations are presented below as well as summary statistics.

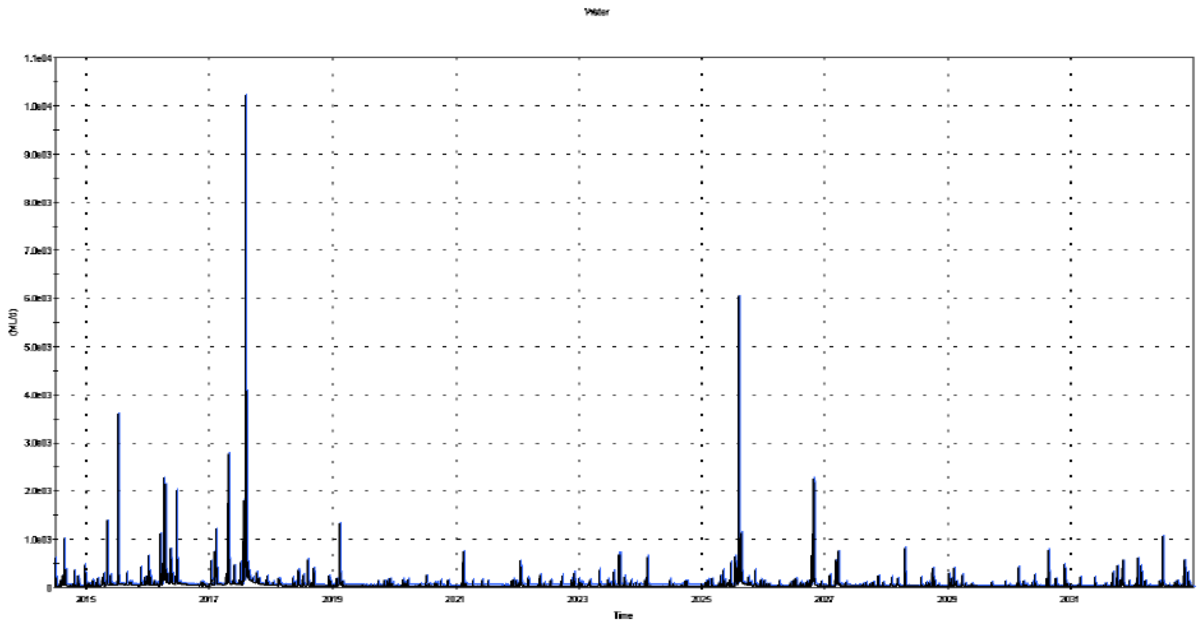


Figure 26 - Predicted Flow (ML/d) at #154

Table 14 - Predicted Daily Flow Statistics (ML/d) at #154

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 2.6 | 0.1 | 6.7 | 6.7 | 6.7 |
| 5% | 10.0 | 2.2 | 29.9 | 29.9 | 29.9 |
| 10% | 10.6 | 3.3 | 32.4 | 32.4 | 32.4 |
| 20% | 11.9 | 5.2 | 36.6 | 36.6 | 36.6 |
| 50% | 37.3 | 12.7 | 48.7 | 48.7 | 48.7 |
| 80% | 90.2 | 44.5 | 75.9 | 75.9 | 75.9 |
| 90% | 116.5 | 84.8 | 118.0 | 118.0 | 118.0 |
| 95% | 156.1 | 161.2 | 192.1 | 191.9 | 191.9 |
| Maximum | 16029.0 | 10223.0 | 10254.0 | 10254.0 | 10254.0 |

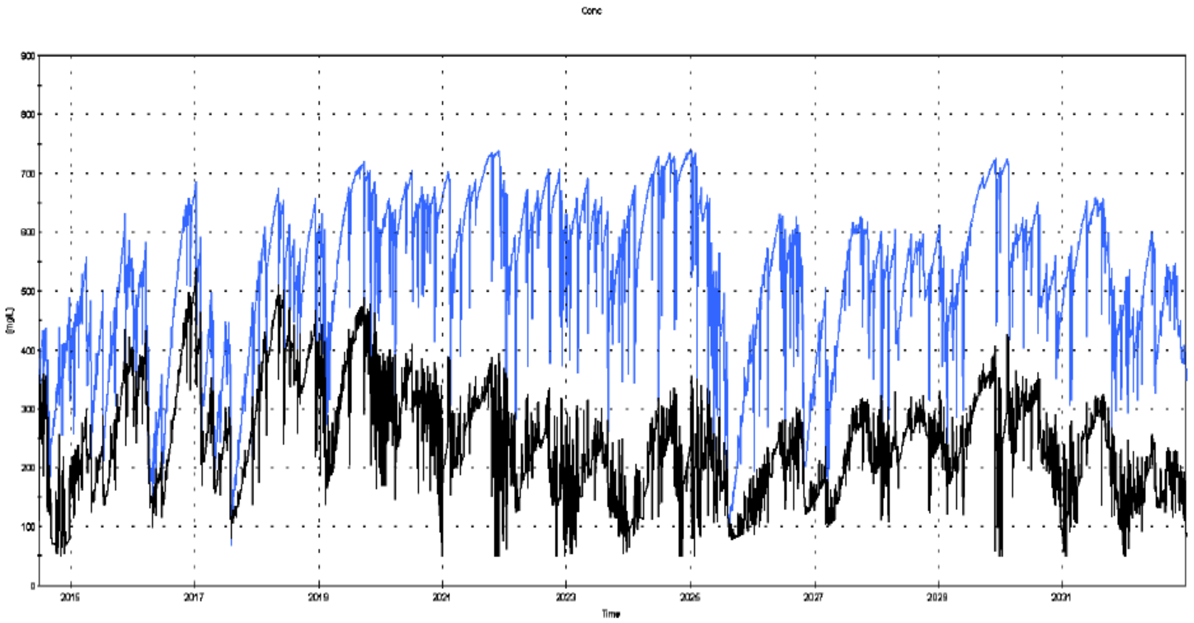


**Figure 27 - Predicted Salinity (mg/L) at #035**
**Blue is WS1 and Black is Null. It is noted that predicted salinity in WS1 is identical at this location to WS2a and WS2b.**

**Table 15 - Predicted Daily Salinity Statistics (mg/L) at #035**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 63 | 50 | 67 | 67 | 67 |
| 5% | 164 | 100 | 263 | 263 | 263 |
| 10% | 229 | 125 | 337 | 337 | 337 |
| 20% | 337 | 159 | 418 | 418 | 418 |
| 50% | 472 | 231 | 552 | 552 | 552 |
| 80% | 658 | 315 | 643 | 643 | 643 |
| 90% | 741 | 366 | 681 | 681 | 681 |
| 95% | 786 | 406 | 705 | 705 | 705 |
| Maximum | 1893 | 540 | 740 | 740 | 740 |

From the above, the calibration simulation underpredicts salinity compared to historical observation. During available monitoring period between 2000 and 2009, salinity at #035 ranged between 200 mg/L and 1200 mg/L. Calibration simulation during that period is 200 to 700 mg/L, by comparison.

From predicted flow chart and tabulated statistics, WS1 (WS2a and WS2b yield identical results) leads to discernible minimum flow in the Coxs River, however, the variability in magnitude of flow is significant.

From predicted salinity chart at #035, expected maximum salinity and variability in salinity is consistent with historical observation.

Comparison of the calibration simulation with historical monitoring of Lake Lyell (#174) (**Figure 28**) and Thompsons Creek Reservoir (#272) (**Figure 29**) is presented below.

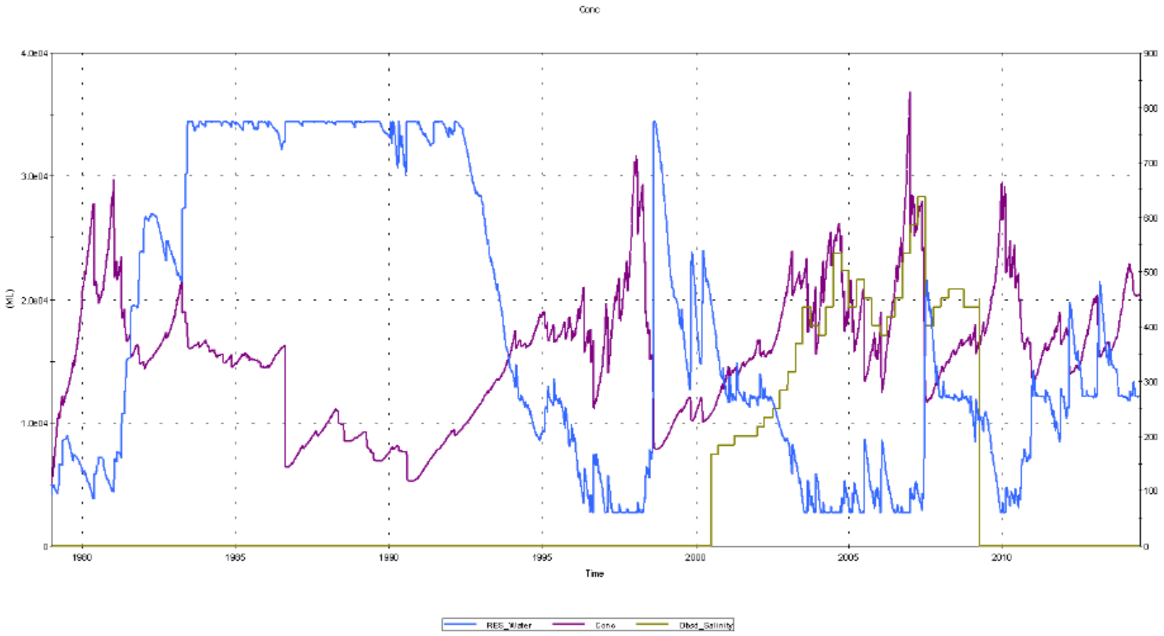


Figure 28 - Historical Volume (ML) and Salinity (mg/L) at #174 (Lake Lyell)

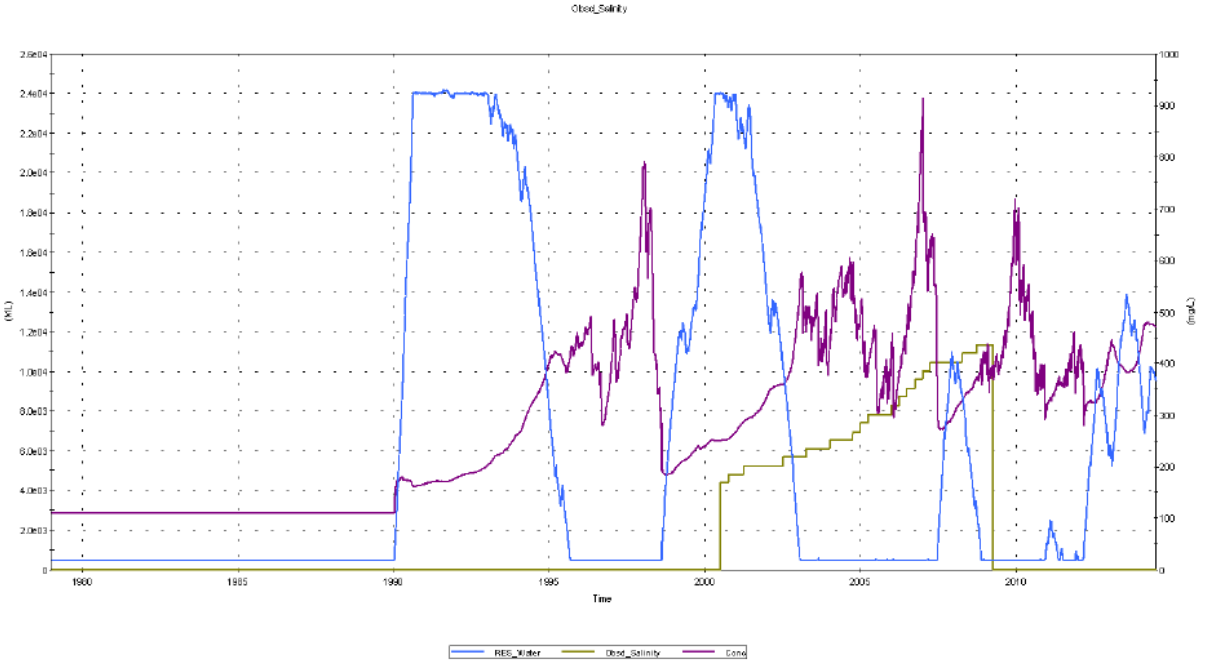


Figure 29 - Historical Volume (ML) and Salinity (mg/L) at #272 (Thompsons Creek Reservoir)

From the above, the modelled salinity in Lake Lyell (#174) during calibration simulation is reasonably matched with historical observation. Modelled storage volume (ML) is somewhat under-predicted, however, this is due to assumptions necessary for daily demand at Wallerawang Power Station and Mount Piper Power Station from 1993 and other input data. The results, however, are suitable for the purpose of cumulative impact assessment.

The modelled salinity in Thompsons Creek Reservoir (#272) is also reasonably matched, although the model is over-predicting salinity, the increasing trend is captured.

The predicted volume (ML) and salinity (mg/L) in Lake Lyell (#174) and Thompsons Creek Reservoir (#272) is presented below.

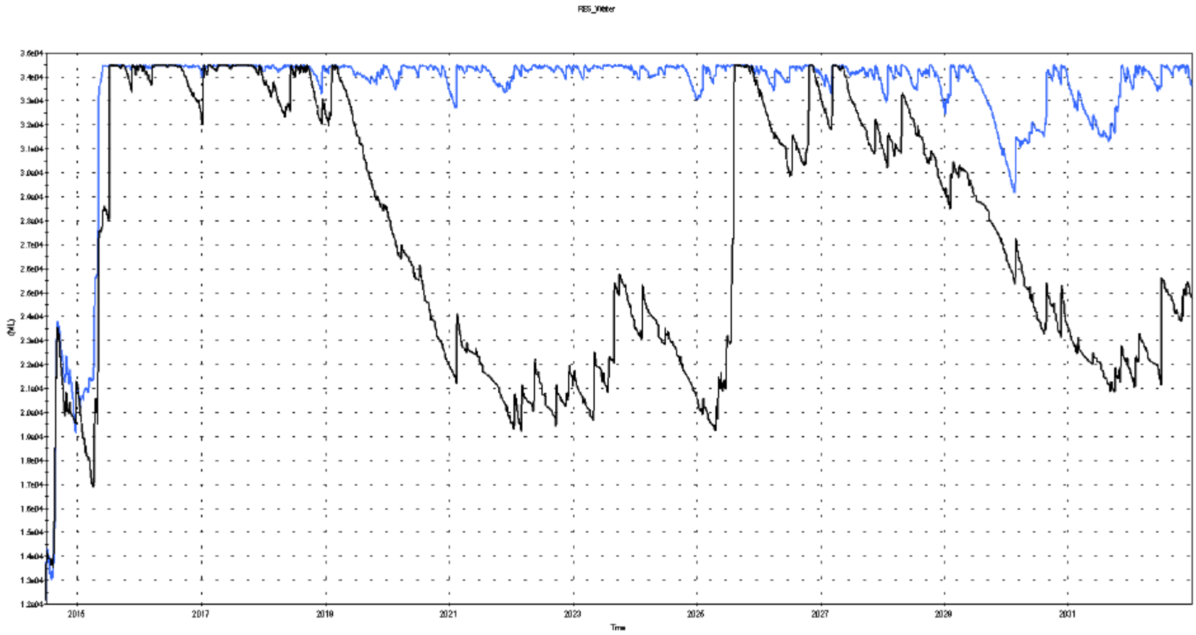


Figure 30 - Predicted Volume (ML) at #174 (Lake Lyell)
Blue is WS1 and Black is Null

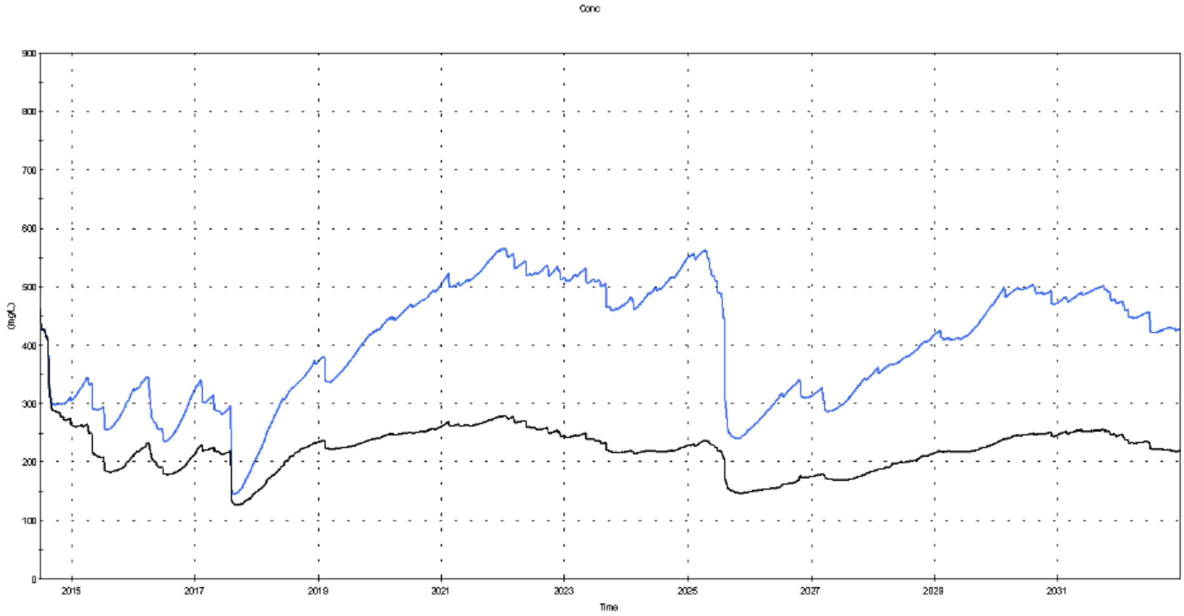


Figure 31 - Predicted Salinity (mg/L) at #174 (Lake Lyell)
Blue is WS1 and Black is Null

Table 16 - Predicted Daily Salinity Statistics (mg/L) at #174 (Lake Lyell).

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 110 | 127 | 145 | 145 | 145 |
| 5% | 165 | 152 | 246 | 246 | 246 |
| 10% | 185 | 170 | 271 | 271 | 271 |
| 20% | 235 | 186 | 303 | 303 | 303 |
| 50% | 355 | 223 | 422 | 422 | 422 |
| 80% | 437 | 251 | 500 | 500 | 500 |
| 90% | 499 | 262 | 522 | 522 | 522 |
| 95% | 559 | 270 | 539 | 539 | 539 |
| Maximum | 830 | 462 | 566 | 566 | 566 |

From the above, the prediction simulation indicates salinity in Lake Lyell is higher due to proposed water management strategy at Angus Place and Springvale, however, concentration is comparable to historical range and variability.

The prediction simulation indicates a positive difference in stored volume in Lake Lyell (#174) due to the proposed water management strategy.

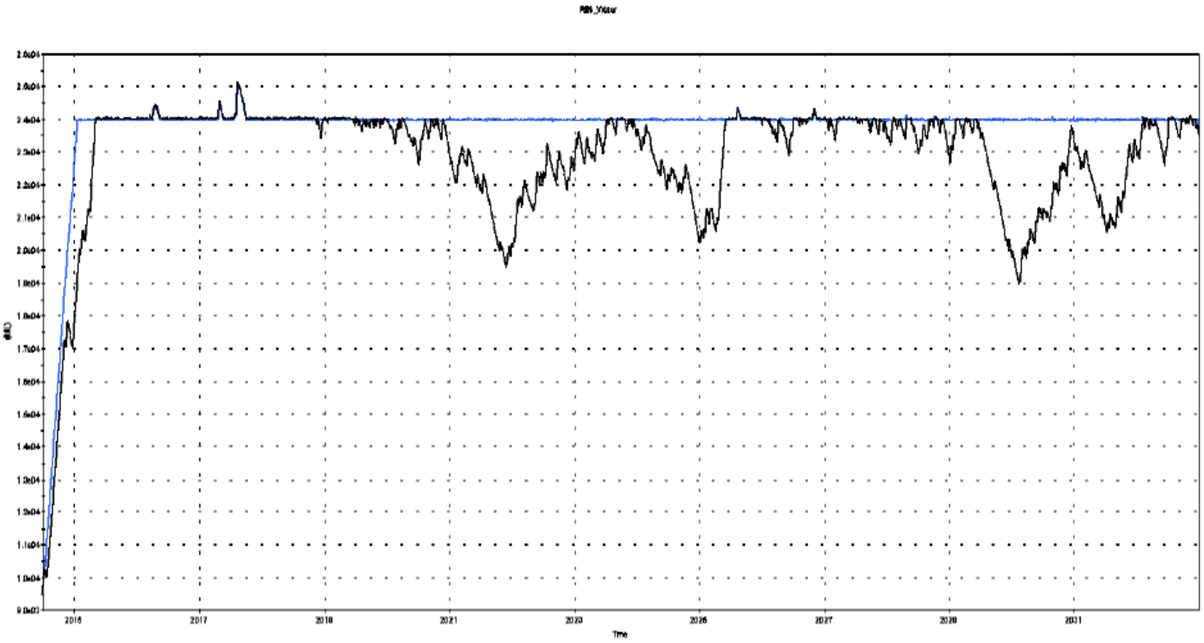


Figure 32 - Predicted Volume (ML) at #272 (Thompsons Creek Reservoir)
Blue is WS1 and Black is Null.

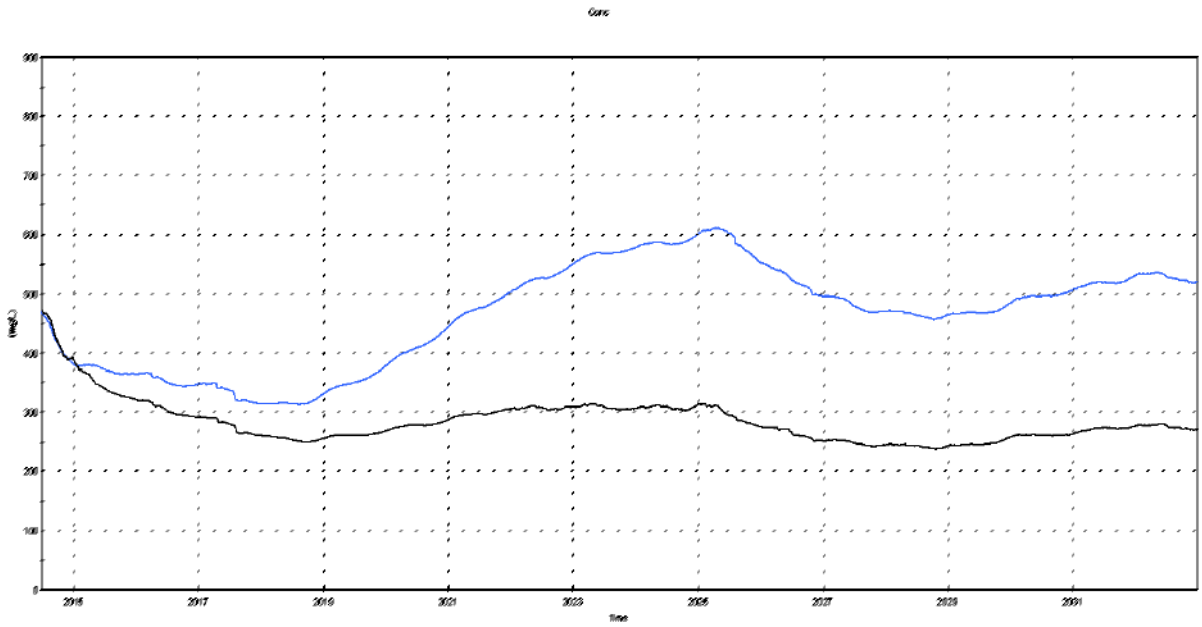


**Figure 33 - Predicted Salinity (mg/L) at #272 (Thompsons Creek Reservoir) Blue is WS1 and Black is Null. It is noted that predicted salinity in WS1 is identical at this location to WS2a and WS2b.**

**Table 17 - Predicted Daily Salinity Statistics (mg/L) at #272 (Thompsons Creek Reservoir).**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 110 | 237 | 314 | 314 | 314 |
| 5% | 110 | 243 | 318 | 318 | 318 |
| 10% | 110 | 245 | 343 | 343 | 343 |
| 20% | 110 | 254 | 365 | 365 | 365 |
| 50% | 274 | 276 | 477 | 477 | 477 |
| 80% | 423 | 307 | 536 | 536 | 536 |
| 90% | 491 | 313 | 575 | 575 | 575 |
| 95% | 561 | 344 | 588 | 588 | 588 |
| Maximum | 914 | 471 | 613 | 613 | 613 |

The predicted salinity in Thompsons Creek Reservoir (#272) is higher due to the proposed water management strategy but is only marginally higher than the modelled calibration values.

Similar to the predicted impact in Lake Lyell, there is a minor positive difference to predicted storage volume (ML) in Thompsons Creek Reservoir due to the proposal.

Water quality modelling encompassed sub-catchments contributing to Lake Burragorang (#280, Warragamba Dam).

The layout of the model below Lake Lyell is presented below. It is noted that catchments of the Wollondilly River are also included in the model. Further detail is presented in the **Appendix 2**.

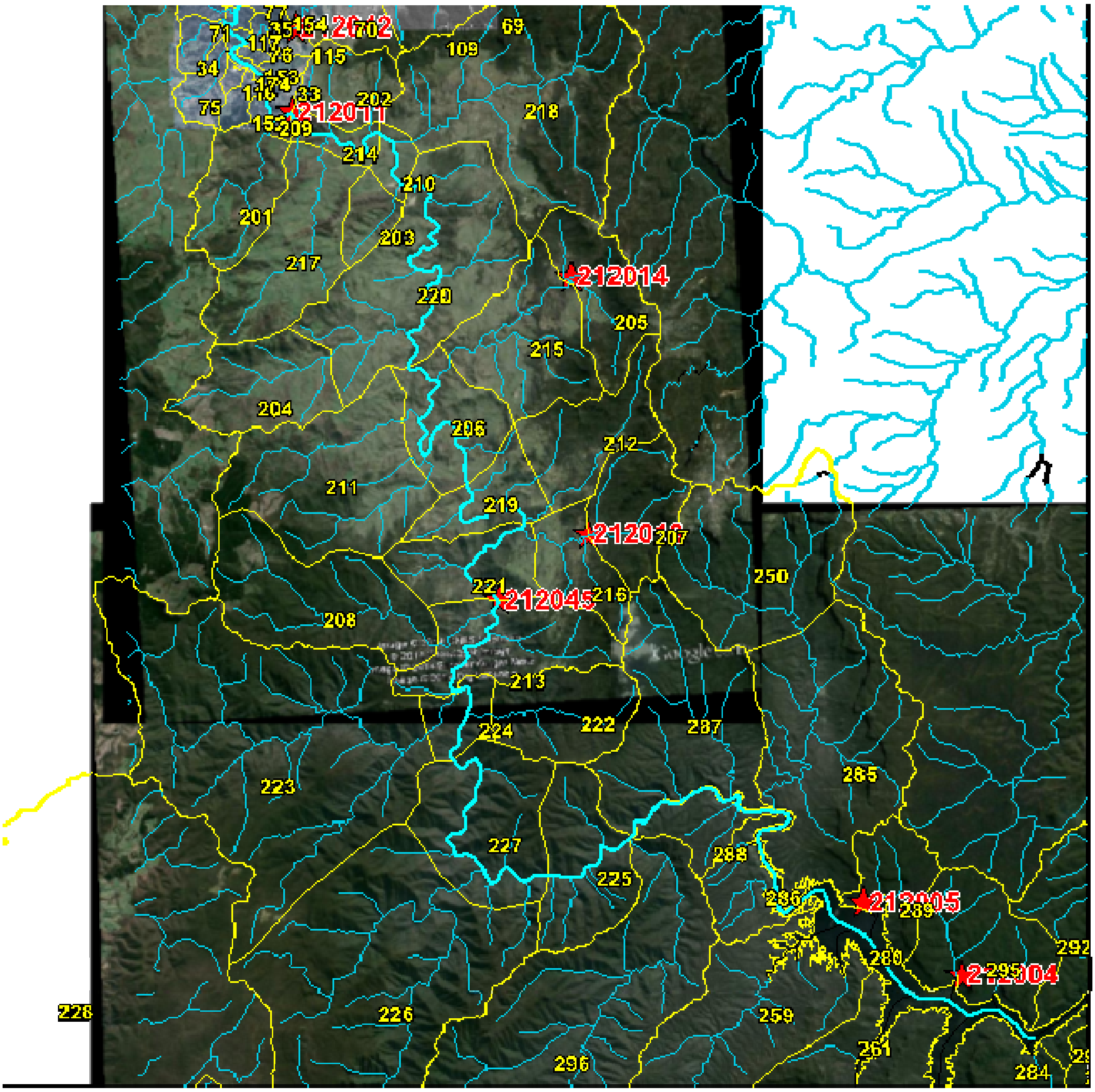


**Figure 34 - Layout of the Water Quality model between Lake Lyell and Lake Burragorang**

Historical volume (ML) (**Figure 35**) and salinity (mg/L) (Figure 36) of Lake Burragorang is presented below.

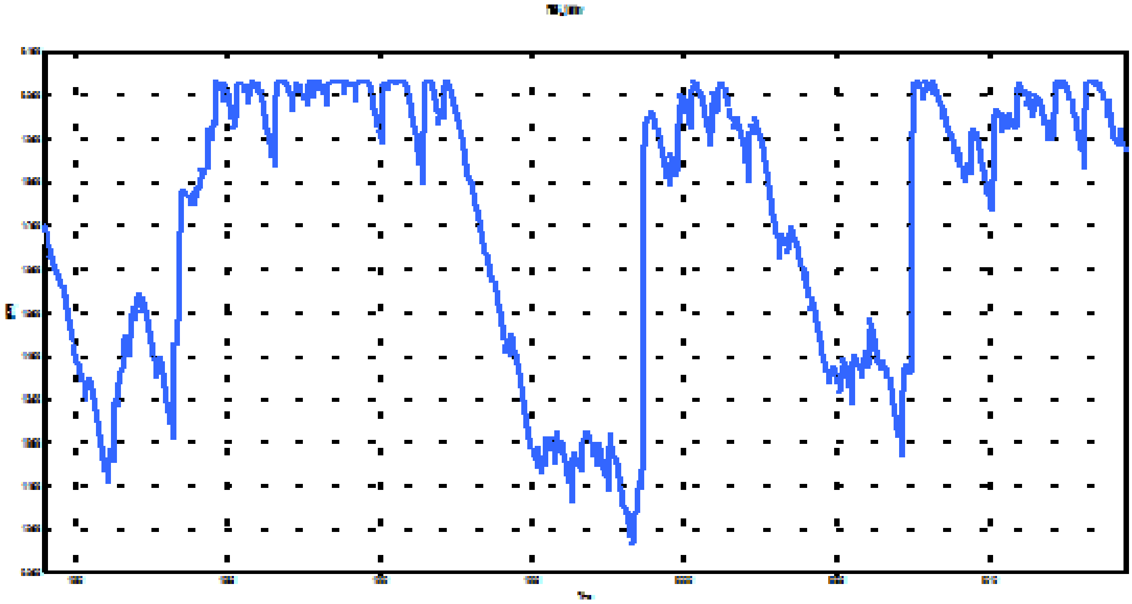


Figure 35 - Modelled Historical Volume (ML) at #280 (Lake Burragorang)

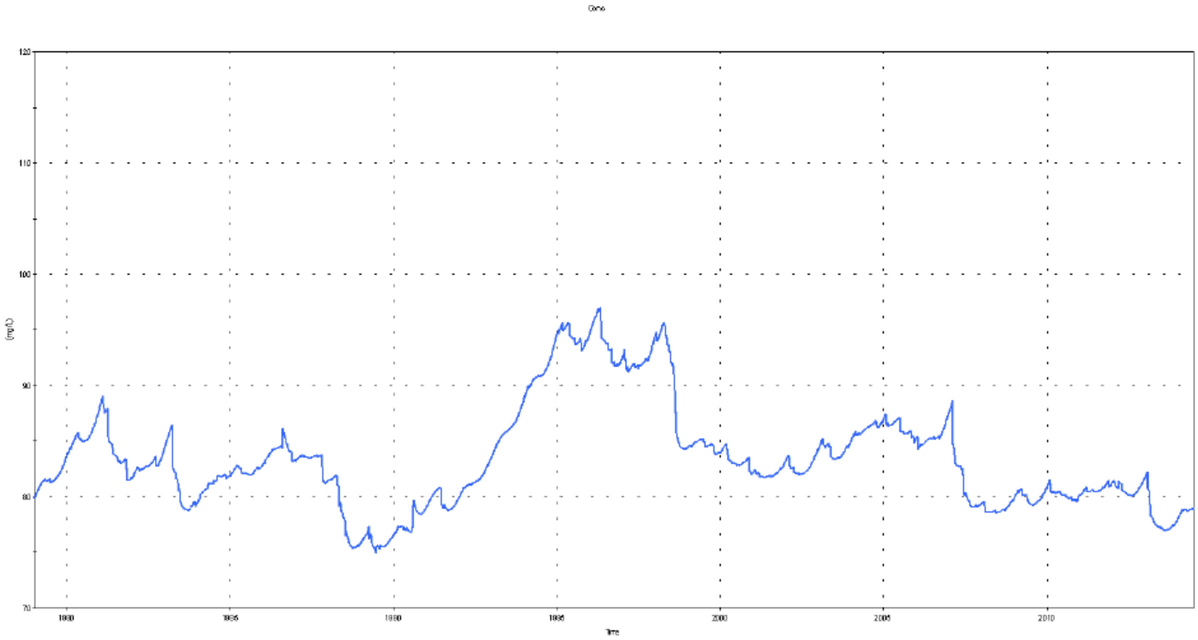


Figure 36 - Modelled Historical Salinity (mg/L) at #280 (Lake Burragorang).

The predicted volume (ML) **(Figure 37)** and salinity (mg/L) (**Figure 38**) in Lake Burragorang incorporating the proposed water management strategy at Angus Place and Springvale is presented below. The associated predicted daily salinity statistics is presented in **Table 18**.

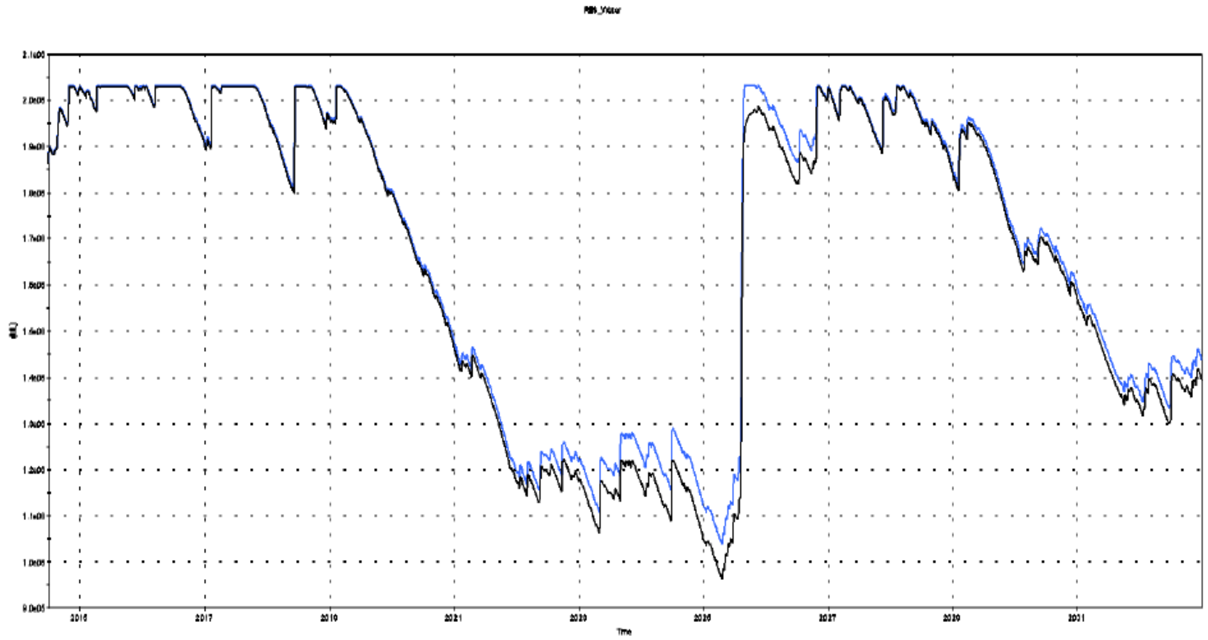


**Figure 37 - Predicted Volume (ML) at #280 (Lake Burragorang)**
**Blue is WS1 and Black is Null. It is noted that predicted volume in WS1 is identical at this location to WS2a and WS2b.**

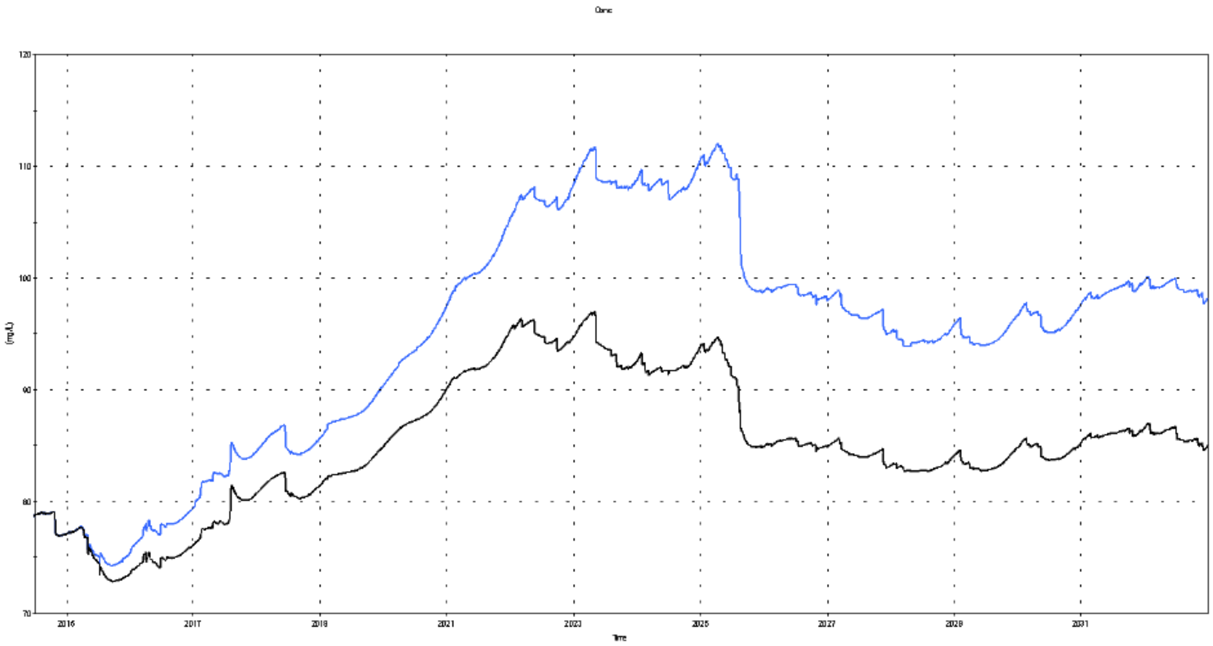


**Figure 38 - Predicted Salinity (mg/L) at #280 (Lake Burragorang)**
**Blue is WS1 and Black is Null. It is noted that predicted volume in WS1 is identical at this location to WS2a and WS2b.**

**Table 18 - Predicted Daily Salinity Statistics (mg/L) at #280 (Lake Burragorang).**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 75 | 73 | 74 | 74 | 74 |
| 5% | 77 | 75 | 77 | 77 | 77 |
| 10% | 79 | 77 | 78 | 78 | 78 |
| 20% | 80 | 81 | 85 | 85 | 85 |

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| 50% | 83 | 85 | 97 | 97 | 97 |
| 80% | 86 | 87 | 104 | 104 | 104 |
| 90% | 92 | 94 | 108 | 108 | 108 |
| 95% | 94 | 95 | 109 | 109 | 109 |
| Maximum | 97 | 97 | 112 | 112 | 112 |

**Table 19** and **Table 20** summarise the water flow and the water quality at the sites assessed.

**Table 19 - Summary of Predicted Daily Flows (ML/d) in the Coxs River catchment**

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

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

**Table 20 - Summary of Predicted Daily Salinity (mg/L) in the Coxs River catchment.**

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

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

From the above, the proposed discharge by the Angus Place and Springvale MEPs to the Coxs River lead to a marginal increase in salinity in Lake Burragorang compared to the null case. In the null case, median salinity is 85 mg/L and is 97 mg/L under WS1, WS2a and WS2b scenarios. There is a small positive impact to volume in Lake Burragorang due to the projects.

SCA has adopted a risk assessment based approach to water quality management (SCA, 2012). As part of that management framework, SCA have developed a Pollution Source Assessment Tool. The outcomes of that work identified the five most significant pollution sources in the catchment which, in general, relate to faecal contamination and/or nutrients (phosphorous and nitrogen). They include the following:

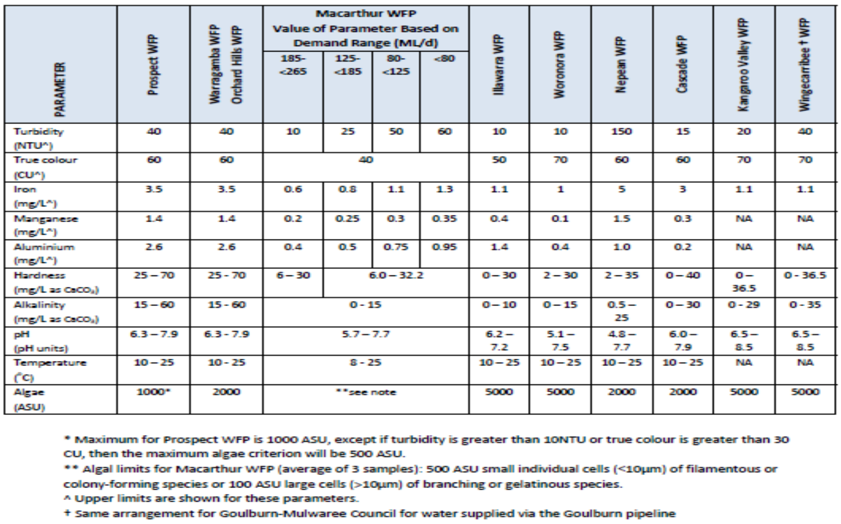
- grazing
- intensive animal production
- on-site wastewater management systems
- sewage collection systems
- urban stormwater.

As outlined in SCA's Annual Water Quality Monitoring Report 2012-2013 (SCA, 2013), water quality management is focussed on:

- Australian Drinking Water Guidelines (health-related)
- Raw Water Supply Agreements (in this case Prospect Water Filtration Plant).

The relevant target water quality parameters are reproduced below from SCA (2013).

**Table 21 - SCA Target Raw Water Supply Agreement water quality characteristics for Lake Burragorang**



| PARAMETER | Prospect WFP | Warragamba WFP Orchard Hills WFP | Macarthur WFP Value of Parameter Based on Demand Range (ML/d) | | | | Illawarra WFP | Woronora WFP | Nepean WFP | Cascade WFP | Kangaroo Valley WFP | Wingecarribee † WFP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 185-<265 | 125-<185 | 80-<125 | <80 | | | | | | |
| Turbidity (NTU^) | 40 | 40 | 10 | 25 | 50 | 60 | 10 | 10 | 150 | 15 | 20 | 40 |
| True colour (CU^) | 60 | 60 | 40 | | | | 50 | 70 | 60 | 60 | 70 | 70 |
| Iron (mg/L^) | 3.5 | 3.5 | 0.6 | 0.8 | 1.1 | 1.3 | 1.1 | 1 | 5 | 3 | 1.1 | 1.1 |
| Manganese (mg/L^) | 1.4 | 1.4 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 | 0.1 | 1.5 | 0.3 | NA | NA |
| Aluminium (mg/L^) | 2.6 | 2.6 | 0.4 | 0.5 | 0.75 | 0.95 | 1.4 | 0.4 | 1.0 | 0.2 | NA | NA |
| Hardness (mg/L as $CaCO_3$) | 25 – 70 | 25 - 70 | 6 – 30 | 6.0 – 32.2 | | | 0 – 30 | 2 – 30 | 2 – 35 | 0 – 40 | 0 – 36.5 | 0 - 36.5 |
| Alkalinity (mg/L as $CaCO_3$) | 15 – 60 | 15 - 60 | 0 - 15 | | | | 0 – 10 | 0 – 15 | 0.5 – 25 | 0 – 30 | 0 - 29 | 0 - 35 |
| pH (pH units) | 6.3 – 7.9 | 6.3 - 7.9 | 5.7 – 7.7 | | | | 6.2 – 7.2 | 5.1 – 7.5 | 4.8 – 7.7 | 6.0 – 7.9 | 6.5 – 8.5 | 6.5 – 8.5 |
| Temperature (°C) | 10 – 25 | 10 - 25 | 8 - 25 | | | | 10 – 25 | 10 – 25 | 10 – 25 | 10 – 25 | NA | NA |
| Algae (ASU) | 1000* | 2000 | **see note | | | | 5000 | 5000 | 2000 | 2000 | 5000 | 5000 |

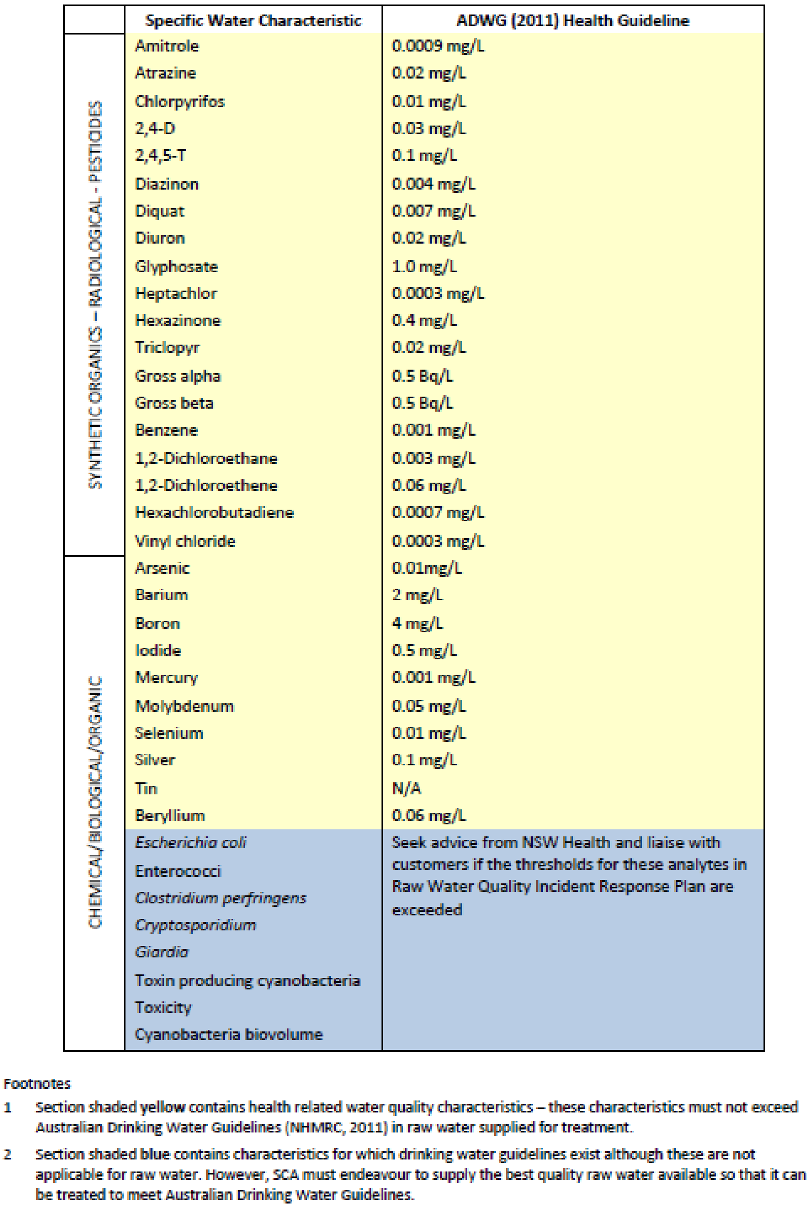
* Maximum for Prospect WFP is 1000 ASU, except if turbidity is greater than 10NTU or true colour is greater than 30 CU, then the maximum algae criterion will be 500 ASU.

** Algal limits for Macarthur WFP (average of 3 samples): 500 ASU small individual cells (<10µm) of filamentous or colony-forming species or 100 ASU large cells (>10µm) of branching or gelatinous species.

^ Upper limits are shown for these parameters.

† Same arrangement for Goulburn-Mulwaree Council for water supplied via the Goulburn pipeline

## Table 22 - SCA Target Health-related water quality characteristics for Lake Burragorang



| | Specific Water Characteristic | ADWG (2011) Health Guideline |
|---|---|---|
| SYNTHETIC ORGANICS – RADIOLOGICAL - PESTICIDES | Amitrole | 0.0009 mg/L |
| | Atrazine | 0.02 mg/L |
| | Chlorpyrifos | 0.01 mg/L |
| | 2,4-D | 0.03 mg/L |
| | 2,4,5-T | 0.1 mg/L |
| | Diazinon | 0.004 mg/L |
| | Diquat | 0.007 mg/L |
| | Diuron | 0.02 mg/L |
| | Glyphosate | 1.0 mg/L |
| | Heptachlor | 0.0003 mg/L |
| | Hexazinone | 0.4 mg/L |
| | Triclopyr | 0.02 mg/L |
| | Gross alpha | 0.5 Bq/L |
| | Gross beta | 0.5 Bq/L |
| | Benzene | 0.001 mg/L |
| | 1,2-Dichloroethane | 0.003 mg/L |
| | 1,2-Dichloroethene | 0.06 mg/L |
| | Hexachlorobutadiene | 0.0007 mg/L |
| | Vinyl chloride | 0.0003 mg/L |
| CHEMICAL/BIOLOGICAL/ORGANIC | Arsenic | 0.01mg/L |
| | Barium | 2 mg/L |
| | Boron | 4 mg/L |
| | Iodide | 0.5 mg/L |
| | Mercury | 0.001 mg/L |
| | Molybdenum | 0.05 mg/L |
| | Selenium | 0.01 mg/L |
| | Silver | 0.1 mg/L |
| | Tin | N/A |
| | Beryllium | 0.06 mg/L |
| | *Escherichia coli* | Seek advice from NSW Health and liaise with customers if the thresholds for these analytes in Raw Water Quality Incident Response Plan are exceeded |
| | Enterococci | |
| | *Clostridium perfringens* | |
| | *Cryptosporidium* | |
| | *Giardia* | |
| | Toxin producing cyanobacteria | |
| | Toxicity | |
| | Cyanobacteria biovolume | |

Footnotes

1 Section shaded yellow contains health related water quality characteristics – these characteristics must not exceed Australian Drinking Water Guidelines (NHMRC, 2011) in raw water supplied for treatment.

2 Section shaded blue contains characteristics for which drinking water guidelines exist although these are not applicable for raw water. However, SCA must endeavour to supply the best quality raw water available so that it can be treated to meet Australian Drinking Water Guidelines.

From the above, there is no target for salinity since ADWG do not have a health-based water quality criterion. There is also no target for salinity for the Prospect Water Filtration Plant with respect to Raw Water Supply Agreement. As identified in the SSTV Assessment (**Appendix 3**), other water quality characteristics meet the ADWG and the Raw Water Supply Agreement specifications.

The predicted minor increase in salinity from 85 mg/L to 97 mg/L in Lake Burragorang due to the Angus Place and Springvale MEPs is therefore considered to have a neutral effect with respect to the Neutral or Beneficial Effect test criteria.

**Discrepancies identified in what the Project estimates will be the mine water discharge volumes from both Angus Place and Springvale combined for each year. The total volume of predicted mine water each year to be discharged to LDPs and the SDWTS from both mines should be the same. (EPA)**

The predicted mine inflows from Angus Place Colliery and Springvale Mine during the MEPs are not expected to be the same. The mine inflows for each project has been predicted using a numerical groundwater model developed by CSIRO; the numerical computer code selected for the assessment of mining related impacts on groundwater and associated environmental values was COSFLOW. As noted in Section 6 of the Groundwater Impact Assessment (Appendix E) for each project the overall objective of the model was to assess the potential impacts of the MEPs, specifically with regard to:

- Predicted mine inflow (and dewatering) rates
- Regional changes in groundwater levels during mining and after mine closure
- Changes in baseflow contributions to surface watercourses and shrub swamps
- Potential impacts to any existing groundwater users and groundwater dependent ecosystems.

The model has been constructed to a level consistent within the groundwater modelling guidelines and has been peer reviewed by Dr Noel Merrick (Heritage Computing Pty Ltd) in accordance with the NSW Aquifer Interference Policy requirements.

The predicted mine inflows for Angus Place Angus Place Colliery and Springvale Mine for the years 2013 - 2032, and the combined mine inflows both mines are shown in Figure 10.11 of each EIS and Figure 16 in the Angus Place and Figure 18 in the Springvale Surface Water Impact Assessment reports (Appendix F). The predicted mine inflows for each mine were used in the respective site water balance, and for the determination of volumes of water to be discharged to the licensed discharge points at Angus Place Colliery (LDP001 and LDP002 (EPL 467)) and Springvale Mine (LDP001 and LDP009 (EPL3067)). Table 5.2 from the Surface Water Impacts Assessment reports (Appendix F) for each project provides mine inflow data for discharge at LDPs and transfer to the SDWTS. These tables have been updated to include the total mine water discharges from each mine to Coxs River and provided in **Appendix 12** of the RTS. The tables in **Appendix 12** have also been updated to include mine inflows for the scenario where the SDWTS is not available to Angus Place Colliery and both Angus Place Colliery and Springvale Mine discharge separately to Coxs River.

As noted above the mine inflows from Angus Place Colliery and Springvale Mine are not expected to be the same. As presented in the Angus Place Groundwater Impact Assessment (Appendix E)), regional groundwater flow direction is to the northeast toward the Wolgan Valley. As such, the Angus Place proposed longwall area is hydrogeologically down-gradient to Springvale Mine and hence inflows from Angus Place Colliery are higher than Springvale Mine.

**OEH is aware that electricity generation from Wallerawang Power Station has been suspended, a process that began in early 2014. The EIS has not been updated to reflect this change in circumstances. OEH assumes, therefore, that the proposal would result in a significant increase in waste water being discharged via the licenced discharge point into Coxs River, with none of the mine water being utilised for power production. OEH considers that the EIS and associated documents need to be revised to take into account the closure of Wallerawang Power Station. In particular, the expected discharges and associated impacts on the Coxs River need to be re-assessed. (OEH)**

A regional water quality impact assessment has been undertaken to assess the impact of direct discharge at Angus Place LDP001 and Springvale LDP009. The full assessment is attached as **Appendix 2**.

### 3.1.26 Water Quality

**Salinity predictions have been undertaken for the location below the confluence with the Coxs River, not where discharge occurs in Kangaroo Creek. No predictions are made on what would be an expected increase in salinity compared to the current conditions at the discharge point LDP001. The SCA notes that there is currently a Pollution Reduction Program (PRP) on EPL467 with respect to discharge at LDP001 which requires a reduction in salinity levels from 1,100 to 350 µS/cm. (SCA)**

The Regional Water Quality Impact Assessment (**Appendix 2**) presents the predicted impact to Kangaroo Creek immediately downstream from the point of discharge Angus Place LDP001.

Springvale Coal has undertaken SSTV assessment for Springvale Mine's LDP009. Results of the SSTV analysis indicate that current water quality at LDP009 exceeds the data for electrical conductivity, aluminium, zinc and copper concentrations meets ANZECC 95% protection of aquatic ecosystems except for copper and zinc concentrations but fall below the adopted trigger value (**Appendix 3**).

**Salinity predictions have not been undertaken for scenario (1) no upgrade of SDWTS and (2) no SDWTS availability and all mine discharges (28.6ML/day) being discharged to the Kangaroo Creek and Coxs River. (SCA)**

The Regional Water Quality Impact Assessment presents this scenario (refer **Appendix 2**).

**Salinity predictions have not been undertaken when excess inflows, more than the Wallerawang power station demand of 30 ML/d, is proposed to be discharged at LDP009, at a point immediately upstream of Lake Wallace. (SCA)**

The Regional Water Quality Impact Assessment has assessed the potential impact under this scenario (refer **Appendix 2**).

**There is no assessment on whether elevated salt levels are likely in the Coxs River where it enters Lake Burragorang. (SCA)**

The Regional Water Quality Impact Assessment presents the predicted increase in salinity in Lake Burragorang. Modelling indicates an increase in median salinity from 85 mg/L to 97 mg/L under the proposed water management strategy. Further details are presented in the Regional Water Quality Impact Assessment (refer **Appendix 2**).

**The model predictions for the average Coxs River salinity should include an envelope around the average showing 10th and 90th percentiles. (SCA)**

The Regional Water Quality Impact Assessment includes a low rainfall climate (10th percentile 19 year rainfall total) and a high rainfall climate (90th percentile rainfall total). These results are presented in the water quality impact assessment as uncertainty analysis.

**The EIS states that based on data available, the estimated error in predictions is approximately ±30%. It is not clear if the upper limits would still fall within an acceptable level of impact. (SCA)**

The 30% error margin was suggested in the GHD's Water and Salt Balance Assessment (provided as Appendix F of the EIS) due to the modelled components assumed to rely on "less reliable data". The regional water quality impact assessment (refer **Appendix 2**) has reduced this level of uncertainty via calibration to observed flow and salinity in the Coxs River. The assumed salinity of mine water make at 1,200 µS/cm (804 mg/L) is at the upper end of the range of historical observation. As indicated in the preceding response uncertainty analyses have been undertaken with respect to high rainfall and low rainfall conditions.

**The SCA is concerned about the proposal to transfer mine water to the local power stations (Mt Piper and Wallerawang) which the SCA understands will have limited and reduced availability due to the recent decision to place the Wallerawang power station in care and maintenance. As a consequence, there may be additional discharges of mine water into receiving watercourses of approximately 30 ML/d from this project. These discharges would further impact the quality of receiving waters and the EIS has not addressed this issue. The SCA considers that the Proponent should• either consider an alternative opportunity for mine water reuse or treatment of mine water to a higher level before discharge. (SCA)**

Springvale Coal and Centennial Angus Place have undertaken additional regional water quality modelling to assess potential water quality impacts in light of the recent change in status of the Wallerawang Power Station and reduced water demand. This assessment is attached as **Appendix 2**.

A water management option study was prepared by Centennial Angus Place in response to a PRP condition added to EPL 467 on Angus Place LDP001. It did not identify an economically feasible alternative.

**The Angus Place EIS acknowledges that salinity in the Coxs River is currently in excess of ANZECC guidelines for the protection of aquatic ecosystems and that modelling indicates that salinity will increase due to the extension of Angus Place Colliery. However, the EIS maintains that aquatic and riparian ecosystems are adapted to this environment and predicated salinity is within the range experienced historically in the Coxs River catchment. These conclusions are not supported by the research work of Department of Environment, Climate Change and Water scientists in September to October 2009 that had found that salinity levels in the Coxs River had increased since the 1980's, and that the aquatic ecosystems were now dominated by pollution tolerant taxa, and that Kangaroo Creek downstream of the Angus Place discharge at LDP001 was found to have an impoverished diversity of macroinvertebrate fauna. (EPA)**

The Aquatic Ecology Assessment (Appendix G of the EIS) found that the aquatic habitat and quality of water in the upper Coxs River are both degraded but despite this aquatic biota was relatively diverse. It was found that the current discharge from LDP001 appeared to have some adverse effects on the condition of the aquatic habitats and quality of water at Kangaroo Creek downstream (Site KCdn) and Coxs River downstream of the confluence of Kangaroo Creek (Site CR2), however its effect on biological indicators is less clear with only SIGNAL2 and AUSRIVAS scores being poorer on average at Kangaroo Creek downstream of LDP001 than at Kangaroo Creek upstream of LDP001, and macrophytes being less diverse at CR2 than CR1.

The Aquatic Ecology assessment Section 7.2.1.3 states that:

"a review of the effects of salinity on aquatic biota in Australian freshwater systems indicates direct adverse biological effects are unlikely to occur unless EC levels exceed around 1000 mg/L (approximately 1,500 µS/cm) (Hart et al. 1991). This suggests that the aquatic biota in the river is unlikely to be impacted by the salinities resulting from the change in discharge."

It was assessed that the likely impact of the change in flows and quality of the water on the aquatic flora and fauna would be moderate in the immediate receiving waters of Kangaroo Creek and small to moderate in the Coxs River below the confluence.

Further to the water quality issues, it was found that increased flow due to the discharges may result in more stable aquatic habitats and conditions that are more conducive to the establishment and growth of aquatic macrophytes.

The 2010 State of the Catchment assessment for the Hawkesbury-Nepean Region returns a Very Good to Moderate score for macroinvertibrate condition in the Upper Coxs River.

No direct modelling of impacts on Kangaroo Creek were undertaken for the EIS, however, this is addressed in the Regional Water Quality Impact Assessment presented as **Appendix 2**.

**Salinity predictions have been undertaken upstream of Lake Wallace, not where discharge occurs in Swayers Swamp Creek (LDP009). No predictions are made on what would be an expected increase in salinity compared to the current conditions at the discharge point LDP009 and impacts on water quality in Coxs River downstream of Lake Wallace. The model predictions for average Coxs River salinity should include an envelope around the average showing 1Oth and 90th percentiles. (SCA)**

The regional water quality impact assessment presents the predicted impact to Kangaroo Creek immediately downstream from the point of discharge Angus Place LDP001.

Springvale Coal has undertaken SSTV assessment for Springvale Mine's LDP009. Results of the SSTV analysis indicate that current water quality at LDP009 exceeds the data for electrical conductivity, aluminium, zinc and copper concentrations meets ANZECC 95% protection of aquatic ecosystems except for copper and zinc concentrations but fall below the adopted trigger value (**Appendix 3**).

**The EISs also do not adequately consider the environmental health effects of discharging 30ML/day (rising to 50ML/day if both mine projects are approved) of poorly treated mine water into the Coxs River catchment. (EPA)**

Additional water balance modelling has been undertaken to assess the potential impacts of the discharge of 30 to 50 ML/day to the Coxs River Catchment. This regional water quality impacts assessment is attached as **Appendix 2** to this RTS.

Following public exhibition of the EIS, a review of the EPA Direct Toxicity Assessment on Springvale's LDP009 discharge was undertaken by GHD (**Appendix 9** to this RTS). Following the review, an additional Direct Toxicity Assessment, provided as **Appendix 10** to this RTS, was carried out on discharge water from LDP001 at Angus Place and LDP009 at Springvale. The methodology for the Direct Toxicity Assessment was approved by the EPA in August 2014. The results of the Direct Toxicity Assessment show that there is no toxicity associated with the Discharge water from LDP001. Although toxicity has been observed at LDP009, it has been demonstrated that neither the EC or bicarbonate concentrations have any effect on the toxicity of the water. Lowering the EC may have a detrimental effect on the system as shown by the high toxicity at sites upstream of LDP001. The chemistry of water quality discharged through LDP009 does not point to any source in particular that is leading to the toxicity being observed. As such, Centennial proposes to undertake further investigations into the toxicity of LDP009 water discharge to identify the cause of the toxicity. Without knowing what is causing the toxicity, the application of a treatment system is premature as you won't know what you are treating for. As such, no additional treatment of mine water is considered necessary at this stage.

**The surface water impact assessment provides a very poor characterisation of the effluent discharged through Springvale's Licenced Discharge Point 9 (LDP009). There is no time series for water quality or flow for LDP009 discharges provided in the EIS for Springvale. Of note, though based on the limited data that is available, is that LDP009 already exceeds ANZECC (2000) default water quality criteria for Conductivity and Aluminium (for protection of 95% of species). (EPA)**

Updated water quality data is presented in the Site Specific Trigger Value assessment, provided as **Appendix 3** to this RTS, which provides water quality data for LDP009 since August 2012 and telemetered flow data since December 2013.

The noted exceedance of ANZECC for Conductivity and Aluminium (for protection of 95% of species) occurs at the discharge at LDP009, which is regulated for specific pollutants under the Environmental Protection Licence.

The ANZECC and ARMCANZ (2000) guidelines, section 2.2.1.9, state that:

"the Guidelines have not been designed to deal with mixing zones, explicitly defined areas around an effluent discharge where the water quality may still be below that required to protect the designated environmental values."

The assessment of water quality with respect to trigger values has been undertaken and is presented in the attached **Appendix 3**. Direct toxicity assessments have been undertaken to validate the assertion that riparian ecosystems are in an adapted state and therefore the proposed water management strategy does not lead to significant change to these ecosystems.

There are several Water Quality Objectives that are relevant to the Coxs River catchment. These include:

- Aquatic Ecosystems
- Visual Amenity
- Drinking Water – Groundwater

- Industrial Water Supplies.

**Based on the data presented and EPA/OEH data on previous LOP discharges, the poorly treated mine water is also potentially toxic to aquatic biota. Toxicity assessments have not been done for the Springvale and Angus Place expansion EISs. On 8 May 2014, the EPA/ Office of Environment and Heritage (OEH) collected water samples from the LDP009 discharge and the preliminary toxicity screening results indicate toxicity to at least one species (cladoceran). Earlier toxicity testing by Delta Electricity also raised concerns about the toxicity of the Springvale mine water and the EPA will be following up these matters with Centennial to assess the likely causes and measures to reduce any toxicity. (EPA)**

Site Specific Trigger Values (SSTVs) have been established for LDP009 and detailed in the SSTV Assessment provided as **Appendix 3** to this RTS.

The only analytes noted to consistently exceed ANZECC guidelines (where median values exceed the guideline value for protection of 95% of species for slightly to moderately disturbed ecosystems) at Angus Place Colliery LDP001 and Springvale Mine LDP009 are electrical conductivity, aluminium (LDP009 only), copper (LDP009 only) and zinc. However, for each of these analytes the receiving environment is already at an equivalent or greater concentration, with median values at discharge being less than the upstream 80th percentile (refer SSTV reports, **Appendix 3**). The comparison with ANZECC guideline values therefore, is not valid.

For electrical conductivity, a review of the effects of salinity on aquatic biota in Australian freshwater systems indicates direct adverse biological effects are unlikely to occur unless EC levels exceed around 1,000 mg/L (approximately 1,500 µS/cm) (Hart et al. 1991). At median levels of 1,050 µS/cm and 1,060 µS/cm respectively, discharges from LDP001 and LDP009 are substantially below this level.

Following public exhibition of the EIS, a review of the EPA Direct Toxicity Assessment on Springvale's LDP009 discharge was undertaken by GHD (**Appendix 9** to this RTS). Following the review, an additional Direct Toxicity Assessment, provided as **Appendix 10** to this RTS, was carried out on discharge water from LDP001 at Angus Place and LDP009 at Springvale. The methodology for the Direct Toxicity Assessment was approved by the EPA in August 2014. The results of the Direct Toxicity Assessment show that there is no toxicity associated with the Discharge water from LDP001. Although toxicity has been observed at LDP009, it has been demonstrated that neither the EC or bicarbonate concentrations have any effect on the toxicity of the water. Lowering the EC may have a detrimental effect on the system as shown by the high toxicity at sites upstream of LDP001. The chemistry of water quality discharged through LDP009 does not point to any source in particular that is leading to the toxicity being observed. As such, Centennial proposes to undertake further investigations into the toxicity of LDP009 water discharge to identify the cause of the toxicity. Without knowing what is causing the toxicity, the application of a treatment system is premature as you won't know what you are treating for. As such, no additional treatment of mine water is considered necessary at this stage.

**There is also a major issue with contaminant load because all the mine water flows to the Coxs River and then into Lake Wallace and Lake Lyell. Some of this water also ultimately flows to Warragamba Dam. The potential salt load alone (7,500 to 13,000 tonnes per annum) is extremely large for a freshwater system. The EIS has not appropriately considered the potential impacts of the very large contaminant loads proposed to be discharged to the receiving environment. (EPA)**

The regional water quality impact assessment provided as **Appendix 2** to this RTS presents the predicted increase in salt in Lake Burragorang due to the Angus Place and Springvale MEPs. Modelling indicates that median salinity will increase from 85 mg/L to 97 mg/L under the proposed water management strategy. As presented in the SSTV Assessment (**Appendix 3**), other water quality criteria of mine water discharge meet Australian Drinking Water Guideline values as well as Sydney Water specifications for the Prospect Water Filtration Plant.

Following public exhibition of the EIS, a review of the EPA Direct Toxicity Assessment on Springvale's LDP009 discharge was undertaken by GHD (**Appendix 9** to this RTS). Following the review, an additional Direct Toxicity Assessment, provided as **Appendix 10** to this RTS, was carried out on discharge water from LDP001 at Angus Place and LDP009 at Springvale. The methodology for the Direct Toxicity Assessment was approved by the EPA in August 2014. The results of the Direct Toxicity Assessment show that there is no toxicity associated with the Discharge water from LDP001. Although toxicity has been observed at LDP009, it has been demonstrated that neither the EC or bicarbonate concentrations have any effect on the toxicity of the water. Lowering the EC may have a detrimental effect on the system as shown by the high toxicity at sites upstream of LDP001. The chemistry of water quality discharged through LDP009 does not point to any source in particular that is leading to the toxicity being observed. As such, Centennial proposes to undertake further investigations into the toxicity of LDP009 water discharge to identify the cause of the toxicity. Without knowing what is causing the toxicity, the application of a treatment system is premature as you won't know what you are treating for. As such, no additional treatment of mine water is considered necessary at this stage.

**It is important however that the current water quality conditions will be maintained and it is recommended that this commitment is reflected in the conditions of approval. (OAS&FS)**

The regional water quality impact assessment provided as **Appendix 2** to this RTS presents the predicted increase in salt in Lake Burragorang due to the Angus Place and Springvale MEPs. Modelling indicates that median salinity will increase from 85 mg/L to 97 mg/L under the proposed water management strategy. SCA's water quality monitoring framework does not include salinity. As presented in the SSTV Assessment (**Appendix 3**), other water quality criteria of mine water discharge meet Australian Drinking Water Guideline values as well as Sydney Water specifications for the Prospect Water Filtration Plant.

**Water quality impact estimations for the Coxs River need to consider increased discharge volumes to Coxs River resulting from reduced demand from the Wallerawang Power Station. The assessment of mine water discharges needs to consider the resulting cumulative concentrations of a range of contaminants, in addition to salt, within Coxs River. (DotE)**

A detailed response has been provided in Section 2.1 of **Appendix 16**.

**Are the cumulative water quality impacts of discharges to the Coxs River accurately and reasonably described? (DotE)**

**The cumulative water quality impacts of Angus Place and Springvale mine water discharges to the Coxs River, an important contributing source to Sydney's drinking water supply, were not**

**modelled for all relevant contaminants, did not consider all likely discharge conditions, and are therefore not accurately and reasonably described. (DotE)**

**Salinity was the only water quality variable modelled for cumulative impacts. The cumulative impact of other contaminants was not provided, even though the EIS states (Appendix C within Appendix F) that levels of copper, zinc, nitrogen and phosphorus have been elevated above ANZECC 95th percentile protection level for slightly to moderately disturbed ecosystems. The contributing water quality impacts to Coxs River from other mines in the area are not quantified. (DotE)**

**Water quality impact estimations for the Coxs River for both Angus Place and Springvale were conducted for scenarios that included the transfer of large volumes of water through the Springvale Delta Water Transfer Scheme (SDWTS) to the Wallerawang Power Station. This may no longer be a viable option because the Wallerawang Power Station has been placed into care and maintenance. Increased discharge volumes resulting from reduced demand from the Wallerawang Power Station would affect the outcome of the cumulative water quality impact assessment and should be considered as a potential discharge scenario. (DotE)**

A detailed response has been provided in Section 2.2 of **Appendix 16**.

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

**The proponent's estimation of downstream impacts was limited to site water balance and cumulative salt mass balance modelling that did not model impacts beyond the upper Coxs River catchment (i.e. not downstream of Lake Lyell). In addition, the existing condition of the Coxs River was not adequately described and the downstream impact modelling that was undertaken included transfer of large volumes of water through the SDWTS to the Wallerawang Power Station, which may no longer be a viable option. (DotE)**

A detailed response has been provided in Section 2.2 of **Appendix 16**.

**What are the predicted changes to water quality water quantity in the Coxs River at Kelpie Point and what are the consequences for stored water within Warragamba Dam? (DotE)**

**Water quantity and quality changes in the Coxs River at Kelpie Point cannot be reliably estimated based on the information presented in the EIS documentation, as detailed in the response to Question 7. For similar reasons, the consequences for stored waters in Warragamba Dam also cannot be reliably estimated from information in the EIS. (DotE)**

A detailed response has been provided in Section 2.2 of **Appendix 16**.

**Protection of the long-term ecosystem health of Coxs River should include consideration of the ANZECC and ARMCANZ (2000) Guidelines, through an agreed set of approval trigger discharge values and management protocols. Where salinity or other contaminants of concern are likely to exceed trigger values, management and treatment options may include, but are not limited to, reverse osmosis and ion exchange technologies. (DotE)**

A detailed response has been provided in Section 2.2 of **Appendix 16**.

## 3.2 Response to Special Interest Group Submissions

### 3.2.1 Biodiversity Offset Strategy

**The Director General's requirements for the offset strategy require Centennial Coal to develop 'An offset strategy, which is clearly quantified, to ensure that the development maintains or improves the terrestrial and aquatic biodiversity values of the region in the medium to long term'. Centennial Coal and RPS have taken a miserly interpretation of this direction. (LEG and Colong Foundation)**

Noted.

**Only Matters of National Environmental Significance and Endangered Ecological Communities are considered in relation to indirect impacts. For example, the offset analysis has not been applied to the 200 hectares of the Birds Rock Flora Reserve that will be damaged by the proposed mining. (LEG and Colong Foundation)**

The Flora and Fauna Impact Assessment for the Angus Place MEP includes consideration of the biodiversity values of the Birds Rock Flora Reserve and the potential impacts of the Project to the Reserve.

**Centennial claim that 'the residual impacts following avoidance and mitigation are not significant, as such direct offsets are not required'. Centennial, having found themselves not responsible for impacts, magnanimously offers an offset 'provision of land to compensate potential impacts' to these nationally endangered swamps. (LEG and Colong Foundation)**

Noted.

**Centennial Coal proposes to protect for the conservation by setting aside 342.2 hectares of former farmland in the Capertee Valley it claims may have 160 fauna species and various endangered communities. None of the proposed offset compensate 'like-for- like' the loss of nationally endangered swamps or the impacted Tablelands Snow gum - Black Sallee, - Candlebark and Ribbon Gum Grassy Woodland on or below Newnes Plateau. (LEG and Colong Foundation)**

The EPBC Environmental Offsets Policy requires offsets to be considered where there is a residual impact following measures to avoid and mitigate. Particular consideration, in the context of the residual impacts, should be given to the attributes being impacted, how important that attribute is to the ecology of the MNES and how much the attribute is being impacted (that is, the scale of the impact). The offset package should consider the improvements that the offset will deliver for the attribute being impacted and the level of averted loss resulting from the proposed offset with a view to achieving a minimum conservation gain.

The Flora and Fauna Impact Assessments for the Springvale MEP and the Angus Place MEP conclude that there will be no significant impact to MNES, including the THPSS. Chapter 2 of the EIS for each project provides details on the investigation efforts undertaken to establish the mechanisms that could lead to a mining related impact to THPSS and associated fauna species. These investigations have concluded that there are a number of causal factors that, in combination, would result in impacts occurring. Where any one of these causal factors can be avoided, the causal linkage to impact will not be realised. These causal factors and the management controls implemented by Springvale Coal are detailed in in Table 2.6 of the EIS.

Whilst the combination of these assessments have concluded that there will be no significant impact to MNES, and therefore no requirement for a direct offset, Centennial has committed to improving the quality of THPSS within its Project Application Area for each Project through its Revised Regional Biodiversity Strategy. The Regional Biodiversity Strategy a management strategy (detailed below) for the management of indirect and residual impacts to THPSS where mitigation measures are not successful. This management strategy, and the approach to developing it, is described in detail in **Appendix 4**, and summarised below:

- To ensure impacts to THPSS are within those predicted within the SVMEP EIS and the APMEP EIS, Centennial will:
  - Undertake annual monitoring for ecosystem health using the University of Queensland Monitoring Handbook (Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps, 2014) or its latest version.
    - The objectives of the University of Queensland Monitoring Handbook include, amongst other things:
      - A focus on vegetation community structure and diversity, including biological indicator species.
      - Trigger values focussed on detecting impacts of subsidence and/or changes in groundwater and surface water flows, including information on how the triggers were derived.
      - A sampling design that is statistically capable of detecting changes in the indicator variables.
      - An adaptive management mechanism for refining trigger values and determining the length of time a THPSS is monitored.
    - The following figure, taken from the Monitoring Handbook, identifies how the data collected will be used to inform management decision making.

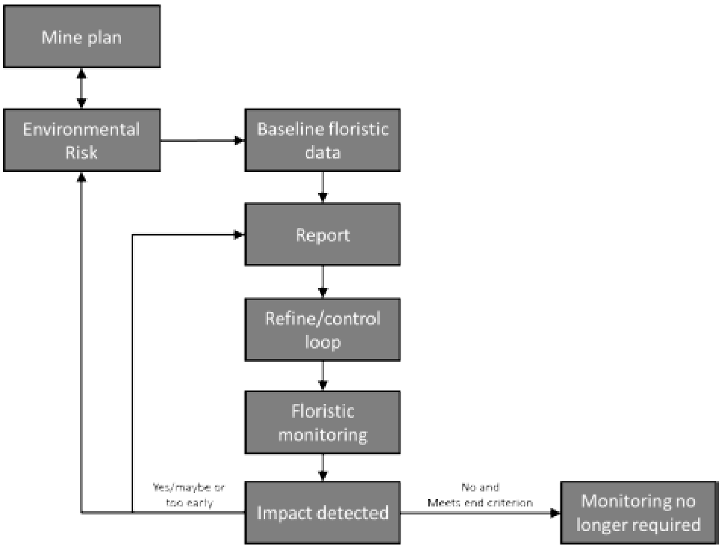


Figure 4.1: Conceptual framework showing how data from flora monitoring informs the environmental risk assessment and monitoring conclusions.

- Where this monitoring identifies mining related impacts, mitigation measures will be implemented (including soft and hard engineering measures discussed further in **Appendix 4**).
- Reconcile the annual monitoring every five (5) years (to allow for trend analysis to occur).
  - Where impacts, attributable to mining, are above triggers, additional mitigation will be undertaken.
  - Where impacts are attributable to mining and cannot be mitigated, or mitigation is not successful, offsets for the residual impacts will be provided.

This THPSS management strategy is considered to adequately compensate for the indirect impacts to that community.

When the EPBC Environmental Offsets Policy is applied to the THPSS, no direct offset is required.

**Lot 135 also covers the new Angus Place Vent Shaft No 2 and Springvale Bore 8, as well as the Western Coal Services Upgrade Project. The proposed offset is also to cover, for reasons that are not explained, the Clarence Reject Emplacement Area VI. (LEG and Colong Foundation)**

The Regional Biodiversity Strategy (revised August 2014) provides additional information on the Western Coal Services Upgrade Project, the Angus Place Ventilation Facility Project, the Springvale Bore 8 Project and the Clarence REA VI Project.

**The total of 100 hectares of swamps and 31.5 hectares of native forest cleared for infrastructure for the two current mine extensions as explained in the tables 11 to 15 is misleading. It is unclear how much clearing and so-called indirect impacts on EEC are being compensated by**

**this one offset, perhaps an additional 200 hectares, perhaps much more land is directly impacted. (LEG and Colong Foundation)**

Table 11 of the Regional Biodiversity Strategy identifies the native vegetation communities that will be directly impacted by the Springvale MEP, that is, the vegetation communities that will be cleared. Table 12 of the Regional Biodiversity Strategy identifies the native vegetation communities that may be indirectly impacted by the Project.

Table 13 and 14 provide similar information for the Angus Place MEP.

Table 15 and 16 provide similar information for the Neubeck Coal Project.

Offsets are required where the residual impacts, following avoidance and mitigation measures, are considered to be significant. Offsets are required for these types of residual impacts.

The subsidence, flora and fauna, and groundwater assessments undertaken for the Springvale and Angus Place MEPs concluded that there will be no significant impact to EECs as a result of these Projects. This is largely attributable to the mine design measures that have been implemented. As a result, the residual impacts are not significant and therefore no offset is required.

Direct offsets are required for impacts to MNES listed under the EPBC Act (Federal) or threatened species/endangered ecological communities listed under the TSC Act (NSW). As there are no direct impacts to MNES or threatened species/endangered ecological communities listed under the TSC Act, no direct offsets are required.

**The omission of the total land area to be cleared and that 'indirectly impacted' means that the offset analysis in Appendix I does not comply with the Director General's requirement for clear quantification. To be clear, the offsets for Angus Place Vent Shaft No 2 and Springvale Bore 8, Western Coal Services Upgrade Project and the Clarence Reject Emplacement Area VI are not quantified. (LEG and Colong Foundation)**

The Regional Biodiversity Strategy (revised September 2014) provides additional information on the Western Coal Services Upgrade Project, the Angus Place Ventilation Facility Project, the Springvale Bore 8 Project and the Clarence REA VI Project.

**Lot 135 DP 755757 is only 86.7 hectares in size (App I, section 6.2 and Table 17), so the earlier reference to '342.2 hectares of critically endangered ecological community and habitat for over 160 fauna species' on page 3 is wrong. The area of endangered ecological community is very small. (LEG and Colong Foundation)**

Table 1 within the Regional Biodiversity Strategy (revised September 2014) has been updated to include consideration of the contribution of each Project under the Strategy to the Offset Land.

**Table 18 reveals that only 10 hectares of a critically endangered Box Gum Woodland and Derived Native Woodlands exists on the site. All the claimed threatened animals listed in Table**

**18 are not recorded from observation, rather it is claimed that the woodlands are 'very likely' to provide habitat for such wildlife (page 23 and note that title of Table 18 is species recorded in the site and locality. (LEG and Colong Foundation)**

Section 6 of the Regional Biodiversity Strategy (revised September 2014) has been updated to include further detail on the biodiversity values of the Offset Land.

**As non-threatened degraded woodland species are used for the credits, then non-threatened species for the indirectly impacted woodlands and forests on Newnes Plateau should also be part of the offset calculation. The proposed Angus Place extension covers 2,638 hectares and the proposed Springvale extension covers 1,860 hectares (including the 131.5 hectares of EECs and clearing). These impacted forests are part of a reserve proposal initially put forward by the National Parks and Primitive Areas Council in 1932. (LEG and Colong Foundation)**

Noted.

**The offset analysis is further confused by the statement that 'Both the Springvale Mine Project and the Angus Place Project will not impact upon 'credit species' and therefore only ecosystem credits are required' (Page 30, App. I). This statement is wrong. Giant Dragonfly, Blue Mountains Sink, and Boronia deanei will be impacted causing the loss of local populations. (LEG and Colong Foundation)**

The subsidence, flora and fauna, and groundwater impact assessments for the Project concluded that the predicted changes in baseflow and average standing water levels are not of a magnitude that will cause swamp habitats to become unsuitable for these species. As a result, no offset is required.

**The offset analysis does not properly consider naturally rare ecosystems, like the three swamp EECs and other Groundwater Dependent Ecosystems. In Table 21 all the Temperate Highlands Peat Swamps on Sandstone (BioBank Units 562 and 592, equivalent to MU's 50,51 and 52), for example, receive a total score of only -1,306 units and this is for damaging 100 hectares in 63 near-pristine EEC swamps. This score compares with a total score of -1,424 units given for clearing 23 hectares open forest and shrubby woodlands at the proposed Angus Place extension for facilities. The latter result seems reasonable for common sclerophyll forests and woodlands, the former result is grossly underestimated for swamps extending over five times the area being impacted by a key threatening process. (LEG and Colong Foundation)**

**The Ecosystem Credit Balance in Table 21 does not properly recognise the important value of these swamps and is completely unacceptable. The analysis demonstrates that reducing ecosystems to numbers does not inform decision making, but rather confuse the issue. (LEG and Colong Foundation)**

The BioBank Assessment Methodology (BBAM) was applied to assess the offset requirements resulting from the proposal and the offset value of the Offset Land. The online Biobanking Credit Calculator was used for the Project to establish the credits likely to be sought by the Office of Environment and

Heritage. These assessment methodologies identify the ecosystems and species required to be considered.

**The offset analysis is deficient as the values for known populations of threatened species at risk of local extinction are not individually calculated. (LEG and Colong Foundation)**

Appendix 1 and Appendix 2 of the Flora and Fauna Impact Assessment for the Project includes consideration of the threatened species at risk of local extinction.

**The statement regarding MU20 made on page 32 and in Table 23 is not reported in Table 17 and appears as double counting. It should be ignored. (LEG and Colong Foundation)**

Table 23 relates to both Lot 163 and Lot 135. Table 17 relates to Lot 135 only.

**Eliminating the 8 hectares of cleared derived grassland that appears to be cattle paddocks leaves just 2 hectares of a critically endangered community in the proposed offset. The proposed exchange of 2 hectares of critically endangered box gum woodlands on farmland for 100 hectares of diverse, intact EEC swamps is presented in a misleading manner. (LEG and Colong Foundation)**

Section 6 of the Regional Biodiversity Strategy (revised September 2014) has been updated to provide further information on the biodiversity values of the Offset Land.

**LEG does not consider the proposed research to be an appropriate supplementary measure for the loss of threatened plants and animals through development. Recovery plans and research are needed, but not at the expense of retaining important habitat. (LEG and Colong Foundation)**

Noted.

### 3.2.2 Compliance

**Between 2000 and 2012 1039 Incidents of Licence Non-compliance were recorded under Environmental Protection Licences (EPLs) issued to Angus Place (EPL 467) and Springvale Colliery (EPL 3607) under the Protection of the Environment Operations Act 1997 (POEO Act). None of these Non-compliances, Penalty Notices, or Pollution Reduction Notices are mentioned anywhere in the EIS. Why not? (LEG)**

Any non-compliances are reported via Springvale Mine's EPL 3607 Annual Return and in the site's Annual Review reports. Both these documents are made publicly available. In addition, Springvale Coal reports any non-compliances to the Springvale Mine Community Consultative Committee (CCC) which meet two times a year. CCC minutes are made available on the Centennial Coal website (www.centennialcoal.com.au).

### 3.2.3 Consultation

**None of the Colong Foundation's concerns were properly addressed. The Colong Foundation has not been approached by Centennial for a meeting in the last four years. Very few, if any, of the concerns raised by the Colong Foundation have been 'closed out' as suggested by Centennial in Table 7.1. The claim that 'Centennial will continue to consult and engage with these groups to achieve outcomes of the Consultation Strategy' has not been the Colong Foundation's experience in the last four years. (Colong Foundation)**

Consultation between Centennial Coal and the Colong Foundation broke down in 2012. Consultation between Centennial Coal and the Colong Foundation prior to this is detailed in Section 7 of the EIS. On 14 September 2012 an email was sent from Centennial Coal to the Colong Foundation requesting their interest in the re-instatement of consultation. No response from the Colong Foundation was ever received.

### 3.2.4 Ecology

**The sandstone rock supporting the 41 nationally endangered swamps, and particularly the 11 shrub swamps affected by the proposal, will also develop a large number of fractures. Centennial predicts these cracks to be 5 to 50mm wide And 10 to 15 metres deep. All these nationally endangered swamps will dry Out and the peat soils that support these swamps will decompose. Over a period of years eucalypts and banksias will migrate into these dying swamps as they evolve to dry land communities. (NCC and The Colong Foundation)**

**One of the more important components of the Newnes Plateau environment is the system of shrub swamps (NPSS). The expansion of these mines would put at risk 17 swamps listed as nationally endangered, plus 31 hanging swamps. These swamps store water and release it gradually, maintaining stream flow even in drier periods. The loss of water into cracked streambeds upstream of, or under, these swamps leads to their desiccation and the complete destruction of the ecosystem in each affected valley. (BMCS)**

**The Lithgow Environment Group disputes that the impacts on the three EECs that comprise the Temperate Highlands Peat Swamps on Sandstone (THPSS) are indirectly impacted by the proposed longwall mining operations. Longwall mining is a Key Threatening Process and is likely to directly impact on THPSS through mine subsidence. Damage to swamps above the area of direct influence of the mining operations is clearly a likely impact. (LEG)**

**The sandstone strata supporting the 22 nationally endangered swamps, including the 7 shrub swamps must not be fractured. (SCSGBM)**

The mining layout at Springvale Mine has also been designed so as to reduce the potential impacts on the shrub swamps resulting from mine subsidence movements, in particular, the proposed longwalls in the Project Application Area which lie beneath Newnes Plateau Shrub swamps (LW416 – LW432) are designed to have sub-critical W/H ratios and chain pillars at least 55 m wide.

Section 5.12 of the Subsidence Assessment, provided as Appendix D to the EIS, provides a detailed assessment of the potential impacts to shrub swamps and hanging swamps as a result of the Project.

Predicted post mining grades are similar to the natural grades within the shrub swamps. There are no predicted significant reductions or reversals of grade. The hanging swamps are located on the sides of the valleys and, therefore, that natural gradients are greater than those shown for the shrub swamps. It is not expected, therefore, that there would be any adverse changes in ponding or scouring within the swamps resulting from the predicted mine subsidence movements. It is also not anticipated that there would be any significant changes in the distribution of the stored surface waters within the swamps as a result of the mining induced tilt or vertical subsidence.

Fracturing of the uppermost bedrock has been observed in the past, as a result of longwall mining, where the tensile strains have been greater than 0.5 mm/m or where the compressive strains have been greater than 2 mm/m.

The swamps which are located outside the extents of the proposed longwalls, including Sunnyside Swamp and Nine Mine Swamp, are predicted to experience tensile strains less than 0.5 mm/m and compressive strains less than 2 mm/m due to the proposed mining. It is unlikely, therefore, that the bedrock beneath these swamps would experience any significant fracturing.

Although some minor and isolated fracturing could occur in the bedrock beneath the swamps located outside the extents of the proposed longwalls, it is unlikely to result in any adverse impacts on these swamps.

The swamps which are located directly above the proposed longwalls are predicted to experience tensile strains greater than 0.5 mm/m and compressive strains greater than 2 mm/m. It is expected therefore, that fracturing would occur in the top most bedrock beneath these swamps.

The surface cracking across the mining area is expected to be generally isolated and minor in nature, due to the reasonable depths of cover which typically vary between 350 m and 400 m, and due to the plasticity of the surface soils which allows them to more readily absorb the ground strains. Surface crack widths are expected to be similar to those observed above the previously extracted longwalls at Angus Place and Springvale Collieries, which were typically between 5 mm and 25 mm, but with isolated surface cracking in some locations greater than 50 mm.

The shrub swamps have peat layers which overlie the shallow natural surface soils and underlying bedrock along the alignments of the drainage lines. In most cases, cracking would not be visible at the surface within these swamps, except where the depths of bedrock are shallow or exposed. The shrub swamps comprise significant quantities of sediment and, therefore, fracturing of shallow bedrock beneath these swamps are likely to be filled with soil during subsequent flow events along the drainage lines.

The hanging swamps have soft soil or peat layers which overly the bedrock on the valley sides. It is expected that the potential for fracturing in these locations would be less when compared to the bases of the valleys, where higher compressive strains occur due to the valley related movements, and due to the higher depths of cover along the valley sides.

Whilst some minor surface cracking could occur in the swamps resulting from the extraction of the proposed longwalls, the previous experience of mining beneath swamps at Angus Place, Springvale and in the Southern Coalfield indicate that the likelihoods and extents of these impacts are very small.

The dilated strata beneath the drainage lines, upstream of the swamps, could result in the diversion of some surface water flows beneath parts of the shrub swamps. It is noted, however, that the drainage lines upstream of the swamps are generally ephemeral and, therefore, surface water flows occur during and shortly after rainfall events. Any diverted surface water flows are expected to remerge short distances downstream, due to the limited depth of fracturing and dilation and due to the high natural stream gradients.

The incidence of impacts on swamps due to mine subsidence ground movements is very low and, in some of these cases, the impacts that were observed were associated with natural events or mining related surface activities. It is expected, therefore, that the incidence of impacts on the swamps within the Extension Area resulting from mining induced ground movements will also be low.

Previous longwalls at Angus Place and Springvale Collieries have been extracted directly beneath or partially beneath 13 shrub swamps and 26 hanging swamps. Surface impacts have been observed at four swamps which were directly mined beneath by the previously extracted longwalls at Angus Place and Springvale Collieries. It has been recognised that past mining related surface activities, i.e. the discharge of high quantities of mine water and construction of various roads and access paths, have resulted in surface impacts to some swamps. Springvale Mine and Angus Place Colliery have developed management plans to minimise the potential for future impacts resulting from these mining related surface activities.

An environmental monitoring program was established to assess the effects of longwall mining on the groundwater systems associated with the swamps at Angus Place and Springvale Collieries. The monitoring comprised swamp piezometers, shallow aquifer piezometers and multi-level vibrating wire piezometers at Junction, Sunnyside, Sunnyside West and West Wolgan Swamps. The monitoring results were reviewed by RPS which found that the monitoring results provided no evidence that longwall mining had affected the groundwater systems for these swamps.

The Groundwater Impact Assessment prepared by RPS to support the Project and provided as Appendix E to the EIS determined that the most significant reductions to average standing groundwater levels are predicted in Twin Gully Swamp within the Angus Place mining area but not to be undermined This swamp has a projected drop in average standing water levels from 12.4 cm to 10.6 cm above the soil surface. The post mining values predicted at Twin Gully Swamp therefore suggest that soil saturation would persist, maintaining water availability for flora and fauna, as well as soil anoxia, allowing for continued peat formation. All other monitored swamps have smaller projected decreases in average standing water levels and monitored swamps are projected to maintain average standing water levels above the surface.

Additionally, highly organic peat soils with low bulk density capillary forces are likely to be saturated for some distance above the water table itself. Natural decreases in water levels, in addition to the small predicted decreases from the CSIRO model are still likely to enable capillary forces to saturate the peat layer. Therefore, a possible reduction in the average standing water levels, by the magnitudes predicted is unlikely to result in drying of the peat layer.

The Project is not expected to have a significant impact upon the hydrology of any hanging swamps. The reliance of these areas on perched aquifer systems effectively isolate them from any hydrological changes that may occur to the regional water table as a result of mining operations.

**The consultants have asserted 'that any effects on potential populations of the endangered Adams Emerald Dragonfly will be insignificant'. It is impossible to make such a statement, considering that there have never been any ecological studies of this species and limited aquatic sampling was undertaken for this project. (BMCS)**

An Aquatic Ecology Impact Assessment undertaken by Cardno Ecology Lab to support the Project and is provided as Appendix G to the EIS.

The life cycle of Adams Emerald Dragonfly would be adversely affected if the construction, operation, decommissioning and/or rehabilitation phases of the Project resulted in loss or modification of its habitat or reduced the quality of the water. If fracturing of the Wolgan River bed does occur during extraction of the longwalls it could lead to drainage of overlying pools and loss of aquatic habitat and changes in concentrations of iron, manganese, aluminium, zinc and nickel and levels of iron staining. These impacts are expected to be minor, localised and temporary in nature, persisting until the cracks are infilled and overtopping of flows is resumed. Mining is unlikely to have any adverse impacts on aquatic habitats in Carne Creek. Given the above, it is highly unlikely that the lifecycle of this dragonfly would be affected to such an extent that it would place a viable local population of this species, if one exists within the Project Application Area, at risk of extinction.

As the macroinvertebrate surveys undertaken in the Project Application Area are limited in frequency, spatial extent, duration and intensity but suitable habitats for this species are present, the possibility of Adams Emerald Dragonfly being present cannot be discounted. As such, an Assessment of Significance was prepared as a precautionary measure. The assessment of the significance of impacts on Adams Emerald Dragonfly was prepared in accordance with the Threatened Species Assessment Guideline – The Assessment of Significance (DPI 2008). These guidelines specify the important factors that must be taken into considered when assessing potential impacts on threatened species, populations or ecological communities listed under Schedules 4, 4A and 5 of the Fisheries Management Act.

The assessment of the significance of impacts indicated that if viable populations of Adams Emerald Dragonfly were present within the proposed workings area they could be subject to temporary, localised, minor impacts. It is consequently highly unlikely that the proposed mining would have a significant impact on this threatened species.

**The BMCS strongly supports the consultants' recommendation to undertake more comprehensive, and better designed, pre-mining surveying, and finer resolution taxonomic identification of stygofauna; such surveying must be implemented if this project proceeds to ensure that the diversity of stygofauna is properly assessed and potential risks of the project determined. (BMCS)**

No significant impacts are predicted on aquatic habitats, aquatic flora or aquatic fauna and or stygofauna. As is included in the Statement of Commitments contained in Chapter 11 of the EIS, because the aquifer systems across the Newnes Plateau are consistent, stygofauna will be monitored using standing water levels within one borehole in each aquifer where stygofauna are known to occur (AQ4 to AQ6). Where available, monitoring of the deep aquifer system, AQ1 to AQ3 will be undertaken to establish presence of stygofauna.

Additionally, Centennial Angus Place and Springvale Coal will commit to undertaking a regional stygofauna assessment which will:

- Collate existing available information on groundwater bores, water quality and characteristics in Centennial Coal's area of operations throughout the Western Coalfield.
- Use this information to form a prioritisation list of likely areas for GDE to occur.
- Use the prioritisation protocol to identify bores that can be sampled to provide data on the presence and significance of fauna both within and outside mine areas.
- Identify any stygofauna found to a minimum of Family level.
- Advise on the significance of the findings.
- Examine relationship between bore characteristics and presence of stygofauna.

The Statement of Commitments contained in **Section 5.0** of this RTS has been updated to include this commitment.

**Dr Baird disputes the conclusion of the consultants that there will be no significant impact in relation to the Key Threatening Process of subsidence from longwall mining. (BMCS)**

As detailed in Section 6.5 of the Flora and Fauna Impact Assessment provided as Appendix H to the EIS, it is acknowledged that the Project is likely to incrementally contribute to the Key Threatening Process (KTP) 'Alteration of habitat following subsidence due to longwall mining'. A number of threatened species potentially occurring within the Study Area are listed within this KTP as being at risk. These include Boronia deanei, Blue Mountains Water Skink, Giant Dragonfly and Stuttering Frog. Newnes Plateau Shrub Swamp is also listed within the final determination of this KTP.

Subsidence monitoring within Springvale has shown that nearly all measurements are less than those predicted. Based on the monitoring data, there is an approximate 95% confidence level that the maximum observed total subsidence will be less than the maximum predicted total subsidence. Flora and fauna monitoring since 2005 has not recorded any losses to threatened species populations or EECs as a result of subsidence. This is due to appropriate mine design to limit subsidence to acceptable levels. However, conservative predictions for maximum baseflow and standing water level changes in several shrub swamps as a result of subsidence have determined that potential low-scale changes to swamp hydrology is possible.

The magnitude of the potential hydrology changes have, however, been considered against the likely capillary forces of the peat to maintain saturation. The predicted change to average water level is within the expected capillary forces such that the magnitudes of water table decline predicted in Adhikary and Wilkins (2013), is unlikely to result in drying of the peat layer. The conversion of perched water table flows into subsurface flows through voids is unlikely. Cracks may divert some water temporarily from swamps, but will initially fill with water before eventually filling with silt/peat from within the swamp, so that there should be no long-term or permanent impact on flows in the swamp. Therefore, the minor alterations to the hydrological regime predicted are unlikely to modify the vegetation communities present in the short or long term.

**Newnes State Forest has only been subjected to selective logging in certain places, and is mostly unlogged old growth forest, contrary to the claims on page 97, s 2.8.1 in Vol. 1 of the EIS. The claim that 'as a consequence of forest harvesting and fires, large areas of forest are relatively young with a low to moderate density of hollow-bearing trees' is an overstatement. These eucalypt forests and woodlands are adapted to wild fire and mostly old-growth with a high density of hollows. Further, the sheltered gully forests offer protection for wildlife and even the hottest fires do not entirely burn Newnes Plateau due to its dissected, rocky terrain. The overall importance of this forest should not be discounted as claimed by Centennial Coal. (Colong Foundation)**

Section 2.5.1.2 and 2.8.1 of the EIS identifies the past land use history of the Project Application Area and acknowledges the importance of the area as habitat to a diverse range of faunal species.

**Centennial distinguished plant communities that are allegedly indirectly impacted from those that are directly impacted. By indirectly impacted, Centennial means plant communities that have been subjected to longwall mining where it claims there is no significant impact to these communities. Notwithstanding the fact that longwall mining is a Key Threatening Process for nationally threatened swamps, Centennial has convieniently found that longwall mining is 'unlikely' to have an impact on these swamps. (LEG)**

Indirect impacts relate to any potential impact on plant communities due to the subsidence effects. Based on the subsidence predictions in the Subsidence Impact Assessment (MSEC, Appendix D to the EIS) the Flora and Fauna Impact Assessment (Appendix H of the EIS) assessed the impacts of the predicted subsidence parameters on the biodiversity within the Project Application Area. The outcomes of this assessment are described in detail in the Flora and Fauna Impact Assessment and summarised in Section 10.3.4.1 of the EIS. The environmental consequences are described in Section 10.3.5.1 of the EIS.

Those species and communities recorded or expected within the subsidence impact areas were subjected to 7 part test of significance under the TSC Act and/or assessment of significance under the EPBC Act, the results of which are provided in Table 10.14 and Table 10.15, respectively, in the EIS. Details of these assessments undertaken are included as Appendices 1 (TSC Act 7 part test of significance) and 2 (EPBC Act assessment of significance) of the Flora and Fauna Impact Assessment.

With regards to impacts on the two vegetation communities within the Project Application Area, namely, MU50 – Newnes Plateau Shrub Swamp; and MU51 Newnes Plateau Hanging Swamp which provide known or potential habitat for threatened flora and fauna, the assessments found that the Project is unlikely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction. This conclusion is also supported by the following observations.

- Monitoring of swamp water levels and surface water gauging has shown that over the life of the current mining operations, no impacts to the swamps or surface water flows have occurred as a result of mining to date at Angus Place Colliery.

- Regular seasonal monitoring of the flora and fauna since 2005 have also revealed no observable impacts on the flora and fauna recorded within undermined areas, including Shrub Swamps.

- There exists a high level of confidence in subsidence predictions, as shown by post-mining subsidence monitoring data.

Alteration of habitat following subsidence due to longwall mining is a KTP under the TSC Act. Section 10.3.5.1 of the EIS notes that the project will contribute to this KTP, however, the application of the proven mine design principles and the proven accuracy of the subsidence predictions will minimise the risk associated with the process and that the threatened species and communities are not endangered.

**Centennial claims the proposed longwall mining will have no likely cause extinction for local populations of the Giant Dragonfly, Blue Mountains Skink, and Boronia deanei due to the drying out of nationally endangered swamps that paradoxically would be a direct impact of mining. The analysis of the impact on these species is not unlikely or low, as claimed, but likely as longwall mining is a key threatening process to the swamp habitat in with they live. (LEG)**

Alteration of habitat following subsidence due to longwall mining is a KTP under the TSC Act. Section 10.3.5.1 of the EIS notes that the Project will contribute to this KTP, however, the application of the proven mine design principles and the proven accuracy of the subsidence predictions will minimise the risk associated with the process and that the threatened species and communities are not endangered.

A review of the potential impacts to the Shrub Swamp EEC discussed in the Subsidence Impact Assessment (Appendix D to the EIS), Groundwater Impact Assessment (Appendix E to the EIS) and

Surface Water Impact Assessment (Appendix F to the EIS) was undertaken within the Flora and Fauna Impact Assessment (Appendix H to the EIS) to assess the impact of the Project on the biodiversity of the Project Application Area. The Flora and Fauna Impact Assessment concluded it is unlikely that the effects of subsidence would have an adverse effect on shrub swamps or hanging swamps such that the ecological functioning of these swamps would be impaired given that:

- there is unlikely to be significant reductions or reversals of grade that could otherwise cause ponding or scouring

- the limited depth of fracturing above the Mount York Claystone aquitard and lack of dilation of bedrock of shrub swamp or upstream drainage lines would not result in losses of infiltrated water and minimal divergence of surface water would occur.

RPS completed a study in November 2012 (RPS, 2012) to assess whether any impacts attributable to the undermining of the swamps could be ascertained based on swamps hydrographs and groundwater level trends. All of the swamps which were included in this study have a significant history of water level monitoring, are located away from licensed discharge points (to minimise potential for conflicting information), and have all been either undermined by longwall extraction or were in very close proximity to extracted longwall panels.

The results of the RPS 2012 study showed that no water level impacts that could be attributed to past or present mining operations (subsidence-related impact or depressurisation) were observed. Rather, the water levels in the swamps showed a strong correlation to cumulative rainfall trends, and this was found to be the driving factor.

As no mining influenced water level fluctuations can be identified in any of the monitored swamps (both undermined and baseline) it is accurate to say that mining at Springvale Mine (and the adjoining Angus Place Colliery) has not led to any identifiable water level impacts on the monitored swamps, and that all undermined swamps continue to display baseline water levels.

As part of the Flora and Fauna Impact Assessment 7 part test of significance under the TSC Act were conducted for Giant Dragonfly, Blue Mountains Skink, and Boronia deanei, and the assessment of significance under the EPBC Act for Boronia deanei. The results of these assessments are provided in full in Appendices 1 and 2 of the Flora and Fauna Assessment and summarised in Table 10.14 and Table 10.15, respectively in the EIS. Conclusions drawn from these assessments are as follows.

- The Project will not or unlikely to have an adverse effect on the populations of Giant Dragonfly, Blue Mountains Skink, and Boronia deanei, to such that their local occurrences are likely to be placed at risk of extinction (TSC Act).

- The Project will not lead to the long-term decrease in the size of the Boronia deanei population in the locality (EPBC Act). No record of the Boronia deanei population exists within the Project Application Area.

Given the outcomes of the assessments and the fact that the Project is not expected to have a significant impact upon any shrub swamps, such that their ecosystem functioning may be compromised, any alterations to potentially important habitats from subsidence, will not affect the long-term survival of the Giant Dragonfly and Blue Mountains Water Skink in the locality.

**LEG believes that the monitoring of the nationally endangered swamps is misleading and that proper mapping of these swamps is still incomplete after decades of ineffective management. Despite the expense, the mapping is inadequate so that dramatic changes to mined vegetation communities over time have not been reported. (LEG)**

The mapping of the Shrub Swamps within the Project Application Area is consistent with DEC (2006) mapping and has been ground-truthed by Centennial Angus Place and Springvale Coal during opportunistic ecology surveys. Further mapping of these swamps are currently being undertaken by Centennial Coal in collaboration with University of Queensland.

The Centre for Mined Land Rehabilitation at the University of Queensland is currently completing a mapping and classification project covering 2600 km$^2$ area of the Blue Mountains from Penrith to Lithgow and Narrow Neck to Wollemi National Park. The region was selected based on extents of currently mapped upland swamp communities existing at a density of more than 1000 mapped communities per degree of latitude and longitude. The project has collected vegetation survey data using two different methodologies on 72 communities across this region. These two swamp vegetation community mapping methodologies were:

- Standard 400 m$^2$ vegetation survey plots in central homogenous location
- Distributed 1 m$^2$ micro plots with number of plots determined by the size of the community sampled.

Floristic diversity, environmental and landscape characteristics are currently being used to determine the range of distinct mapping units represented across the region. This data will be tested using existing monitoring plot floristic data collected for statutory monitoring purposes. Project completion is planned for mid-October 2014.

**The swamps to be impacted upon by the proposed mining are the best remaining on Newnes Plateau. The reported findings in Table 2 to Table 5 (App. I) are inaccurate and misleading in relation to swamps and the abovementioned species found within them as they are inconsistent with the evidence. (LEG)**

Table 4 and Table 5 of the Regional Biodiversity Strategy (Appendix I to the EIS (sperceded)) and Tables 10.14 and Table 10.15 of the Springvale EIS provide, respectively, a summary of the outcomes of TSC Act 7 part test of significance and a summary of the outcomes of EPBC Act Assessment of Significance of those species recorded or expected in impact areas due to the proposed infrastructure and mining induced subsidence. These tests/assessments have been undertaken by a qualified ecologist (P Hillier, RPS Australia East Pty Limited) with many years' experience in undertaking ecological assessments and conducting numerous field surveys, including on the Newnes Plateau.

The summaries provided in Regional Biodiversity Strategy and in the EIS in the tables noted above serve, as background information on the significance of impacts on threatened species and EECs which have been recorded during surveys or have the potential to occur within the project area and likely to utilise habitat to be potentially impacts by the proposed activities in the Project. The summaries should not be evaluated in isolation for impacts on species but instead should be reviewed in conjunction with the detailed assessments provided in the Flora and Fauna Impact Assessment (Appendix H to the EIS) as that will provide context to assessment outcomes noted in the tables. Appendix 1 of the Flora and Fauna Impact Assessment provides details of the 7 part test (TSC Act) while Appendix 2 provides details of the Assessment of Significance (EPBC Act).

It should also be noted that the assessment outcomes and conclusions on the likely impacts of the Project on the biodiversity discussed in the Flora and Fauna Impact Assessment (Appendix H to the EIS) and Section 10.3 of the EIS have been informed by a number of other technical assessments, namely, Subsidence Impact Assessment (Appendix D to the EIS), Groundwater Impact Assessment (Appendix E to the EIS) and Surface Water Impact Assessment (Appendix F to the EIS).

With regards to the potential impacts of the Project on the species referred in in the comment (Boronia deanei, Blue Mountains Water Skink, Giant Dragonfly and Stuttering Frog) Section 6.5 of the Flora and Fauna Impact Assessment notes that the Project is likely to incrementally contribute to the Key Threatening Process (KTP) 'Alteration of habitat following subsidence due to longwall mining'. This section has noted that threatened species, Boronia deanei, Blue Mountains Water Skink, Giant Dragonfly and Stuttering Frog, potentially occurring within the impact areas are listed within this KTP as being at risk. Newnes Plateau Shrub Swamp is also listed within the final determination of this KTP.

However, monitoring of swamp water levels and surface water gauging has shown that over the life of the current mining operations, no impacts to the swamps or surface water flows have occurred as a result of mining to date at Angus Place (RPS 2013). Regular seasonal monitoring of the flora and fauna since 2005 have also revealed no observable impacts on the flora and fauna recorded within undermined areas, including Shrub Swamps. This observation is supported by a high level of confidence in subsidence predictions, as shown by post-mining subsidence monitoring data. Therefore the Project is unlikely to have an adverse effect on the extent of the populations such that the local occurrences are likely to be placed at risk of extinction.

**The claim in Appendix I that the proposed mining is consistent with the threat abatement plan for Blue Mountains Skink is wrong, as the impacts are not adequately mitigated by the proposed longwall mining arrangements. (LEG)**

Impacts to swamps have been adequately mitigated through the mine design criteria adopted during the mine planning phase of the Springvale MEP. Sub-critical longwalls with voids of 261 m and chain pillars of 58 m have been proposed for all longwalls proposed under or in the vicinity of shrub swamps (LW416 – LW432) (refer Figure 2.29 and Figure 10.1 in the EIS). Springvale Mine's previous experience extracting longwalls with a wide range of void widths showed sub-critical longwalls exhibited significantly less subsidence than the wider critical longwalls through reduction in the height of fracturing. An outcome of the significantly less subsidence was that impacts on sensitive surface features was minimised. The sub-critical panels under the shrub swamps to be under mined means the habitat to the Blue Mountains Skink is not likely be potentially impacted.

Section 10.1.5.3 of the EIS notes that no subsidence effects to swamp hydrology or flora communities have been identified in areas where sub-critical panels have been implemented. The height of fracturing resulting from the extraction of these longwalls is not likely to propagate above the 22 m thick Mount York Claystone aquitard ie, the Mount York Claystone contains the majority of the mining induced fracturing to below that aquitard.

The limited extent of the downward cracking from the surface means that fracturing and dilation of bedrock of shrub swamps would not result in losses of infiltrated water, and minimal divergence of surface water would occur. It follows then that it is unlikely that subsidence effects would have an adverse impact on shrub swamps and hanging swamps such that the ecological functioning of these swamps would be impaired. No previous subsidence effects to swamp hydrology or flora communities have been identified above sub-critical longwall panels.

With regards to the potential impacts of the Project on the Blue Mountains Water Skink Section 6.5 of the Flora and Fauna Impact Assessment (Appendix H to the EIS) notes that the Project is likely to incrementally contribute to the Key Threatening Process (KTP) 'Alteration of habitat following subsidence due to longwall mining'. This section has noted that the Blue Mountains Water Skink potentially occurring within the impact areas are listed within this KTP as being at risk. Newnes Plateau Shrub Swamp is also listed within the final determination of this KTP.

However, monitoring of swamp water levels and surface water gauging has shown that over the life of the current mining operations, no impacts to the swamps or surface water flows have occurred as a result of mining to date at Angus Place Colliery or Springvale Mine (RPS 2013). Regular seasonal monitoring of the flora and fauna since 2005 have also revealed no observable impacts on the flora and fauna recorded within undermined areas, including Shrub Swamps. This observation is supported by a high level of confidence in subsidence predictions, as shown by post-mining subsidence monitoring data. Therefore the Project is unlikely to have an adverse effect on the extent of the populations such that the local occurrences are likely to be placed at risk of extinction.

**In Table 4 of Appendix I that bulldozing an unnecessary road and ten metre wide pipeline easement through a Tablelands Snow gum - Black Sallee - Candlebark and Ribbon Gum Grassy Woodland is unlikely to have an adverse impact on this Threatened Ecological Community is also wrong. (LEG)**

The clearing of the Tableland Gully Snow Gum – Ribbon Gum Montane Grassy Forest, an endangered ecological community in accordance with the NSW *Threatened Species Conservation Act 1995*, is proposed to avoid impacts to the nearby shrub swamp (Sawyers Swamp Creek).

Table 10.8 of the EIS shows the Project is proposing to clear 0.22 ha of Tableland Gully Snow Gum – Ribbon Gum Montane Grassy Forest, This proposed clearing represents 1% of the community mapped within the Project Application Area to be cleared and 0.01% of the 1584.43 ha of the community mapped in the western Blue Mountains area (DEC 2006). The 0.22 ha of the Tableland Gully Snow Gum – Ribbon Gum Montane Grassy Forest proposed to be cleared already exists in a highly modified (regrowth) condition. The 7-Part Test of Significance undertaken for this EEC concluded the remaining community within the Project Application is unlikely to be significantly impacted by the project, such that the EEC would be placed at risk of extinction.

The Regional Biodiversity Strategy has taken this proposed clearing into consideration when determining the native vegetation communities to be directly impacted by the project (refer Table 11 of Appendix I of the EIS). Section 6.1 of the revised Regional Biodiversity Offset Strategy (September 2014) notes the offset area proposed provides compensation for the residual impacts associated with the Springvale MEP and this includes clearing of 0.22 ha of Tableland Gully Snow Gum – Ribbon Gum Montane Grassy Forest. .

**The analysis regarding frog impacts in Table 2 to Table 5 is wrong, as it assumes that swamps and streams are unaffected by the proposed longwall mining. (LEG)**

Centennial Angus Place has developed a reliable and detailed understanding of the environmental constraints as a result of experience from operating Angus Place Colliery over many years and from the environmental management and monitoring regimes. Using this knowledge, potential environmental constraints have been taken into account during the mine design process for the Angus Place Extension Project to ensure the Project is undertaken safely and in the most environmentally sensitive manner feasible. The approach taken in the Springvale MEP has been to apply a best practice system of environmental management comprising a hierarchy of avoiding, minimising, mitigating and finally, offsetting residual impacts.

An outcome of detailed mine planning and design process implemented in the Springvale MEP is that the mine plan minimises predicted subsidence and reduces the occurrence of subsidence effects beyond predictions. Springvale Mine's previous experience extracting longwalls with a wide range of void widths showed sub-critical longwalls had significantly less subsidence than the wider critical longwalls through reduction in the height of fracturing. An outcome of the significantly less subsidence was that impacts on sensitive surface features was minimised.

A comprehensive multi-disciplinary risk-based approach to mine planning and mine design resulted in the following controls being implemented.

- Proposed longwalls LW501 to LW503 have been positioned between clusters of cliffs; only one cliff lies over LW501. Previously approved LW419 to LW422 have been shortened to avoid cliffs and pagodas.
- The mine plan has been modified to avoid most of the pagodas, however a limited number of pagodas exist above LW501 and LW502.
- The proposed longwalls in the Project Application Area which lie beneath Newnes Plateau Shrub Swamps (LW416 – LW432) are designed to be sub-critical panels with void widths of 261 m, resulting in void width to depth of cover (W/H) ratios <1.00, and chain pillars at least 55 m wide.

The shrub swamps to be undermined are Sunnyside East, Carne West, Gang Gang South West, Gang Gang East, Pine Swamp, Pine Swamp Upper, Marrangaroo Creek, Marrangaroo Creek Upper and Paddys Creek Swamps.

Carne Central, Barrier, Sunnyside and Nine Mile Swamps have been avoided in the mine design. The potential impacts of the Project on the watercourses overlying the mining area are discussed in Section 10.1.3.2 of the EIS while the environmental consequences of the potential impacts are discussed in Section 10.1.3.3. The mine plan (Figure 4.2 in the EIS) shows Wolgan River will not be undermined and nor will it be within the 26.5 degree angle of draw. The closest that mining will approach Carne Creek is approximately 400 m southeast of LW1019. The unnamed watercourses above the mining area drain into either Wolgan River or Carne Creek and are predicted to experience subsidence movements noted in Table 8.1 in the EIS. Cracking is predicted in these watercourses although net loss of water from the catchment is not predicted as any diverted water is expected to re-emerge downstream. Springvale Mine and Angus Place Colliery have previously extracted longwalls from beneath more than 40 km of watercourses and monitoring shows that any impacts to surface water flows are transient at worst.

Section 10.1.5.3 of the EIS notes that no subsidence effects to swamp hydrology or flora communities have been identified in areas where sub-critical panels are implemented. The height of fracturing resulting from the extraction of these longwalls is contained below the 22 m thick Mount York Claystone aquitard ie, the Mount York Claystone prevents the mining induced fracturing in the strata above the coal seam to the surface. The limited extent of the downward cracking from the surface means that fracturing and dilation of bedrock of shrub swamps would not result in losses of infiltrated water, and minimal divergence of surface water would occur. It follows then that it is unlikely that subsidence effects would have an adverse impact on shrub swamps and hanging swamps such that the ecological functioning of these swamps would be impaired. No previous subsidence effects to swamp hydrology or flora communities have been identified above sub-critical longwall panels.

Tables 4 and 5 in Appendix I of the EIS (Table 10.14 and Table 10.15 in the EIS), respectively, provide summaries of outcomes of the TSC Act 7 part test and the EPBC Act Assessment of Significance for Stuttering Frog, Giant Burrowing Frog, Littlejohn’s Tree Frog (listed under both TSC Act and EPBC Act) and Red-crowned toadlet (listed under the TSC Act) that have been recorded or are expected to occur in the Project Application Area. Full details of the assessments are provided in Appendix 1 (TSC Act 7 part test) and Appendix 2 of the Flora and Fauna Impact Assessment (Appendix H of the EIS) and should be reviewed in conjunction with the review of information presented in table noted above.

Conclusions drawn from the Flora and Fauna Impact Assessment (Appendix H of the EIS) are as follows:

- No potential breeding habitat would be removed for the Giant Burrowing Frog, Stuttering Frog, Red-crowned Toadlet or Littlejohn’s Tree Frog although the proposed clearing in the Project may cause a loss of potential foraging habitat for these species.

- Breeding habitat of these species may occur as a result of subsidence causing minor cracking and tilting, however the impacts would be isolated and often short term. Subsidence may also cause ponding in localised areas, which may create additional breeding opportunities for these species.

The overall conclusion is that given:

- suitable habitats for these species occur widely through the Newnes Plateau and more preferred habitat, in the form of small headwater creek lines and slow flowing to intermittent creek-lines, occurs throughout the wider Blue Mountains area, and

- the habitats within the Project Application Area are only a small proportion of the available habitat within the locality, much of which is conserved within the nearby national parks

As such, the Project is unlikely to affect the lifecycle of Giant Burrowing Frog, Stuttering Frog, Redcrowned Toadlet or Littlejohn's Tree Frog as a result of clearing or subsidence, such that a local population of these species is likely to be placed at risk of extinction.

**Swamp ecosystems cannot be replanted or repaired following damage by longwall mining. (LEG)**

A considerable amount of effort has been invested by the Blue Mountains City Council (BMCC) to date to investigate ways in which swamps can be rehabilitated, as discussed below.

The BMCC Upland Swamp Rehabilitation Program was commenced in 2006 after Blue Mountains Swamps were listed nationally as part of the Temperate Highland Peat Swamps on Sandstone (THPSS) endangered ecological community, with the aim of protecting and restoring Blue Mountains Swamp across the local government area (LGA).

In August 2008 the BMCC and Lithgow City Council formed a partnership to deliver the 'Save our Swamps' project to restore THPSS across both LGAs supported by grant funding of $250,000 over 3 years from the Urban Sustainability Program of the NSW Environmental Trust. The 'Save our Swamps"' project has been since then assisting in the management and conservation of THPSS ecological community across the Blue Mountain and Lithgow LGAs.

In 2009 the 'Save our Swamps' project received a $400,000 federal 'Caring for Country' grant to expand the program to incorporate Wingecarribee Shire Council and Gosford City Council.

The innovative integrated and landscape scale approach to the management of THPSS has resulted in the 'Save our Swamps 'project receiving four awards including:

- National Governments Local Government Award for Innovation in Natural Resource Management 2010;

- United Nations World Environment Day Award for Excellence in Overall Environmental Management 2011 (Special Commendation);

- NSW Sustainable Cities award for Biodiversity Conservation 2010; and

- National Keep Australia Beautiful (Tidy Town award) for Biodiversity Conservation 2011.

As part of a collaborative approach to information and skill sharing the practical knowledge and lessons learnt from the Save Our Swamps project, BMCC has developed a practical set of guidelines entitled

"Soft engineering solutions for swamp remediation - a 'how-to' guide". The guide was created by Blue Mountains City Council with the assistance of Lithgow City Council, Gosford City Council, Wingecaribee Shire Council. This publication comprehensively covers soft engineering swamp rehabilitation applications, techniques and materials. It also covers background information on swamp geomorphology, threats and impacts to Temperate Highland Peat Swamps on Sandstone swamps.

The ‘How to guide’ includes case studies on successful implementation of remediation to THPSS comprising:

- Braeside Swamp located in the Blue Mountains LGA;
- Marmion Swamp located in the Blue Mountains LGA;
- Wentworth Falls Swamp located in the Blue Mountains LGA;
- Happy Valley Swamp located in the Lithgow LGA;
- Ellem Gully Swamp located in the Gosford LGA; and
- Paddys River Swamp located in the Wingecarribee LGA.

In addition to the Save our Swamps recognised success at remediation of THPSS, Springvale Coal has recently applied for approvals from DotE and OEH to enable rehabilitation works on East Wolgan Swamp to be carried out. These applications were made on 16 August 2012. Springvale Coal obtained approval from the former Federal Department of Sustainability, Environment, Water, Populations and Communities on 21 September 2012. OEH approved the undertaking restoration actions at East Wolgan Swamp and issued a certificate under Section 95 of the Threatened Species Conservation Act 1995 (TSC Act) on 25 November 2013. A specific rehabilitation strategy has been prepared to prevent further impacts to East Wolgan Swamp and to assist the recovery of the swamp vegetation community.

This strategy has been approved by DotE and OEH and rehabilitation works are currently being conducted. Rehabilitation works at East Wolgan Swamp commenced in January 2014 and the following activities are being undertaken:

- detailed vegetation mapping (before rehabilitation)
- swamp re-hydration works- construction and strategic placement of coir logs, sandbag and jute mesh weirs.
- direct seeding - collecting seeds off targeted species already within the swamp and placing in rehabilitation area.
- brush matting - collecting branches from vegetation in the area adjacent and placing it in the rehabilitation area to encourage and provide cover for new growth.

Excavation and rehabilitation of the slumping sites will be conducted after the summer thunderstorm season, which has caused high intensity rainfall events over the past several years. These events have caused significant erosion of swamp peat / soil at the slumping sites in East Wolgan Swamp and it is intended to avoid rehabilitation works of these sites during this period.

Rehabilitation activities at the East Wolgan Swamp will continue until the success criteria detailed within the rehabilitation strategy have been achieved. **Figure 1**, **Figure 2** and **Figure 3** show the progress of rehabilitation undertaken to date.

Based on the successful implementation of remediation techniques for the rehabilitation of THPSS using BMCC’s ‘How to guide’ described above for many shrub swamps noted above, Centennial Coal considers the success of the rehabilitation of the East Wolgan Swamp to be high.

**Important terrestrial and stream environments in this significant part of the Gardens of Stone region must not be damaged by longwall mining but instead protected in a state conservation area. (SCSGBM)**

1,860 hectares of land is within the potential subsidence impact area. As detailed in Section 6.5 of the flora and fauna impact assessment, provided as Appendix H to the EIS, flora and fauna monitoring undertaken at Springvale Colliery since 2005 has not recorded any losses to threatened species populations or EECs as a result of subsidence. This is due to appropriate mine design to limit subsidence to acceptable levels.

The mining layout for the Project has been designed to minimise the potential for impacts and so the majority of the cliffs and pagoda complexes are located outside the 26.5 degree angle of draw line from the extents of the proposed longwalls. No impacts are expected to these features and, subsequently, no impacts would be expected to potential habitats of those threatened species that may utilise these habitats.

No significant impacts to the dry woodland and forest habitats are predicted as a result of subsidence. Destabilisation of slopes is unlikely to be substantial such that it would significantly affect threatened flora or fauna that may occupy woodland environments.

Section 6.7.4 of the Flora and Fauna Impact Assessment includes an assessment of impacts on the Projects impacts on the Gardens of Stone National Park which is part of the Greater Blue Mountains Area (GBMA). The GBMA is a World Heritage Property and National Heritage Place which occurs approximately 6 km to the east of the Springvale Mine’s northern longwall block and approximately 7 km to the north.

DoE (2013) provides Significant Impact Assessment criteria for World Heritage Properties and National Heritage Places. The Flora and Fauna Impact Assessment includes an assessment of the potential impacts from the Project against the DoE criteria. In summary, the proposed surface disturbance areas are surrounded by large areas containing contiguous forest, woodland, heath, swamp and rocky habitats. These habitats continue throughout the Newnes State Forest and into the Gardens of Stone National Park, Blue Mountains National Park and Wollemi National Park. For those more mobile species, including the threatened birds, bats, arboreal mammals and terrestrial mammals, which are likely to be impacted upon by the Project, local populations of these species would extend into these adjacent protected habitats. Those less mobile fauna, such as threatened frogs and the Blue Mountains Water Skink, have specific habitat niches important for their survival, which are not represented within the defined environmental study areas for the Project, and therefore no impacts are expected to these species.

The proposed clearing of 11.4 ha is unlikely to reduce the diversity or modify the composition of plant and animal species within the GBMA. However, habitats for fauna species that may occupy both the Project Application Area and the GBMA as part of their home range will be subject to a minor reduction in habitat due to proposed clearing.

Given the above considerations, the Project is not expected to lead to indirect impacts from clearing, be significantly affected by subsidence or be affected by changes in water quality. Therefore, the Project is unlikely reduce the diversity or modify the composition of plant and animal species within any part of the GBMA.

No direct or indirect impacts are expected that would fragment, isolate or substantially damage habitat for rare, endemic or unique animal populations or species, or habitat that is important for the conservation of biological diversity within the GBMA.

As is detailed in Section 5.15 of the Subsidence Assessment prepared by MSEC and provided as Appendix D to the EIS, the Gardens of Stone National Park is located more than 7 km north of the proposed northern longwalls in the Springvale mine plan. At this distance, the National Park will not experience any measurable subsidence movements resulting from the extraction of the proposed LW416 to LW432 and LW501 to LW503.

Consequently, the Project is not expected to cause a long-term reduction in rare, endemic or unique plant or animal populations or species within the GBMA.

### 3.2.5 Economic

**Various – The Australia Institute raised a number of concerns in relation to the adequacy of the Economic Assessment for the Project in the context of:**

- **Its compliance with 'state and federal guidelines' for preparation of cost benefit analyses; and**
- **Its failure to 'meet standards expected in the economics profession'. (TAI)**

A response to the issues raise by The Australia Institute has been addressed in a report titled "Springvale and Angus Place MEPs – Response to Submission by the Australia Institute' prepared by Aigis Group and provided as **Appendix 5** to this RTS.

### 3.2.6 General

**The proposed 15 year Consent Period is far too long given the history of 'unforeseen' impacts associated with Angus Place and Springvale Colliery's including cliff falls, swamp deaths, and water quality breaches. Planning consent should be limited to a maximum of 5 years, and must be subject to performance 'triggers' that ensure the health and integrity of nationally endangered swamps, the Coxs River and Sydney Drinking Water Catchment, and national and World Heritage values. If the trigger levels are exceeded then the Consent should be reviewed to address any failures. (BMCS)**

Springvale Coal is seeking approval for continued operations for 13 years from date of consent. The proposed Project is a life of mine project and has been designed in accordance with the principles of ecological sustainable development (ESD).

A wide range of technical assessments were undertaken to assess the potential impacts of the Project on the environment by specialist consultants with many years' experience in their respective areas of expertise. Controls were adopted at the design phase of the Project where potential impacts could not be avoided. Impacts have been minimised as far as practical through the mine design and surface infrastructure positioning which have already taken into account a number of surface, geological and environmental constraints. Most importantly, the controls are based on previous Springvale Mine's experiences in longwall mining and infrastructure establishment, including extracting longwalls of varying void widths. Furthermore, mitigation measures recommended in the technical assessments will be adopted as relevant at the implementation phase of the Project to ensure potential impacts are managed appropriately.

The suite of existing environmental management plans, to be updated for the Project, have been developed on a risk-basis to appropriately identify, mitigate and manage environmental risks, and provide procedures for the ongoing management and monitoring of Springvale Mine in line with the objectives of ESD. Environmental performance reporting of actual versus predicted impacts will continue to be undertaken annually as part of the Springvale Mine's Annual Review reporting requirements. The Annual Review is made publicly available on the Centennial Coal website. Accordingly, Springvale Coal contends that the Project will meet environmental performance and should be considered for approval for the proposed 13 years project life.

Lastly, the consent period of 13 years is required to ensure the sustainable operations at Springvale Mine and this project life will provide a level of certainty to the company to ensure the continued ongoing employment Springvale Mine provides.

**The Angus Place and the adjoining Springvale mine extension proposals must be subject to a Planning Assessment Commission review with concurrent Public Hearings. (SCSGBM)**

Determination of the Angus Place MEP and the Springvale MEP will be by the NSW Planning and Assessment Commission following public hearings for both projects. The Planning and Assessment Commission will determine how these public hearings are structured.

### 3.2.7 Historic Impacts

**Various special interest groups have raised concerns regarding a number of impacts considered to be attributable to the mining operations of Angus Place Colliery. These historic issues raised can be summarised into 5 specific areas which include:**

- **Loss of water flow in creeks as a result of subsidence cracking;**
- **Changes to ecological communities;**
- **Impacts to water quality;**
- **Impacts to swamps; and**
- **Cliff falls. (Various)**

Springvale Coal acknowledges that previous mining has resulted in some localised impacts to the environment as a result of its operations. As discussed in Section 2.6.2.7 of the EIS, surface impacts have been observed at five shrub swamps (Kangaroo Creek Swamp, Narrow Swamp North, Narrow Swamp South, East Wolgan Swamp, Junction Swamp). Numerous investigations have been undertaken and extensive monitoring launched by both Angus Place Colliery and Springvale Mine to understand the causal factors involved. These are discussed below.

An independent investigation by Goldney et al (2010), undertaken on behalf of the then Commonwealth Department of, Environment, Water, Heritage and the Arts (DEWHA), found that the major cause of most of the impacts at Narrow Swamp North and Narrow Swamp South was mine water discharge and not subsidence related ground movements. Impacts at East Wolgan Swamp and Kangaroo Creek Swamp appear to have been caused by a combination of subsidence-related ground movements, mine water discharge and erosion, with the particular contribution of subsidence impacts unable to be quantified.

Since 2002, Springvale Mine has been involved in intensive monitoring, investigations and research to better understand the surface environment overlying the mining areas. These investigations have included groundwater, surface water, ecological aspects and the interplay of these aspects on swamps. The data collected and analysed over the past 11 years has been critical to proving that the technologies and engineering methodologies for longwall mining will minimise impacts to sensitive surface features

At Springvale Mine, the application of risk based planning, has driven mine planning, mine design and subsidence management, based on the geological and geotechnical constraints, and the overlying sensitive features.

As detailed in Section 8 of the EIS, the approach of Springvale Mine to the MEP has been to apply a best practice system of environmental management: that is a hierarchy of avoiding, minimising, mitigating and finally, offsetting residual impacts.

In a general chronology, the following steps have been taken to design the Project:

- a detailed geological investigation to delineate the target coal seams and understand associated strata;
- a detailed geotechnical investigation to understand important structures such as faulting that can affect how mineable certain areas of coal are, and the way in which subsidence might occur in these areas;
- a detailed investigation of natural underground features;
- a detailed survey of natural surface features such as cliffs, pagodas, swamps and watercourses;
- a first pass consideration of subsidence effects based on unlimited extraction across the Project area and the subsequent elimination of avoidance areas from further mining consideration;
- the formulation of mine design alternatives based on remnant available areas and potential environmental impacts;
- a detailed cost benefit analysis of the alternate mine designs to select a preferred option;
- detailed subsidence predictions of the preferred mine plan to identify further required avoidance areas or specific mitigation measures required; and
- a consideration of existing approval requirements that may impact upon the Project.

There are two management strategies for avoiding or minimising the impacts to sensitive surface features as a result of mining. These are:

- Avoid mining under the sensitive surface feature; or
- Mine design under the sensitive surface feature has a sub-critical void width.

The following controls have been applied through the mine design process to minimise impacts to the environment:

- proposed longwalls LW501 to LW503 have been positioned between clusters of cliffs. LW419 to LW422 have been shortened to avoid cliffs and pagodas;
- the proposed longwalls in the Project Application Area which lie beneath Newnes Plateau Shrub Swamps (LW416 – LW432) are designed to have sub-critical W/H ratios and chain pillars at least 55 m wide.

In addition, the Project does not propose any mine water discharge to the THPSS on the Newnes Plateau and therefore there is no proposed change to flow variability in those catchments.

As a result of impacts identified to swamps in the past, Centennial Angus Place and Springvale Coal have modified the mine design to minimise the potential risk of these impacts occurring into the future. Table 2.6 in the EIS is reproduced below as **Table 23** to emphasise the changes made to the mine layout through the mine design process for the Project to reduce the potential for impacts to swamps to occur in the future.

**Table 23 - Causal Factors to East Wolgan Swamp Impacts and Management Response**

| Causal Factors | Management Response |
|---|---|
| Mine water discharge | Cease mine water discharge to Newnes Plateau (including proposed underground water storage for future emergency mine water discharges).<br>NB. No Newnes Plateau discharges since April 2010. |
| Intersection of major geological fault structures | Major geological structure zones identified through detailed topographic, geological and geophysical analysis, The relationship between mine subsidence, geological faulting and groundwater response is well understood from historical monitoring data(based on piezometers, extensometers, subsidence monitoring (terrestrial and LIDAR), exploration borehole data). This understanding is used in the mine planning and design process to ensure that combinations of risk factors do not occur in future mining areas in the Project Application Area. |
| Orientation of longwall panels sub-parallel to major structures | Angle of orientation increased for future swamps e.g increase to 24o for Carne West and 51o for Sunnyside East. |
| Steepness and depth valley containing swamps | Surface topography is well understood from Digital Terrain Model. Analysis of topographic and subsidence data identified no measured impacts at slope angles <18°. |
| In situ stress direction and magnitude | Horizontal stress orientation mapped through exploration borehole geophysical testing / analysis. Horizontal stress magnitude measured through installation of instrumentation in surface to seam boreholes and in the roof at seam level. |
| Critical width longwall panel design | Future longwalls in the vicinity of swamps are based on Subcritical panel design. |
| Location and orientation of geological structure adjacent to the permanent barrier pillar | Future Mine workings designed to avoid alignment of major geological structure zones sub-parallel with edge of permanent barrier pillar subject to multiple panel subsidence effects. |
| Subsidence Interaction of Adjacent Angus Place and Springvale Workings | Springvale and Angus Place future mining areas are not adjacent to each other (separated by over 500m) thus interaction will be avoided. |

The impacts predicted in the EIS are based on extensive monitoring data, robust modelling and a comprehensive understanding of the environment in which the Project will operate. It has been determined that the impacts experienced in the past are unlikely to occur as a result of the Project and any impacts would not be significant. Should impacts be identified, an adaptive management approach will be developed to manage impacts into the future.

**Centennial Coal must not be allowed to simply replicate the damage it has already caused to nationally threatened upland swamps on the Newnes Plateau for which it was required by the Commonwealth Government to pay $1.45 million in reparations. (NCC and SCSGBM)**

Centennial Coal acknowledges in Section 2.6.2.7 of the EIS the historical impacts to Swamps as a result of previous mining and mining related activities. Longwalls have been extracted directly or partially beneath 13 shrub swamps and 26 hanging swamps. Surface impacts have been observed at five swamps including Kangaroo Creek Swamp, Narrow Swamp North, Narrow Swamp South, East Wolgan Swamp and Junction Swamp. These have been investigated and where impacts have been observed, these have been identified as largely the result of mine water discharge, discussed in Section 1.3.2.

Investigations have identified that erosional and flora dieback impacts at Narrow Swamp North, Narrow Swamp South, East Wolgan Swamp and Junction Swamp were caused by changes to swamp hydrology related to mine water discharge and were not related to subsidence. As a result of this finding, future mine dewatering systems have been designed to ensure that discharge of mine water to Newnes Plateau Shrub Swamps is avoided.

Subsidence effects to aspects of swamp hydrology have been noted at two swamps (Kangaroo Creek Swamp and East Wolgan Swamp). In both of these cases investigations have revealed that mine design was a primary causative factor. The ratio of longwall mining void width to depth of cover over mine workings was identified to be in the critical subsidence behaviour range. Following this investigation, the mine design was modified for all future proposed mining areas in the vicinity of Newnes Plateau Shrub Swamps to ensure that the ratio of longwall mining void width to depth of cover over mine workings was in the sub-critical subsidence behaviour range. No subsidence effects to swamp hydrology or flora communities have been identified in areas where sub-critical mine design have been used in the past.

Section 2.8.4 of the EIS details the cause and outcomes of an Enforceable Undertaking under section 486DA of the EPBC Act. Centennial Coal acknowledged that its operations had a significant impact on THPSS, a federally listed endangered ecological community and as such Springvale Coal Pty Limited and Centennial Angus Place Pty Limited undertook to pay $1,450,000 for a four year research program.

The objectives of this research program are to:

- Provide the necessary knowledge to conserve, manage and restore THPSS;
- Use that knowledge to promote best management practices for these areas;
- Transfer knowledge gained in the program to agencies, land managers and relevant stakeholders; and
- Maximise the educational and training opportunities of the Program.

The research themes under the program are:

- Understanding the THPSS which includes detailed mapping, location, distribution and extent of the swamps, including those under threat.
- Understanding swamp systems, including water balance and dynamics, the functionality of peatland swamps, environmental history and origins, ecology/biodiversity of major structural species and contribution of THPSS to the landscape.
- Understanding land management and impacts, including condition status mapping and trends.
- Application of understanding, including monitoring of reference sites and thresholds for recovery and resilience.

In 2012, approximately $900,000 of the research fund had been allocated to five projects, with additional funding set aside to support swamp hydrology research when a suitable project was identified by the Steering Committee. The Committee meets twice annually and holds an annual workshop to review the status of the research findings and outcomes.

**Local mining history has demonstrated that subsidence damage and/or eco-toxic mine water effluent discharges from Angus Place and Springvale Colliery's have caused irreparable damage to a Federally Listed Endangered Ecological Community THPSS at Junction Swamp, Narrow Swamp, East Wolgan Swamp, Kangaroo Swamp, and Lamb's Creek Swamp. That is clearly an unacceptable situation. (BMCS)**

Springvale Coal acknowledges in Section 2.6.2.7 of the EIS the historical impacts to Swamps as a result of previous mining and mining related activities. Longwalls have been extracted directly or partially beneath 13 shrub swamps and 26 hanging swamps. Surface impacts have been observed at five swamps including Kangaroo Creek Swamp, Narrow Swamp North, Narrow Swamp South, East Wolgan Swamp and Junction Swamp. These have been investigated and where impacts have been observed, these have been identified as largely the result of mine water discharge.

Investigations have identified that erosional and flora dieback impacts at Narrow Swamp North, Narrow Swamp South, East Wolgan Swamp and Junction Swamp were caused by changes to swamp hydrology related to mine water discharge and/or subsidence. While mine water discharges was the primary causative factor, in the cases of Kangaroo Creek Swamp and East Wolgan Swamp subsidence-related impacts were also contributing factors. This finding is supported by Goldney et al (2010), an independent investigation undertaken on behalf of the then Commonwealth Department of, Environment, Water, Heritage and the Arts (DEWHA), who agreed that the major cause of most of the impacts at Narrow Swamp North and Narrow Swamp South was mine water discharge and not subsidence related ground movements. Impacts at East Wolgan Swamp and Kangaroo Creek Swamp were caused by a combination of subsidence-related ground movements, mine water discharge and erosion, with the particular contribution of subsidence impacts unable to be quantified.

As a result of this finding, future mine dewatering systems have been designed to ensure that discharge of mine water to Newnes Plateau Shrub Swamps is avoided.

Investigations of subsidence impacts to aspects of swamp hydrology changes identified at Kangaroo Creek Swamp and East Wolgan Swamp have revealed that mine design was one of the co-incident causative factors. The ratio of longwall mining void width to depth of cover over mine workings was identified to be in the critical subsidence behaviour range. Following this investigation, the mine design was modified for all future proposed mining areas in the vicinity of Newnes Plateau Shrub Swamps at Springvale Mine to ensure that the ratio of longwall mining void width to depth of cover over mine workings was in the sub-critical subsidence behaviour range. No subsidence effects to swamp hydrology or flora communities have been identified in areas where sub-critical mine design has been used in the past.

**In addition to mine subsidence and mine water discharge damage there are other mine related impacts to endangered swamps which must be avoided. For example, LEG believes that the trail bike tracks below running from Campbell's Road down into East Wolgan Swamp were initially started by Consultants monitoring for Springvale and/or Angus Place Colliery, and subsequently have been used by other trail bike riders. The resultant erosion gullies are very deep and is**

**causing localised drying out of a hanging swamp. We believe that Centennial should be required to remediate the tracks put in by their Consultants. (LEG)**

Springvale Mine has adopted a progressive approach to rehabilitation to reduce and mitigate potential environmental impacts. Exploration sites, ventilation and dewatering facilities and access tracks are rehabilitated promptly with periodic inspections and maintenance as necessary based upon evidence of endemic regrowth, weeds and soil disturbance.

As proposed in Section 8.1.1.3 of the Rehabilitation and Decommissioning Strategy prepared by SLR to support the Project and provided as Appendix P to the EIS, access tracks upgraded or established as part of the Project on the Newnes Plateau will remain for use as access tracks by recreational users and by Forestry Corporation of NSW.

As detailed in Section 10.3.7 of the EIS, Centennial Coal's monitoring effort on the Newnes Plateau is extensive and contributes to an increase in other anthropogenic impacts, such as recreational 4WDs, through the establishment of access tracks for monitoring. Should the current suite of monitoring persist, these incidental (but not insignificant) impacts will continue across the Newnes Plateau, placing greater pressure on areas where conservation values are currently retained.

The monitoring program proposed as part of the Regional Biodiversity Offset Strategy will be regionalised with greater effort on remote sensing data collection across a wider distribution of the Newnes Plateau and will focus on supporting research into rapid mapping techniques and defining vegetation community boundaries. This will reduce the potential impacts on the Newnes Plateau from monitoring by consultants.

To compensate for the clearing required for new surface infrastructure, Centennial Coal has developed a Biodiversity Strategy that that takes into consideration both the direct impacts of clearing potential habitat and indirect impacts to the Temperate Highland Peat Swamps on Sandstone, incorporating Newnes Plateau Shrub Swamps and Newnes Plateau Hanging Swamps. Details of the offset strategy proposed to be implemented are detailed in the revised Regional Biodiversity Offset Strategy (September 2014) provided as **Appendix 4** of this RTS.

**Bushfire is a serious problem for damaged swamps, as the peat can burn deeply, can massively accelerate erosion, and subsequently affect natural regeneration. Centennial's rehabilitation efforts at East Wolgan Swamp could all be gone in a matter of minutes. It is better not to damage swamps in the first place, but when they have been damaged some fire management planning must be undertaken by those responsible. (LEG)**

Bushfire risk management within the Newnes State Forest is undertaken by Forestry Corporation of NSW, and is not the responsibility of Centennial Angus Place or Springvale Coal.

The applications for the rehabilitation works at East Wolgan Swamp were submitted to the former SEWPAC (now Department of the Environment) on 16 August 2012. Approval from the then SEWPAC was received on 21 September 2012 while the approval from OEH under Section 95 of the TSC Act was not received till 25 November 2013. Rehabilitation works on the East Wolgan Swamp were commenced in January 2014 and the rehabilitation works have progressed to a stage where the peat is no longer exposed, as shown in **Figure 39**.

It should be pointed out that it is not only the "damaged swamps" that can be impacted by bushfires. Section 10.14.4 of the EIS assessed the general area of Newnes Plateau encompassing the Springvale and Angus Place Project Application Areas as defined bushfire category of Level 3 or Extreme in accordance with RFS (2006). Bushfires do occur with high frequency on Newnes Plateau, with the last major bushfire observed in mid-October 2013. In this bushfire event Gang Gang Shrub Swamp was impacted, as shown in **Figure 39**, however the natural regeneration of the swamp commenced within a few weeks of the bushfire damage (**Figure 40**). **Figure 41** shows the swamp approximately 10 weeks after the bushfire.

**Figure 39 - Gang Gang Swamp following Bushfire Event of mid-October 2013**

**Figure 40 - Gang Gang Swamp on 30 October 2013 showing Onset of Natural Regeneration**

Figure 41 - Gang Gang Swamp approximately 10 Weeks after the Bushfire in Mid-October 2013

Fire management planning is undertaken by both Angus Place Colliery and Springvale Mine. Given the high risk of bushfire risk on Newnes Plateau, Centennial Angus Place and Springvale Coal have reduced the operational risk of bushfire through incorporation and avoidance measures in the MEP designs. Section 10.14.4.3 of the Angus Place EIS and Section 10.14.4.4 of the Springvale EIS discuss in detail the mitigation measures that have been or will be implemented in the projects. These include:

- incorporation of adequate (minimal 20-metre) Asset Protection Zones around all proposed infrastructure (dewatering bore facilities, ventilation facility, mine services borehole area)

- trenching 11 kV power cables to dewatering borehole sites which avoids the potential for overhead lines to trigger bushfires (or be destroyed by bushfires)

- undertaking a number of bushfire risk management procedures, as outlined in Section 10.14.4.4 of the EIS.

Angus Place Colliery and Springvale Mine have established Bushfire Management Plans and Bushfire Management Procedures, in consultation with NSW Rural Fire Service, which identify both the risks posed by bushfire to the mine assets on Newnes Plateau and control strategies to mitigate these risks. Conversely, the control strategies ensure that no bushfires on Newnes Plateau are ignited by the high voltage equipment located within the mine infrastructure facilities.

### 3.2.8 Mine Design

**Centennial Coal must be required to consider alternative bord and pillar mining methods for its proposed Springvale extension. Centennial's Airly mine in the Capertee Valley operates to a depth of 405 metres underground in the same geology. If Centennial can operate Airly Colliery as a bord and pillar mine, then it can also operate Springvale mine in this manner. (The Colo Committee)**

**Bord and pillar is a clearly more benign process, and has been practiced at Centennial's nearby Clarence Colliery. However, in this instance, the mining method was chosen for reasons of engineering safety (the stope back was too solid to collapse in a controlled manner) rather than any display of environmental sensitivity. (BMCS)**

**The mining footprint must be significantly lessened and mining methods reduced in intensity to protect Carne Creek, pagodas, cliffs and the nationally endangered swamps of the proposal area. Centennial Coal must be required to consider alternative bord and pillar mining methods for the proposed extension to Springvale Colliery. Centennial's Airly Mine in the Capertee Valley operates to depth of 405 metres in the same geology, which includes bad mine roof conditions and many structural features. If Centennial can operate Airly Colliery as a bord and pillar mine, then it can also operate Springvale mine in this manner. (Colong Foundation)**

**The mining footprint of the Springvale Mine Extension must be significantly lessened and the intensity of mining methods reduced to protect nationally endangered swamps, Carne Creek, pagodas and cliffs. Centennial Coal must be required to consider alternative bord-and-pillar mining methods in these environmentally sensitive areas. (LEG)**

As is detailed in Section 8.2.2 of the EIS, the combination of a weak roof and a high stress environment means that longwall mining in the Lithgow seam at Springvale Mine is the only viable and safe mining method. Strata Engineering Pty. Ltd (Australia) in Report No. 03-123-AGP-33 identify that in Australia there is no known precedent for safe and viable partial extraction (i.e. bord and pillar) operation in the geotechnical environment under consideration within the Project Application Area.

The geological and geotechnical constraints to mining, combined with the extensive knowledge of the hydrogeological environment has resulted in a mine design that is reflective of decades of mining experience at the Angus Place Colliery and Springvale Mine and there has been significant effort to prioritise avoidance and reduction of potential impacts and constraints of surface features and geological and geotechnical issues, while considering mine safety, feasibility and optimisation. The mine has been designed to avoid, to the largest extent possible, sensitive surface features. Where a sensitive surface feature has not been avoided, a sub-critical void width has been applied in the mine design.

**The intensity of longwall mining is reduced so that all nationally endangered swamps are protected – this includes significantly narrowing longwalls in the northern longwalls 416 to 422 to prevent surface cracking under the best developed, largest and most intact swamps on Newnes Plateau; Shortening longwalls 432, 431, 430 and 429 to prevent damage to the Marrangaroo swamps, and shortening longwalls 425 and 426 to prevent Paddys Creek Swamp; Longwall 501 should also be shortened to protect cliffs and pagodas. (The Colo Committee, BMCS and LEG))**

Chapter 8 of the EIS details the evolution of the mine design at Springvale Colliery and how the mine design proposed for the Project has been developed taking into consideration safety, geological and environmental features.

Springvale Mine has applied a risk based approach to the Project to identify, quantify and reduce risks of environmental consequences wherever feasible. Previous subsidence monitoring has been used to develop and validate a predictive model of subsidence for the proposed mining area. This model has a high level of confidence in its predictions and is built upon a significant dataset comprising geological and geotechnical data. The mine has been designed to avoid, to the largest extent possible, sensitive surface features. Where a sensitive surface feature has not been avoided, a sub-critical void width has been applied in the mine design.

The geological and geotechnical constraints to mining, combined with the extensive knowledge of the hydrogeological environment has resulted in a mine design that is reflective of decades of mining experience at the Angus Place Colliery and Springvale Mine.

The approach of Springvale Mine to the MEP has been to apply a best practice system of environmental management: that is a hierarchy of avoiding, minimising, mitigating and finally, offsetting residual impacts.

Significant effort has been invested to evaluate the available coal resource and to avoid or minimise potential impacts that could be associated with the Project.

The primary objective of mine design is safety, underground and on the surface. By managing safety, the mine manages subsidence impacts on the surface and in turn manages environmental and social consequences. Springvale Mine has implemented two management strategies for avoiding or minimising the impacts to sensitive surface features as a result of mining. These are:

- Avoid mining under the sensitive surface feature; or
- Mine design under the sensitive surface feature has a sub-critical void width.

The following controls have been applied to the Project:

- proposed longwalls LW501 to LW503 have been positioned between clusters of cliffs. LW419 to LW422 have been shortened to avoid cliffs and pagodas;
- the proposed longwalls in the Project Application Area which lie beneath Newnes Plateau Shrub Swamps (LW416 – LW432) are designed to have sub-critical W/H ratios and chain pillars at least 55 m wide.

Potential environmental constraints have already been taken into account during the mine design process to ensure the Project is undertaken safely and in the most environmentally sensitive manner feasible. Where impacts are predicted, monitoring management and where appropriate, offset strategies, have been proposed to be implemented.

Section 8.3.4 of the EIS describes in detail the alternative mine layouts which considered further reduction in longwall widths as an option, including not mining under shrub swamps. This option did not represent a viable business case for Springvale Coal. It is not considered necessary to avoid the shrub swamps as the longwalls have been designed to be sub-critical panels. No subsidence effects to swamp hydrology or flora communities have been identified in areas where sub-critical mine design have been used in the past.

**All 1,860 hectares affected by the proposed longwall mining will be subject to surface cracking. Whole sub-catchments will be fractured to a depth of 15 to 20 metres. These fractures will link with remobilised faults and joints that extend across the area mined. Surface groundwater aquifers will become more permeable and interconnected. Centennial predicts surface aquifer drawdown in the Burralow Formation, the topmost strata and an unconfined aquifer, to range from 10 metres under ridges to 0.5 metres under shrub swamps. For such groundwater dependent swamps such a drop in groundwater level is significant because the peat will remain drier more often and for longer. (Colong Foundation)**

As detailed in Section 5.12.5 of the Subsidence Assessment prepared by MSEC and provided as Appendix D to the EIS, the surface cracking across the mining area is expected to be generally isolated and minor in nature. This is due to the reasonable depths of cover, which typically vary between 270 m and 450 m, and due to the plasticity of the surface soils which allows them to more readily absorb the ground strains. Surface crack widths are expected to be similar to those observed above the previously extracted longwalls at Angus Place and Springvale Collieries, which were typically between 5 mm and 25 mm, but with isolated surface cracking in some locations greater than 50 mm.

Section 10.2.3.1 of the EIS identifies that modelled drawdown indicates that there is minimal impact on surrounding groundwater users and groundwater works identified within the Project Application Area that have a cumulative impact of more than 2 m are not used for water supply purposes. This is compliant with Level 1 Minimum Harm Criteria of the NSW Aquifer Interference Policy for Porous Rock Water Sources. The predicted water table decline beneath shrub swamps themselves is <0.5 m. The greatest water level declines are predicted to occur beneath the upper reaches of the swamps where the swamps are generally above the water table and not reliant on groundwater. Monitoring indicates that this has not occurred.

RPS completed a study in November 2012 (RPS, 2012) to assess whether any impacts attributable to the undermining of the swamps could be ascertained based on swamps hydrographs and groundwater level trends. All of the swamps which were included in this study have a significant history of water level monitoring, are located away from licensed discharge points (to minimise potential for conflicting information), and have all been either undermined by longwall extraction or were in very close proximity to extracted longwall panels.

The results of the 2012 study showed that no water level impacts that could be attributed to past or present mining operations (subsidence-related impact or depressurisation) were observed. Rather, the water levels in the swamps showed a strong correlation to cumulative rainfall trends, and this was found to be the driving factor.

As no mining influenced water level fluctuations can be identified in any of the monitored swamps (both undermined and baseline) it is accurate to say that mining at Angus Place Colliery and Springvale Mine has not led to any identifiable water level impacts on the monitored swamps, and that all undermined swamps continue to display baseline water levels.

A Subsidence Impact Assessment was undertaken for the Springvale MEP by MSEC and provided as Appendix D to the EIS. Mining is predicted to cause maximum of 1650 mm of conventional subsidence above longwall extraction areas. Based on the predicted maximum strains calculated by the subsidence study it is likely that some fracturing will occur in the uppermost bedrock, beneath the surface soils/regolith. It has been observed in previous studies, that the depth of fracturing and dilation of the surficial lithologies, resulting from longwall mining, is generally less than 10 to 15 m.

This shallow fracturing will, in general terms, enhance shallow permeability, favouring infiltration of rainfall and surface water to the ground, and recharging the shallow aquifers hence reducing available runoff during rain events. In no case, is it expected that the infiltrated water will be lost to deeper aquifers since the fracturing will be only superficial (upper most 10 to 15 m) and is isolated from the deeper zones of connective vertical fracturing. It is likely that any infiltrated flow will re-emerge to the surface further downstream and with some degree of delay, contributing to prolong the base flow contribution to the watercourses

The predicted water table decline beneath the shrub swamps is predicted to range from negligible to <0.5 m with the greatest water level declines predicted to occur beneath elevated ridges and the upper reaches of the swamps where the swamps are generally above the water table and not reliant on groundwater.

The reliance of the shrubs swamps on groundwater from the perched aquifer system is due to the lateral groundwater flow along the low permeability aquitards and not the absolute water level within each aquifer. The predicted water level decline within the perched aquifer system is due to bed separation effects applied to the model that result in increased horizontal hydraulic conductivity. In many cases the decline in water table has meant a corresponding increase in lateral groundwater baseflow to the swamps and not a decrease.

Given the similarities of the proposed development with past operations, there is no reason to believe that the results of the proposed mining activities will cause any impacts where none have previously been observed.

The groundwater impact model predicts that some minor impacts to the shallow groundwater and baseflow will occur. However, it is considered that the groundwater modelling results are conservative, particularly in respect to the predicted impacts to baseflows. The model assumes dilation of horizontal 'plies' will occur through to ground surface, however, this has not been observed in the field. In any regard, the model is not able to replicate the self-healing nature of the creeks and swamps and as such, it is conservative, over-predicting the magnitude of potential impacts.

### 3.2.9 Monitoring

**The monitoring has not provided the necessary information to assist decision-makers regarding the damage to these swamps and streams. This could be as simple as the provision of clear images to regulators of the worst examples of dead swamp vegetation and streambed cracking. Groundwater monitoring bores, for example, meet regulatory requirements but do not appear to identify problems that can be observed in dying swamp vegetation. (Colong Foundation)**

Springvale Mine and Angus Place Colliery have an extensive and ongoing monitoring programme to monitor the impacts to swamps as a result of mining and mining related activities. The monitoring techniques employed since 2009 are wide-ranging and complementary, and the combined results provide multiple lines of evidence into roles that factors such as geology, hydrogeology, topography play in Newnes Plateau Shrub Swamp formation, and the effects of mine subsidence on these swamps. The results of investigations undertaken to date have allowed Angus Place Colliery and Springvale Mine to understand the multiple co-incident factors that have led to historical mining-related impacts and implement management practices to ensure mining impacts will be avoided in the future or can be managed appropriately.

**Subsidence monitoring should be by a third party agency, such as the Office of Environment and Heritage, and monitoring should be paid for by Centennial Coal. Monitoring of surface flow and near-surface groundwater monitoring must create a comprehensive picture of the sub-catchments affected by mining. Monitoring of changes in ecosystem condition must include well exposed, wide angle impacts of affected areas with GPS co-ordinates. (Colo Committee)**

Subsidence monitoring is undertaken by suitably qualified and certified surveyors registered with the Board of Survey and Spatial Information. Surveyors are required to keep their qualifications up to date to maintain their registration. All surveys are undertaken in accordance with relevant government guidelines. Subsidence monitoring is undertaken in accordance with agreed subsidence monitoring programmes detailed within an extraction plans and Subsidence Management Plan and within accuracy requirements determined by the NSW Division of Resources and Energy.

### 3.2.10 Physical Impacts

**Minimal impact is zero impact. Since the document then states that "Impacts that do arise would be managed by …" clearly indicates that impacts are expected, not minimised. (BMCS)**

The EIS details the proposed impacts of the Project. Springvale Coal acknowledges throughout the EIS that impacts will occur as a result of the Project. These impacts are based on detailed modelling, an understanding of the existing environment, and data collected over a number of years. Impacts have been minimised as far as practical through the mine design and surface infrastructure positioning which have already taken into account a number of surface, geological and environmental constraints. Where impacts are predicted, monitoring and management strategies have been identified to ensure the risk of impacts are further minimised and where residual impacts are predicted, they are offset where applicable.

### 3.2.11 Rehabilitation

**Progressive rehabilitation undertaken by Centennial has proven ineffective and incomplete. Many tens of kilometres of access roads have not been closed and rehabilitated. (NCC)**

**All past tracks and trails created by Centennial Coal and its consultants, including those established by trail bikes, should be recorded and plans set in place as soon as practicable to rehabilitate these trails on an on-going basis and as part of the rehabilitation program for this mine. (Colo Committee)**

As detailed in Section 3.13 of the EIS, the current approved MOP for Springvale Mine details the proposed rehabilitation objectives to ensure the final landform is commensurate with the surrounding topography and relevant zoning requirements of the time.

Springvale Mine has adopted a progressive approach to rehabilitation to reduce and mitigate potential environmental impacts. Exploration sites, ventilation and dewatering facilities and access tracks are rehabilitated promptly with periodic inspections and maintenance as necessary based upon evidence of endemic regrowth, weeds and soil disturbance. Rehabilitation acceleration techniques are undertaken, if required following approval from the Forestry Corporation of NSW.

The success of progressive rehabilitation activities is monitored against appropriate performance indicators identified within the Springvale EMS framework and relevant legislative requirements.

The new infrastructure components of the Project will require rehabilitation as a result of surface disturbance during construction. The progressive approach to rehabilitation will continue to be applied. The success of existing and future rehabilitation will be monitored against appropriate performance indicators identified within the rehabilitation strategy and MOP.

Conceptual Rehabilitation Success Criteria have been provided in Section 10.11 of the EIS. Rehabilitation activities will continue to be undertaken until these rehabilitation objectives are achieved.

### 3.2.12 Subsidence

**All 1,860 hectares affected by the proposed longwall mining will be subject to surface cracking. Whole sub-catchments will be fractured to a depth of 15 to 20 metres. (NCC)**

As detailed in Section 5.12.5 of the Subsidence Assessment prepared by MSEC and provided as Appendix D to the EIS, the surface cracking across the mining area is expected to be generally isolated and minor in nature, due to the reasonable depths of cover which typically vary between 270 m and 450 m, and due to the plasticity of the surface soils which allows them to more readily absorb the ground strains. Surface crack widths are expected to be similar to those observed above the previously extracted longwalls at Angus Place and Springvale Collieries, which were typically between 5 mm and 25 mm, but with isolated surface cracking in some locations greater than 50 mm.

**The mining footprint must be significantly lessened and mining methods reduced in intensity to protect Carne Creek, pagodas, cliffs and the nationally endangered swamps of the proposal area. (NCC)**

**There should be no surface cracking of stream beds, under swamps or of pagodas, rock outcrops or cliffs. (BMCS)**

As detailed in Section 5.4 of the Subsidence assessment provided as Appendix D to the EIS, fracturing of the uppermost bedrock has been observed in the past, as a result of longwall mining, where the tensile strains have been greater than 0.5 mm/m or where the compressive strains have been greater than 2 mm/m. It is likely, therefore, that fracturing would occur in the uppermost bedrock based on the predicted maximum strains. It has been observed in the past, that the depth of fracturing and dilation of the uppermost bedrock, resulting from longwall mining, is generally less than 10 m to 15 m.

Where the beds of the drainage lines comprise natural surface soils, it is possible that fracturing in the bedrock would not be seen at the surface. In the event that fracturing of the bedrock occurs in these locations within the alignments of the drainage lines, the fractures are likely to be filled with soil during subsequent flow events.

Where the beds of the drainage lines have exposed bedrock, there may be some diversion of surface water flows into the dilated strata beneath them and the draining of pooled water within the alignments. It is unlikely that there would be any net loss of water from the catchment, however, as the depth of dilation and fracturing is expected to be less than 10 m to 15 m and, therefore, any diverted surface water is likely to re-emerge into the catchment further downstream.

Carne Creek is directly above the proposed longwalls LW416- LW419. The predicted tilt of 0.25 mm/m, is less than the typical natural grade of Carne Creek, which ranges from 25 mm/m to 300 mm/m and therefore no significant ponding, flooding, scouring is predicted and is unlikely to have any adverse effect.

The maximum predicted valley related movements, due to the extraction of the proposed longwalls only, are 65 mm upsidence and 75 mm closure. It has also been predicted that the Carne Creek has already experienced valley related movements up to 270 mm upsidence and 330 mm closure due to the extraction of the existing longwalls at Angus Place and Springvale Collieries. No significant fracturing or surface water flow diversions have been observed along the river due to the existing mining. It is unlikely, therefore, that the extraction of the proposed longwalls would result in any significant fracturing or surface water flow diversions.

The Wolgan River is located at a distance of 460 m west of LW416, at its closest point to the proposed longwalls. It is unlikely, therefore, that fracturing would occur in the river as a result of the proposed mining. If any fracturing were to occur in the river, it would be expected to be isolated and minor in nature. Fractures would only be visible within the base of the river valley in exposed areas of bedrock. The fractures are expected to be shallow and discontinuous and, therefore, are not expected to result in any diversion of surface water flows into subterranean flows.

The surface cracking across the mining area is expected to be generally isolated and minor in nature, due to the reasonable depths of cover which typically vary between 270 m and 450 m, and due to the plasticity of the surface soils which allows them to more readily absorb the ground strains. Surface crack widths are expected to be similar to those observed above the previously extracted longwalls at Angus Place and Springvale Collieries, which were typically between 5 mm and 25 mm, but with isolated surface cracking in some locations greater than 50 mm.

Fracturing of the uppermost bedrock has been observed in the past, as a result of longwall mining, where the tensile strains have been greater than 0.5 mm/m or where the compressive strains have been greater than 2 mm/m.

The swamps which are located outside the extents of the proposed longwalls, including Sunnyside Swamp and Nine Mine Swamp, are predicted to experience tensile strains less than 0.5 mm/m and compressive strains less than 2 mm/m due to the proposed mining. It is unlikely, therefore, that the bedrock beneath these swamps would experience any significant fracturing.

Fracturing has been observed in streams located outside the extents of previously extracted longwalls in the NSW Coalfields. Minor and isolated fracturing has been observed up to 400 m from longwalls, however, these have occurred within large river valleys in the Southern Coalfield and have not resulted in any adverse impacts. Hence, it is possible that some minor and isolated fracturing could occur in the bedrock beneath the swamps located outside the extents of the proposed longwalls, however, it is unlikely to result in any adverse impacts on these swamps.

The swamps which are located directly above the proposed longwalls are predicted to experience tensile strains greater than 0.5 mm/m and compressive strains greater than 2 mm/m. It is expected, therefore, that fracturing would occur in the top most bedrock beneath these swamps.

The shrub swamps have peat layers which overlie the shallow natural surface soils and underlying bedrock along the alignments of the drainage lines. In most cases, cracking would not be visible at the surface within these swamps, except where the depths of bedrock are shallow or exposed. The shrub swamps comprise significant quantities of sediment and, therefore, fracturing of shallow bedrock beneath these swamps are likely to be filled with soil during subsequent flow events along the drainage lines.

Mining can potentially affect surface water flows through swamps, if the mining induced tilts are much greater than the natural gradients, potentially resulting in increased levels of ponding or scouring, or affecting the distribution of the captured water within swamps.

The maximum predicted tilts are 13 mm/m (i.e. 1.3%, or 1 in 75) for both the shrub swamps and hanging swamps within the mining area. As such, it is not expected, that there would be any adverse changes in ponding or scouring within the swamps resulting from the predicted mine subsidence movements. It is also not anticipated that there would be any significant changes in the distribution of the stored surface waters within the swamps as a result of the mining induced tilt or vertical subsidence.

The mining layout has been designed such that the majority of the cliffs and pagoda complexes are located outside the 26.5 degree angle of draw line from the extents of the proposed longwalls. There are some cliffs and pagoda complexes which have been identified within the 26.5 degree angle of draw line, however, they are all located outside the extents of the proposed longwalls. Whilst the cliffs and pagodas complexes could experience low levels of subsidence, they are not expected to experience any significant conventional tilts, curvatures or strains. These features are located along the valley sides and, therefore, are not expected to experience the valley related upsidence or compressive strains due to valley closure.

It is unlikely, therefore, that the cliffs and pagoda complexes would experience any adverse impacts resulting from the extraction of the proposed longwalls. This is supported by extensive experience from the NSW Coalfields, at depths of cover greater than 200 m, where no cliff instabilities have been observed where cliffs have been located wholly outside the extents of extracted longwalls.

**The western coalfield has a history of cliff collapses due to subsidence from longwall mining. As was demonstrated by the nearby Coalpac Consolidated Project, the companies involved greatly underestimated the level of cliff collapse that has already occurred. Conservation volunteers have been able to find, locate and document a great many instances that mining consultants failed to find. (BMCS)**

The mining layout has been designed such that the majority of the cliffs and pagoda complexes are located outside the 26.5 degree angle of draw line from the extents of the proposed longwalls. There are some cliffs and pagoda complexes which have been identified within the 26.5 degree angle of draw line, however, they are all located outside the extents of the proposed longwalls. Whilst the cliffs and pagodas complexes could experience low levels of subsidence, they are not expected to experience any significant conventional tilts, curvatures or strains. These features are located along the valley sides and, therefore, are not expected to experience the valley related upsidence or compressive strains due to valley closure.

It is unlikely, therefore, that the cliffs and pagoda complexes would experience any adverse impacts resulting from the extraction of the proposed longwalls. This is supported by extensive experience from the NSW Coalfields, at depths of cover greater than 200 m, where no cliff instabilities have been observed where cliffs have been located wholly outside the extents of extracted longwalls.

Springvale Coal will undertake periodic visual monitoring of the cliffs, minor cliffs and pagodas throughout the mining period and for a period after the completion of mining. Details of the monitoring of these structures will be provided within the Extraction Plans to be prepared and approved for the Project.

### 3.2.13 Surface Infrastructure

**The scenic western edge of the Newnes Plateau must be protected from further scarring by new roads, pipeline and electricity easements. (SCSGBM)**

Springvale Coal is seeking approval for the construction of new proposed which include:

- Extension of the existing SDWTS scheme to the proposed Bores 9 and 10 dewatering facilities to be established on Newnes Plateau; and
- Duplication of the existing scheme at sections to a maximum capacity of 50 ML/day to allow for the management of mine inflows from both Springvale Mine and Angus Place Colliery.

Two new dewatering facilities are proposed to be established in the Project on Newnes Plateau. Bore 9 and Bore 10 will be installed sequentially as mining progresses to the east and then the southeast of the existing workings. Bore 9, will be established when the current dewatering facility (Bore 8) will no longer function effectively. Bore 9 will manage mine inflows from LW420 to LW423. Bore 10 will manage mine inflows from LW424 – LW432 and LW501 – LW503.

The timing of the construction, operation and rehabilitation of Bore 9 and Bore 10 will be staged and contingent upon the progression of underground workings. A proposed infrastructure footprint (which will also include a mine services borehole area) of 11.44 ha will be required.

Dewatering bore facility sites have been identified based upon mine design requirements, and environmental constraints from a desktop analysis. The preferred options for the final placement of the dewatering boreholes will balance dewatering needs with potential environmental impacts. It is identified in Section 5.3 of the Social Impact Assessment that the mine design and other mitigating factors have minimised the extent of change to the physical environment to an extent that the Project will not adversely impact on the existing land use, its physical characteristics including surface features and the manner in which the public utilise / access the area for recreation.

A Visual Impact Assessment for the Project was prepared and, as identified in Section 10.12.6 of the EIS, concluded that the visual character and amenity of the regional and local area of the Project Application Area will not be significantly altered by the Project, as the Project involves continued operations of Springvale Mine, which consists of underground mining with minimal surface disturbance.

The Newnes Plateau contains existing surface mining infrastructure, with the Project requiring additional infrastructure to support underground operations. However, the significance of the visual effects of the Project upon Newnes Plateau are predominately none to minor with potential visual impacts on Newnes Plateau being transient and not impacting upon any residential locations. Revegetation will be undertaken appropriately to ensure a suitable end land use that is consistent with the surrounding visual character and zoning of Newnes Plateau.

**The proposed SDWTS augmentation would inappropriately duplicate the easement off Newnes Plateau. This proposal will needlessly bulldoze a second road and ten metre wide easement for a 710mm diameter pipeline off the Newnes Plateau through a Brown Barrel forest between two large, dramatic pagoda-studded ridges and then a nationally endangered grassy tableland forest. This proposal, instead of a parallel duplication of the existing pipeline is unjustified in the EIS and totally unacceptable. (Colong Foundation)**

A second road will not be constructed for the entire length (6.8 km) of the duplication section of the SDWTS. As noted in Section 4.9.3 the EIS existing access tracks on Newnes Plateau will be utilised as much as possible for the construction works to minimise vegetation clearing. Only 1.7 km of the duplication section of the SDWTS on the western end will be new road, shown on Map 8, Appendix 5 of the Flora and Fauna Assessment (Appendix H of the EIS) and will require vegetation clearing for a width of 10 m. For the remaining length of the SDWTS duplication section minimal vegetation clearing will be undertaken to establish 10-metre wide cleared roads from the existing 3.5 m tracks. Following installation of trenched pipeline the cleared areas will be rehabilitated to a final width of 5 m along the entire length of the SDWTS duplication section to allow vehicular access for any maintenance works if required.

**The proposed duplication of the SDWTS must keep to the existing alignment. The current proposal for an additional road and pipeline easement descending off Newnes Plateau will cause totally unacceptable scarring to a scenic part of the Gardens of Stone region. (Colong Foundation)**

The duplication of the SDWTS will keep to the existing alignment for 5.1 km out of the total length of 6.8 km proposed; only 1.7 km at the western end of the propose SDWTS duplication will be new road. This road will initially be constructed to a width of 10 m, however, following installation of trenched pipeline will be rehabilitated to a final width of 5 m. Given that the pipelines will be trenched along the entire length it is not anticipated that the trenched pipeline will result in a significant impact on the visual amenity of the area, and would certainly not result in scarring of a scenic part of the Gardens of Stone region.

**Figure 4.1 page 155 (Vol. 1) reveals that that the proposed SDWTS does not follow the existing corridor in the most sensitive area of the western edge of Newnes Plateau. The road and 10 metre wide easement proposal descends into Sawyers Swamp Creek from the northern side southwards from the Old Bells Line of Road. (Colong Foundation)**

The proposed SDWTS duplication section follows the existing corridor for the 5.1 km out of the proposed 6.8 km length; the remaining 1.7 km section on the western end will be new road. This new road will not descend into Sawyers Swamp Creek but will in fact avoid it completely. The initial desktop analyses undertaken to determine the optimal alignment of the new road based on topography did identify a route traversing the shrub swamp on the western end of the SDWTS. Following ecological surveys for ground-truthing the initial alignment, the new road was re-aligned to avoid the shrub swamp. The avoidance mapping is shown on Map 8, Appendix 5 of the Flora and Fauna Assessment (Appendix H of the EIS). Figure 10.20 of the EIS shows the re-aligned SDWTS (western end) relative to the Sawyers Shrub Creek. This avoidance mapping is discussed in Table 12.3 of the EIS.

**The existing SDWTS infrastructure alignment further to the south must be followed. This will avoid the destruction of a Sheltered Peppermint – Brown Barrel Shrubby Forest between two significant and well featured Pagoda spurs above the creek. It would avoid unnecessary bisection and severe damage to a Tableland Gully Snow Gum – Ribbon Gum Montane Grassy Forest, an endangered ecological community. (Colong Foundation)**

Table 10.8 of the Springvale MEP EIS and Table 9 of the Flora and Fauna Assessment for the project (Appendix H of the EIS) lists areas of specific vegetation communities to be cleared within the proposed infrastructure corridor. The project is proposing clearing of 0.73 ha of Newnes Sheltered Peppermint – Brown Barrel Shrubby Forest, which is not a Threatened Ecological Community. This proposed clearing represents 0.35% of the community mapped within the Project Application Area to be cleared and 0.03% of the 2156.89 ha of the community mapped in the western Blue Mountains area (DEC 2006).

Table 10.8 of the EIS also shows the project is proposing to clear 0.22 ha of Tableland Gully Snow Gum – Ribbon Gum Montane Grassy Forest, an endangered ecological community in accordance with the NSW *Threatened Species Conservation Act 1995*. This proposed clearing represents 1% of the community mapped within the Project Application Area to be cleared and 0.01% of the 1584.43 ha of the community mapped in the western Blue Mountains area (DEC 2006). The 0.22 ha of the Tableland Gully Snow Gum – Ribbon Gum Montane Grassy Forest proposed to be cleared already exists in a highly modified (regrowth) condition. The 7-Part Test of Significance undertaken for this EEC concluded the remaining community within the Project Application is unlikely to be significantly impacted by the Project, such that the EEC would be placed at risk of extinction.

With regards to the clearing of the EEC Tableland Gully Snow Gum – Ribbon Gum Montane Grassy Forest, the Regional Biodiversity Offset Strategy applicable to the project has taken this proposed clearing into consideration when determining the native vegetation communities to be directly impacted by the project (refer Table 11 of Appendix I of the EIS). Section 6.1 of the revised Regional Biodiversity Offset Strategy (**Appendix 4**) notes the offset area proposed in the Regional Biodiversity Offset

Strategy provides compensation for the residual impacts associated with the Springvale MEP and this includes clearing of 0.22 ha of Tableland Gully Snow Gum – Ribbon Gum Montane Grassy Forest.

**As this mine progressively advances under the plateau, there is a concomitant advance of the associated industrial landscape across largely pristine woodland. Exemplifying this forest destruction is the proposed additional clearing of an extraordinary 23.25ha for a ventilation facility, seven dewatering bores and a ten metre wide pipeline easement connecting these sites. All this industrial development significantly adds to the burden of infrastructure on Newnes Plateau in the Gardens of Stone region; to date progressive rehabilitation has proven ineffective. (BMCS)**

The Angus Place MEP is proposing to clear 23.5 ha of vegetation for the establishment of new infrastructure while the Springvale MEP is proposing to clear 11.4 ha of vegetation. Environmental avoidance mapping was undertaken in each project to determine the optimum site for the infrastructure and associated access tracks within the defined environmental study areas, and is described in detail in Section 5.1 of the Flora and Fauna Assessment (Appendix H to the EIS). The areas represent minimal areas required for the infrastructure establishment. Other than the proposed clearing of 0.22 ha of Tableland Gully Snow Gum – Ribbon Gum Montane Grassy Forest EEC for the SDWTS duplication no other threatened flora species or EECs will be impacted. Additionally the widened access tracks for construction will be progressively rehabilitated as pipeline/power cable installation has been completed.

It is recognised that the Springvale and Angus Place MEPs will add to the existing infrastructure on Newnes Plateau, however existing dewatering facilities Angus Place 940 and Springvale Bores 6 and 8 will be progressively decommissioned. As identified in Section 5.3 of the Social Impact Assessment of both EISs that the mine design and other mitigating factors have minimised the extent of change to the physical environment to an extent that the Project will not adversely impact on the existing land use, its physical characteristics including surface features and the manner in which the public utilise / access the area. All infrastructure will be temporary and will be decommissioned and sites rehabilitated when both mines cease operating, in accordance with the Decommissioning and Rehabilitation Strategies for the Projects presented in EIS Section 10.11 and Appendix P.

A Visual Impact Assessment for the Project was prepared and, as identified in Section 10.12.6 of the EIS, concluded that the visual character and amenity of the regional and local area of the Project Application Area will not be significantly altered by the Project, as the Project involves continued operations of Springvale Mine, which consists of underground mining with minimal surface disturbance.

The Newnes Plateau contains existing surface mining infrastructure, with the Project requiring additional infrastructure to support underground operations. However, the significance of the visual effects of the Project upon Newnes Plateau are predominately none to minor with potential visual impacts on Newnes Plateau being transient and not impacting upon any residential locations. Revegetation will be undertaken appropriately to ensure a suitable end land use that is consistent with the surrounding visual character and zoning of Newnes Plateau.

Springvale Mine has adopted a progressive approach to rehabilitation to reduce and mitigate potential environmental impacts. Exploration sites, ventilation and dewatering facilities and access tracks are rehabilitated promptly with periodic inspections and maintenance as necessary based upon evidence of endemic regrowth, weeds and soil disturbance. Rehabilitation acceleration techniques are undertaken, if required following approval from the Forestry Corporation of NSW.

The success of progressive rehabilitation activities is monitored against appropriate performance indicators identified within the Springvale EMS framework and relevant legislative requirements.

### 3.2.14 Surface Water

**Carne Creek is our only source of water. Any impacts to water volumes in Carne Creek impacts our business. (Emirates)**

**Carne Creek is currently in a pristine state, and its waters that flow through the Greater Blue Mountains World Heritage Area are of the highest standard. This creek must not run bright orange or suffer reduced flows, just like the Wolgan River after Centennial Coal wrecked it. (SCSGBM)**

Approximately 2 km of Carne Creek is directly above the proposed longwalls LW416- LW419. The section of creek located above the proposed longwalls is generally confined within Sunnyside East Swamp. The predicted tilt of 0.25 mm/m, is less than the typical natural grade of Carne Creek, which ranges from 25 mm/m to 300 mm/m and therefore no significant ponding, flooding, scouring is predicted and is unlikely to have any adverse effect, apart from the potential for small sections of grade reversal where natural channel grades are very low immediately upstream of chain pillars.

It is expected that Carne Creek will experience compressive strains due to valley related movements between 5 mm/m and 15 mm/m. The greatest compressive strains are expected to occur where the creek is located near the centrelines of the proposed longwalls, and less where the creek is located near the chain pillars.The maximum predicted valley related movements, due to the extraction of the proposed longwalls only, are 65 mm upsidence and 75 mm closure. It has also been predicted that the river has already experienced valley related movements up to 270 mm upsidence and 330 mm closure due to the extraction of the existing longwalls at Angus Place and Springvale Collieries. No significant fracturing or surface water flow diversions have been observed along the river due to the existing mining. It is unlikely, therefore, that the extraction of the proposed longwalls would result in any significant fracturing resulting in surface water flow diversions or water quality impacts.

Existing baseflows to Carne Creek already occur from the near surface aquifers. The water quality from these aquifers that flow into Carne Creek will remain unchanged as a result of the Project and as such there will be no impacts to the operations of the Emirates eco resort. There is no scientific evidence to suggest that the underground mining operations of Angus Place Colliery and Springvale Mine have previously resulted in impacts to water quality within Wolgan River.

### 3.2.15 Tourism

**The growing and sustainable tourist industry is being consistently damaged by the impacts of coal mining in this spectacular region. The price of this development is too high. (BMCS)**

Springvale Coal acknowledges in Section 6.1 of the EIS that the Newnes Plateau is identified as being an important feature of the Lithgow LGA by the local, regional and State stakeholders who access the area for various activities. Consultation was undertaken as part of the development of the Social Impact Assessment prepared by James Marshall & Co and provided as Appendix N to the EIS, with users of the Plateau including adventure visitors (mountain bike riders, motor bikers and four wheel drivers) and passive visitors (include bushwalkers, families visiting a particular destination point). The consultation was undertaken at various times throughout 2013 and found that many visitors who live in the area are aware of mining under the Newnes Plateau. It was generally their opinion that mining has not changed their experience when visiting the area and will not change their experience as long as access to the area was permitted. Many of these visits were for adventure type tourism. Passive visitors, for example, families visiting the area to visit a particular destination point (for example the Glow Worm Tunnels) and bushwalkers generally stated that they did not want their experience changed. The amenity of the area was important to these types of visitors and key words used to describe the area are: quiet, nature, features (pagodas and cliffs) and views from lookouts.

It is identified in Section 5.3 of the Social Impact Assessment (Appendix N) that the mine design and other mitigating factors have minimised the extent of change to the physical environment to an extent that the Project will not adversely impact on the existing land use, its physical characteristics including surface features and the manner in which the public utilise / access the area for recreation.

Stakeholders who access the area for passive recreation including bushwalking and bird watching who have a low impact on the environment may experience a minor amenity impact in a small area on Sunnyside Ridge Road to the east of the existing Angus Place Colliery's Vent Shaft Facility (APC-VS2 area) which is predicted to experience small exceedences of the project specific noise criteria for a passive recreational area. However this area is primarily used as a four wheel drive track so any amenity impact is unlikely.

The Project is assessed to have significance of visual effects of none or minor at receptor locations with the exception being the mine services borehole compound due to the woodland clearing required during construction and its proximity to motorists on Old Bells Line of Road. However, placed in the context of being a transient viewpoint within a much larger area that commonly has larger clearings of pine plantation, Old Bells Line of Road not having direct line of site to this receptor and combined with the proposed appropriate dismantling and rehabilitation during decommissioning of this infrastructure, there will be no long term visual impact.

The Social Impact Assessment determined that the there will be no social change arising from the Project because there is no adverse impact on how people use the area.

### 3.2.16 Water Management

**NCC objects to the proposed discharge of up to 43.8ML/day of untreated eco-toxic mine effluent to the Coxs River via the Springvale-Delta Water Transfer Scheme (SDWTS). This inappropriate discharge is inconsistent with the Sydney Catchment Authority Sydney Drinking Water Audit 2010 recommendations that require improved treatment of such licensed discharges. (NCC)**

**The Wallerawang Power Plant is shut, possibly permanently, and the current proposal to supply cooling water is not viable. (NCC).**

**Before discharge, the mine water must be treated to a standard that protects undisturbed aquatic ecosystems. The mine effluent, currently running at 12.5 Ml/day must be treated using reverse osmosis technology to remove all metals and salts. (NCC)**

**All effluent discharges from the SDWTS must be subjected to reverse osmosis treatment to remove all salts and metals so that these discharges do no harm to sensitive downstream environments. (Colong Foundation)**

**All proposed discharge of up to 43.8 ML/day of mine effluent to the Coxs River via the Springvale-Delta Water Transfer Scheme (SDWTS) is treated by reverse osmosis technology to remove salt and metals to a standard that protects, the Coxs River, the downstream drinking water supply and near-pristine ecosystems in the World Heritage Area. (Colo Committee)**

**Reinserted mine effluent must be properly treated and not allowed to re-emerge in an unauthorised or unregulated manner. (Colo Committee)**

**The proposed discharge of up to 43.8ML/day of eco-toxic mine effluent must be treated using reverse osmosis technology to remove all metals and salts before discharge to the Coxs River. (SCSGBM)**

**The EIS claims that untreated discharges will go to Wallerawang Power Station, but it has ceased operation and is expected to remain so. As a result these untreated discharges will go directly into the Coxs River via the licenced discharge point LDP009, or into LDP1 in Kangaroo Creek upstream of Lake Wallace. (LEG)**

**Any discharge needs to be subject to high level remediation, such as via reverse osmosis filtration, to remove environmentally damaging heavy metals and salts, so the treatment must be undertaken prior to the water leaving the mine site. It is essential that the Centennial Angus Place guarantees that ANZECC guidelines for upland waterways will be heeded. The responsible approach would be to discharge only water that has been treated to a pristine level. (BMCS)**

**The proposed discharges from LDP001 and LDP009 are inconsistent with the Sydney Catchment Authority Audit 2010, which included recommendations requiring improved treatment of POEO licenced discharges in the Coxs River Catchment. Numerous reports since 1966 have highlighted the highly polluted condition of the Coxs River. (LEG)**

**The proposed discharges risk cancelling out negotiations between the EPA, Blue Mountains Conservation Society, and Delta Electricity to establish EPL limits for concentrations of Copper, Zinc, Aluminium, Boron, Fluoride, Arsenic, Nickel and Salts being discharged from LDP009 into the Coxs River. Delta had agreed to construct a Reverse Osmosis (RO) Plant to treat the SDWTS effluent after use for cooling, and pipe the brine waste to Mt Piper Flyash Repository for disposal. The closure of Wallerawang Power Station jeopardises this. (LEG)**

**It is in the public interest to control metal and salt pollutants at their source – the coal mines that operate within the Sydney Drinking Water Catchment. The current SDWTS proposal to provide cooling water to Wallerawang Power Station is no longer viable. The closure of this plant means these salts and metals will instead be flushed into the Coxs River through the Greater Blue Mountains World Heritage Area and into Lake Burragorang – Drinking Water Supply for 4 million people. Before discharge, this mine water must be treated to a standard that protects undisturbed aquatic ecosystems and the health of downstream water-users. The only effective way to treat the high levels of turbidity, heavy metals (including Aluminium, Zinc, Copper and Nickel) and salinity is by requiring Centennial to install reverse osmosis (RO) technology to remove all metals and salts. (LEG)**

**The Springvale Delta Water Transfer Scheme (SDWTS) seeks to inappropriately dispose of up to 43.8 MIML/day of untreated mine effluent to the Coxs River, adding 30 tonnes of metal enriched salts per day to Sydney's drinking water supplies. (Colong Foundation)**

The SDWTS pipeline network, covering Angus Place Colliery's dewatering bores 930 and 940 and Springvale Mine's bores 6 and 8 and licensed discharged point 9 (EPL 3607) and Energy Australia's Wallerawang Power Station, are predominantly trenched and hence the risk of bushfire destroying the network is minimal. In the event a bushfire destroyed the short exposed section of the SDWTS, the mine water would cascade down Newnes Plateau and will be captured within the Sawyers Swamp Creek Ash Dam, owned by Energy Australia.

Centennial Angus Place and Springvale Coal confirm that no emergency discharges into Wolgan River occur currently or is proposed in the future. No discharges into Wolgan River have occurred since 10 April 2010. Angus Place Colliery's EPL 467 was varied on 29 July 2013 to remove LDP006 as the emergency discharge point on Newnes Plateau. No new LDPs have been proposed in the Angus Place MEP (refer Section 4.11.3 of the Angus Place MEP).

While Springvale Mine's EPL 3607 still has provisions for two emergency discharge points (LDP004 and LDP005) on Newnes Plateau no emergency discharges have been proposed via these LDPs in the Springvale MEP. Instead it has been proposed (refer Section 4.10.1 of the Springvale MEP EIS) that these LDPs be relinquished post-approval when infrastructure required to re-direct emergency discharge water from the SDWTS back underground to the Angus Place Colliery's 900 water storage area has been installed.

There has never been any mine water discharges into Carne Creek and neither is there any proposal to do discharge into that catchment as part of the project.

A Regional Water Quality Impact Assessment has been undertaken as part of the RTS process and is attached as **Appendix 2**. This report assesses the impact (water quality and quantity) of the proposal to discharge all mine water from Springvale and Angus Place MEPs into Cox River i.e. the report assesses the scenario where no mine water is transferred to Wallerawang Power Station.

Following public exhibition of the EIS, a review of the EPA Direct Toxicity Assessment on Springvale's LDP009 discharge was undertaken by GHD (**Appendix 9** to this RTS). Following the review, an additional Direct Toxicity Assessment, provided as **Appendix 10** to this RTS, was carried out on discharge water from LDP001 at Angus Place and LDP009 at Springvale. The methodology for the Direct Toxicity Assessment was approved by the EPA in August 2014. The results of the Direct Toxicity Assessment show that there is no toxicity associated with the Discharge water from LDP001. Although toxicity has been observed at LDP009, it has been demonstrated that neither the EC or bicarbonate concentrations have any effect on the toxicity of the water. Lowering the EC may have a detrimental effect on the system as shown by the high toxicity at sites upstream of LDP001. The chemistry of water quality discharged through LDP009 does not point to any source in particular that is leading to the toxicity being observed. As such, Centennial proposes to undertake further investigations into the toxicity of LDP009 water discharge to identify the cause of the toxicity. Without knowing what is causing the toxicity, the application of a treatment system is premature as you won't know what you are treating for. As such, no additional treatment of mine water is considered necessary at this stage.

**Any malfunction of SDWTS, such as following a bushfire, must not result in emergency discharges to the World Heritage Area via Wolgan River or Carne Creek but be reinserted underground into the mine. (NCC, BMCS and Colo Committee)**

The SDWTS pipeline network, covering Angus Place Colliery's dewatering bores 930 and 940 and Springvale Mine's bores 6 and 8 and licensed discharged point 9 (EPL 3607) and Energy Australia's Wallerawang Power Station, are predominantly trenched and hence the risk of bushfire destroying the network is minimal. In the event a bushfire destroyed the short exposed section of the SDWTS, the mine water would cascade down Newnes Plateau and will be captured within the Sawyers Swamp Creek Ash Dam, owned by Energy Australia.

Centennial Angus Place and Springvale Coal confirm that no emergency discharges into Wolgan River occur currently or is proposed in the future. No discharges into Wolgan River have occurred since 10 April 2010. Angus Place Colliery's EPL 467 was varied on 29 July 2013 to remove LDP006 as the emergency discharge point on Newnes Plateau. No new LDPs have been proposed in the Angus Place MEP (refer Section 4.11.3 of the Angus Place MEP EIS).

While Springvale Mine's EPL 3607 still has provisions for two emergency discharge points (LDP004 and LDP005) on Newnes Plateau no emergency discharges have been proposed via these LDPs in the Springvale MEP. Instead it has been proposed (refer Section 4.10.1 of the Springvale MEP EIS) that these LDPs be relinquished post-approval when infrastructure required to re-direct emergency discharge water from the SDWTS back underground to the Angus Place Colliery's 900 water storage area has been installed.

There has never been any mine water discharges into Carne Creek and neither is there any proposal to discharge into that catchment as part of the project.

**The ownership and responsibility for the SDWTS is very unclear, as the situation regarding who is responsible for rehabilitating the Kerosene Vale Fly Ash Repository. Critical Issues such as the EPL's, land ownership, and final rehabilitation of the entire route of the SDWTS should have been clarified in the EIS, and must be clarified prior to any consent approval. (LEG)**

Springvale Coal Pty Limited, operator of Springvale Mine, has a commercial agreement with Energy Australia on the ownership and management of the Springvale Delta Water Transfer Scheme (SDWTS). Springvale Coal maintains components of the SDWTS infrastructure on Newnes Plateau while Energy Australia manages sections of the SDWTS leading to the Wallerawang Power Station. Any rehabilitation works that will be required when Angus Place Colliery and Springvale Mine cease operations will be undertaken in accordance with the commercial agreement.

Springvale Mine staff and contractors are authorised by Energy Australia to operate and maintain infrastructure associated with the settling ponds (for water treatment) downstream of emergency licensed discharge point LDP010 and upstream from LDP009; the latter LDP being the SDWTS bypass point west of the Swayers Swamp / Kerosene Vale Ash Dam. LDP009 and LDP010 are on Springvale Mine's Environment Protection Licence EPL 3607. Emergency discharge points LDP004 and LDP005 also associated with the SDWTS are on EPL 3607. LDP004 and LDP005 have not been used to discharge any mine water on Newnes Plateau since April 2010 and the Project is proposing to relinquish them when infrastructure required to divert water underground to manage energy discharges have been established (refer Section 4.10.1 of the EIS).

The Kerosene Vale Fly Ash Repository is owned and maintained by Energy Australia as part of the Wallerawang Power Station operations. Its rehabilitation is not proposed in the Decommissioning and Rehabilitation Strategy proposed for the Angus Place MEP or the Springvale MEP.

**Figure 26 from the EIS clearly shows that salinity levels will spike dramatically reaching a peak from 2020 to 2025. Section 4.2.2, p. 65, identifies that the median salinity at LDP001 is 1,010µS/cm. Several Metals at LDP1 already exceed the ANZECC guidance including Copper at 0.002mg/L (guidance 0.0014mg/L); Aluminium of 0.02mg/L; and Zinc at 0.046mg/L (guidance 0.008mg/L). These pollution effects will be magnified during drought conditions, which are likely to become more prevalent during the life of these mines due to climate change. (LEG)**

A Regional Water Quality Impact Assessment (**Appendix 2** to this RTS) has been undertaken to assess the impact of direct discharge at Angus Place LDP001 and Springvale LDP009. This assessment has quantified the impact (water quality and water quantity) of the proposed discharges from Angus Place Colliery and Springvale Mine into the Coxs River catchment, including Lake Burragorang.

Springvale Coal has undertaken SSTV assessment for Springvale Mine's LDP009. Results of the SSTV analysis indicate that current water quality at LDP009 exceeds the data for electrical conductivity, aluminium, zinc and copper concentrations meets ANZECC 95% protection of aquatic ecosystems except for copper and zinc concentrations but fall below the adopted trigger value (**Appendix 3**).

**On 9 May 2010 the EPA issued Angus Place (EPL 467) with a Pollution Reduction Notice to reduce the estimated 1,000 tonnes of salt deposited from LDP1 into Kangaroo Creek each year based on the average flow rate of 731ML4. This Proposal aims to increase that flow rate 3 – 14 times. The proponent proposes to treble the flow from LDP1 to 2,300ML, and if the SDWTS is unavailable, to increase the flow from between 6 and 14 times (4,750ML up to 10,457ML). In total**

**this proposal will discharge and some 31 tonnes/day (or 11,247 tonnes/year) of metal-rich Salts into the Coxs River which supplies Sydney with drinking water. (LEG)**

Similarly, Springvale Coal has undertaken SSTV assessment for Springvale Mine's LDP009. Results of the SSTV analysis indicate that current water quality at LDP009 exceeds the data for electrical conductivity, aluminium, zinc and copper concentrations meets ANZECC 95% protection of aquatic ecosystems except for copper and zinc concentrations but fall below the adopted trigger value. (**Appendix 3**).

A Regional Water Quality Impact Assessment (**Appendix 2**) has been undertaken to assess the impact of direct discharge at Angus Place LDP001 and Springvale LDP009. This assessment has quantified the impact (water quality and water quantity) of the proposed discharges from Angus Place Colliery and Springvale Mine into the Coxs River catchment, including Lake Burragorang.

**At LDP005 LEG Streamwatch volunteers recorded a Salinity level of 1030 µS/cm; Turbidity of 40 NTU (exceeded EPL limit); pH 7.5; Dissolved Oxygen 4.3 mg/L (52%); Available Phosphate 0.07 ppm; and Water Temperature of 25°C. The water had a chemically odour – attributable we believe to Solcenic water-soluble hydraulic oils, used in and spilled in vast quantities by long wall mining equipment. (LEG)**

Water discharged from the mine is groundwater that has accumulated in the underground mine workings and originates from the coal seam and the overlying strata. The chemical composition of the groundwater is a result of the geology and environment in which it originates and is not influenced by mining processes. No evidence has been provided to support the statement made by the Lithgow Environment Group that water discharged from the mine was contaminated by hydraulic oils used in the underground mining operations. "Chemically odour" description does not constitute an analytical result to confirm the presence of hydraulic oil contaminants in the mine water. Both Angus Place Colliery and Springvale Mine have robust water quality testing regimes at all licensed discharge points and report water quality parameters in accordance with the respective Environmental Protection Licences, EPL 467 and EPL 3607.

**The proposed discharge of 43.8 ML/day of eco-toxic saline minewater will have adverse impacts on aquatic life and natural ecosystems in the Coxs River, Sydney Drinking Water Catchment and Greater Blue Mountains Heritage Area which it flows through, as well as potentially for Carne Creek, the Wolgan River, and Wollemi National Park if any SDWTS malfunctions necessitate further Emergency Discharge's on Newnes Plateau. (LEG)**

Springvale Coal has undertaken SSTV assessment for Springvale Mine's LDP009. Results of the SSTV analysis indicate that current water quality at LDP009 exceeds the data for electrical conductivity, aluminium, zinc and copper concentrations meets ANZECC 95% protection of aquatic ecosystems except for copper and zinc concentrations but fall below the adopted trigger value (**Appendix 3**).

A Regional Water Quality Impact Assessment (**Appendix 2**) has been undertaken to assess the impact of direct discharge at Angus Place LDP001 and Springvale LDP009. This assessment has quantified the impact (water quality and water quantity) of the proposed discharges from Angus Place Colliery and Springvale Mine into the Coxs River catchment, including Lake Burragorang.

No emergency discharges are proposed on Newnes Plateau into Wolgan River or Carne Creek in the Angus Place and Springvale MEPs. No mine water emergency discharge on Newnes Plateau into

Wolgan River has occurred since April 2010. There has never been any mine water discharges into Carne Creek.

Angus Place Colliery's emergency discharge provisions at LDP006 (EPL 467) were able to be relinquished on 29 July 2013 and EPL467 was varied to remove LDP006 from the licence as a result of changes to the mine water management system at Angus Place Colliery.

While Springvale Mine's EPL 3607 still has provisions for two emergency discharge points (LDP004 and LDP005) on Newnes Plateau no emergency discharges have been proposed via these LDPs in the MEP. Instead it has been proposed (refer Section 4.10.1 of the EIS) that these LDPs be relinquished post-approval when infrastructure required to re-direct emergency discharge water from the SDWTS back underground to the Angus Place Colliery's 900 water storage area has been installed.

Following public exhibition of the EIS, a review of the EPA Direct Toxicity Assessment on Springvale's LDP009 discharge was undertaken by GHD (**Appendix 9** to this RTS). Following the review, an additional Direct Toxicity Assessment, provided as **Appendix 10** to this RTS, was carried out on discharge water from LDP001 at Angus Place and LDP009 at Springvale. The methodology for the Direct Toxicity Assessment was approved by the EPA in August 2014. The results of the Direct Toxicity Assessment show that there is no toxicity associated with the Discharge water from LDP001. Although toxicity has been observed at LDP009, it has been demonstrated that neither the EC or bicarbonate concentrations have any effect on the toxicity of the water. Lowering the EC may have a detrimental effect on the system as shown by the high toxicity at sites upstream of LDP001. The chemistry of water quality discharged through LDP009 does not point to any source in particular that is leading to the toxicity being observed. As such, Centennial proposes to undertake further investigations into the toxicity of LDP009 water discharge to identify the cause of the toxicity. Without knowing what is causing the toxicity, the application of a treatment system is premature as you won't know what you are treating for. As such, no additional treatment of mine water is considered necessary at this stage.

**At the source of the Coxs River in Long Swamp LEG Streamwatch volunteers have consistently recorded salinity levels of 30 µuS/cm. Just 4.8km downstream at LDP001 the median salinity is 33 times higher at 1,010 µS/cm and 1,055 µuS/cm at LDP009. The high salinity of this mine water will significantly affect aquatic and riparian ecosystems that have evolved under very low nutrient conditions, and water users in the Sydney Drinking Water Catchment. (LEG)**

A Regional Water Quality Impact Assessment has been undertaken as part of the RTS process and is attached as **Appendix 2**. This report assesses the impact (water quality and quantity) of the proposal to discharge all mine water from Springvale and Angus Place MEPs into Cox River i.e. the report assesses the scenario where no mine water is transferred to Wallerawang Power Station. The potential impacts have been quantified, including Lake Burragorang.

The Aquatic Ecology Impact Assessment (Appendix G to the EIS) undertaken for the Angus Place MEP found that the aquatic habitat and quality of water in the upper Coxs River are both degraded but despite this aquatic biota was relatively diverse. It was found that the current discharge from LDP001 appeared to have some adverse effects on the condition of the aquatic habitats and quality of water at Kangaroo Creek downstream (Site KCdn) and Coxs River downstream of the confluence of Kangaroo Creek (Site CR2), however its effect on biological indicators is less clear with only SIGNAL2 and AUSRIVAS scores being poorer on average at Kangaroo Creek downstream of LDP001 than at Kangaroo Creek upstream of LDP001, and macrophytes being less diverse at CR2 than CR1.

Section 7.2.1.3 of the Aquatic Ecology Impact Assessment in Angus place EIS states that:

"a review of the effects of salinity on aquatic biota in Australian freshwater systems indicates direct adverse biological effects are unlikely to occur unless EC levels exceed around 1000 mg/L (approximately 1,500 µS/cm) (Hart et al. 1991). This suggests that the aquatic biota in the river is unlikely to be impacted by the salinities resulting from the change in discharge."

It was assessed that the likely impact of the change in flows and quality of the water on the aquatic flora and fauna would be moderate in the immediate receiving waters of Kangaroo Creek and small to moderate in the Coxs River below the confluence.

Similar observations have been made for the proposed discharges at Springvale Mine's LDP009. The peak discharges, between 2019 and 2025, would have moderate to significant effects on low flows, small to moderate effects on low to moderate flows and minimal to small effects on high flows. The changes in discharges before 2019 and after 2025 would be small and would thus have minimal impacts on river flow. The marked increase in discharge between 2019 and 2025 could exacerbate the existing erosion of the stream bank and channel and could lead to further downstream transport of sediment. Such impacts are likely to be short-lived and would be negligible relative to those that occur naturally during high flow events. The increase in dilution resulting from the greater flow may counteract the increase in turbidity and potential for flow-on effects on aquatic biota.

Further to the water quality issues, it was found that increased flow due to the discharges may result in more stable aquatic habitats and conditions that are more conducive to the establishment and growth of aquatic macrophytes.

The 2010 State of the Catchment assessment for the Hawkesbury-Nepean Region returns a Very Good to Moderate score for macroinvertibrate condition in the Upper Coxs River.

Following public exhibition of the EIS, a review of the EPA Direct Toxicity Assessment on Springvale's LDP009 discharge was undertaken by GHD (**Appendix 9** to this RTS). Following the review, an additional Direct Toxicity Assessment, provided as **Appendix 10** to this RTS, was carried out on discharge water from LDP001 at Angus Place and LDP009 at Springvale. The methodology for the Direct Toxicity Assessment was approved by the EPA in August 2014. The results of the Direct Toxicity Assessment show that there is no toxicity associated with the Discharge water from LDP001. Although toxicity has been observed at LDP009, it has been demonstrated that neither the EC or bicarbonate concentrations have any effect on the toxicity of the water. Lowering the EC may have a detrimental effect on the system as shown by the high toxicity at sites upstream of LDP001. The chemistry of water quality discharged through LDP009 does not point to any source in particular that is leading to the toxicity being observed. As such, Centennial proposes to undertake further investigations into the toxicity of LDP009 water discharge to identify the cause of the toxicity. Without knowing what is causing the toxicity, the application of a treatment system is premature as you won't know what you are treating for. As such, no additional treatment of mine water is considered necessary at this stage.

**A map was provided to LEG at a Delta Western Reference Group Meeting in 2008. It shows the SDWTS Pipeline route, and identifies that a section of Pipeline is managed by Centennial, while Delta Electricity is responsible for another section. Despite 1000's of pages of documents in the EIS, it is still unclear whether Energy Australia has accepted responsibility for Delta's section of the Pipeline, whether Energy Australia are happy for Centennial staff/contractors to access Energy Australia owned land at Kerosene Vale Fly-Ash Repository (KVAR) and Licence Discharge Point LDP009, and who is ultimately responsible for the EPL Licences for all parts of the SDWTS. (LEG)**

Springvale Coal Pty Limited, operator of Springvale Mine, has a commercial agreement with Energy Australia on the ownership and management of the Springvale Delta Water Transfer Scheme (SDWTS). Springvale Coal maintains components of the SDWTS infrastructure on Newnes Plateau while Energy Australia manages sections of the SDWTS leading to the Wallerawang Power Station. Springvale Mine staff and contractors are authorised by Energy Australia to operate and maintain infrastructure associated with the settling ponds (for water treatment) downstream of emergency licensed discharge point LDP010 and upstream from LDP009; the latter LDP being the SDWTS bypass point west of the Swayers Swamp / Kerosene Vale Ash Dam. LDP009 and LDP010 are on Springvale Mine's Environment Protection Licence EPL 3607. Emergency discharge points LDP004 and LDP005 also associated with the SDWTS are on EPL 3607. LDP004 and LDP005 have not been used to discharge any mine water on Newnes Plateau since April 2010.

**Any malfunction of the SDWTS, such as the destruction of the pipeline during a bushfire, must not result in emergency discharges to the World Heritage Area via Wolgan River or Carne Creek. These discharges must be reinserted underground into the mine instead. (Colong Foundation)**

Centennial Angus Place and Springvale Coal confirm that no emergency discharges into Wolgan River occurs currently or is proposed in the future as part of the MEPs. No discharges into Wolgan River have occurred since 10 April 2010. Angus Place Colliery's EPL 467 was varied on 29 July 2013 to remove LDP006 as the emergency discharge point on Newnes Plateau. No new LDPs have been proposed in the Angus Place MEP (refer Section 4.11.3 of the Angus Place MEP EIS).

While Springvale Mine's EPL 3607 still has provisions for two emergency discharge points (LDP004 and LDP005) on Newnes Plateau no emergency discharges have been proposed via these LDPs in the MEP. Instead it has been proposed (refer Section 4.10.1 of the EIS) that these LDPs be relinquished post-approval when infrastructure required to re-direct emergency discharge water from the SDWTS back underground to the Angus Place Colliery's 900 water storage area has been installed.

There has never been any mine water discharges into Carne Creek and neither is there any proposal to do discharge into that catchment as part of the Angus Place and Springvale MEPs.

**The proposal to redirect emergency mine inflows from the SDWTS underground into the Angus Place Colliery's 900 water storage area via the existing Angus Place 940 Bore facility is conditionally supported, provided that these transfers do not then re-emerge to the surface and escape the mine site as untreated effluent. The Colong Foundation is, however, suspicious of the above arrangement given the previous unauthorised mine effluent discharges. (Colong Foundation)**

While Springvale Mine's EPL 3607 still has provisions for two emergency discharge points (LDP004 and LDP005) on Newnes Plateau no emergency discharges have been proposed via these LDPs in the Project. Instead it has been proposed (refer Section 4.10.1 of EIS) that these LDPs be relinquished post-approval when infrastructure required to re-direct emergency discharge water from the SDWTS back underground to the Angus Place Colliery's 900 water storage area has been installed. Springvale Coal can confirm that it will utilise this underground storage area for temporary storage of mine water should the SDWTS infrastructure become unavailable temporarily.

**The Colong Foundation notes that no daily capacity estimates have been provided for this proposed re-insertion arrangement. Given that the capacities are up to 43.8Ml/day, requiring 710mm diameter pipes laid underground, these unspecified arrangements seem highly dubious**

**and require further consideration by the regulatory authorities. The Colong Foundation suspects that the 900 area would be flooded unless constantly kept dry by a major pumping effort.**

**The Colong Foundation notes that the 900 area is contiguous with the 300 area and that unauthorised discharges are still operative on Lambs Creek. (Colong Foundation)**

Section 4.10.1 of the EIS notes that infrastructure will be installed post-approval to allow for the re-direction of mine water back underground into the Angus Place 900 Storage Area. No discharges are proposed on Newnes Plateau to manage emergency discharges via LDP004 and LDP005 (EPL 3607). This underground storage will be a temporary emergency measure and will be implemented when the SDWTS is not available for discharge of mine water into Coxs River via LDP009.

The claim "... that unauthorised discharges are still operative on Lambs Creek." is factually incorrect and not substantiated with evidence. The 300 Underground Storage Area below Lambs Creek has a depth of cover of at least 150 m. It is not possible for the stored mine water in the workings to surface from this depth to discharge into Lambs Creek. It is not possible for the water to emerge further downstream of Lambs Creek on the west and discharge into it as the coal seam / existing workings where water is stored dips to the east and mine water flows in that direction. No pumping of mine water from the storage area to the surface using a seam to surface pumping system occurs currently or is proposed in the Angus Place and Springvale MEPs.

### 3.2.17 Water Resources

**Surface groundwater aquifers will become more permeable and interconnected. Centennial predicts surface aquifer drawdown to be 10 metres under ridges to 0.5 metres under shrub swamps. This range seems to be an underestimate as the longwall mining proposed at Angus Place Mine is more intensive than at Springvale Colliery, but the same degree sandstone cracking and groundwater drawdown is predicted. (NCC)**

Numerous specialist hydrogeological studies have been undertaken at Angus Place with the aim of quantifying mine water inflow and subsidence impacts, groundwater drawdown and depressurisation, and addressing other geotechnical and hydrogeological issues over the past number of years.

RPS completed a study in November 2012 (RPS, 2012) to assess whether any impacts attributable to the undermining of the swamps could be ascertained based on swamps hydrographs and groundwater level trends

All of the swamps which were included in this study have a significant history of water level monitoring, are located away from licensed discharge points (to minimise potential for conflicting information), and have all been either undermined by longwall extraction or were in very close proximity to extracted longwall panels.

The results of the 2012 study showed that no water level impacts that could be attributed to past or present mining operations (subsidence-related impact or depressurisation) were observed. Rather, the water levels in the swamps showed a strong correlation to cumulative rainfall trends, and this was found to be the driving factor.

As no mining influenced water level fluctuations can be identified in any of the monitored swamps (both undermined and baseline) it is accurate to say that mining at Angus Place has not led to any identifiable water level impacts on the monitored swamps, and that all undermined swamps continue to display baseline water levels.

The proposed mine design at Angus Place Colliery has been modified to minimise subsidence beneath sensitive shrub swamp areas. The panel widths at the LW1004 – LW 1006 block and LW1016 - LW1017 block, which underlie the Tri-Star Swamp and Trail 6 Swamp, respectively, have been reduced to 261 m void widths. The width of the inter panel chain pillars is 52 m. In addition to the reduction of panel widths in longwalls that underlie shrub swamps, LW1013 and LW1014 have been stepped around an area of shallow cover associated with a tributary to Carne Creek, and LW1010 has been shortened in the vicinity of Twin Gully Swamp to avoid this swamp altogether. The net result of these modifications is a reduction in subsidence observed at ground surface.

In the case of Springvale Mine all longwalls are designed to have 261 metre void widths and with at least 55 m chain pillar widths. Proposed longwalls LW501 to LW503 have been positioned between clusters of cliffs; only one cliff lies over LW501. Previously approved LW419 to LW422 have been shortened to avoid cliffs and pagodas. The mine plan has been modified to avoid most of the pagodas, however pagodas exist above LW501 and LW502.

The longwalls LW416 – LW432 which underlie shrub swamps (Sunnyside East, Carne West, Gang Gang South West, Gang Gang East, Pine Swamp, Pine Swamp Upper, Marrangaroo Creek, Marrangaroo Creek Upper and Paddys Creek Swamps) are sub-critical panels and not likely to cause subsidence impacts. Carne Central, Barrier, Sunnyside and Nine Mile Swamps have been avoided in the mine design.

Subsidence Impact Assessments were undertaken for the Angus Place and Springvale MEPs by MSEC and provided as Appendix D to the EISs. Mining is predicted to cause maximum of 1.7 m of conventional subsidence above longwall extraction areas. Based on the predicted maximum strains calculated by the subsidence study it is likely that some fracturing will occur in the uppermost bedrock, beneath the surface soils/regolith. It has been observed in previous studies, that the depth of fracturing and dilation of the surficial lithologies, resulting from longwall mining, is generally less than 10 to 15 m.

This shallow fracturing will, in general terms, enhance shallow permeability, favouring infiltration of rainfall and surface water to the ground, and recharging the shallow aquifers hence reducing available runoff during rain events. In no case, is it expected that the infiltrated water will be lost to deeper aquifers since the fracturing will be only superficial (upper most 10 to 15 m) and is isolated from the deeper zones of connective vertical fracturing. It is likely that any infiltrated flow will re-emerge to the surface further downstream and with some degree of delay, contributing to prolong the base flow contribution to the watercourses

The predicted water table decline beneath the shrub swamps is predicted to range from negligible to <0.5 m with the greatest water level declines predicted to occur beneath elevated ridges and the upper reaches of the swamps where the swamps are generally above the water table and not reliant on groundwater.

The reliance of the shrubs swamps on groundwater from the perched aquifer system is due to the lateral groundwater flow along the low permeability aquitards and not the absolute water level within each aquifer. The predicted water level decline within the perched aquifer system is due to bed separation effects applied to the model that result in increased horizontal hydraulic conductivity. In many cases the decline in water table has meant a corresponding increase in lateral groundwater baseflow to the swamps and not a decrease.

Given the similarities of the proposed development with past operations, there is no reason to believe that the results of the proposed mining activities will cause any impacts where none have previously been observed.

The groundwater impact model predicts that some minor impacts to the shallow groundwater and baseflow will occur. However, it is considered that the groundwater modelling results are conservative, particularly in respect to the predicted impacts to baseflows. The model assumes dilation of horizontal 'plies' will occur through to ground surface, however, this has not been observed in the field. In any regard, the model is not able to replicate the self-healing nature of the creeks and swamps and as such, it is conservative, over-predicting the magnitude of potential impacts.

The Springvale and Angus Place Extension Projects operate in similar geological environments using similar mining methods. The impacts to groundwater levels and swamps are therefore predicted to be similar.

**Carne Creek is currently in a pristine state, and its waters that flow through the Greater Blue Mountains World Heritage Area are of the highest standard. The extensive fracturing of the sandstone associated with longwall mining of headwater swamps will release high levels of metals, notably manganese and iron, polluting Carne Creek and making it run bright orange, just like the Wolgan River did once. Flows in Carne Creek will also become irregular. (NCC)**

**Carne Creek is currently in a pristine state, and its waters that flow through the Greater Blue Mountains World Heritage Area are of the highest standard. This creek was a key determinant in the location of the Emirates eco-resort. The extensive fracturing of sandstone associated with longwall mining under its headwater swamps will release high levels of metals, notably manganese and iron, polluting Carne Creek and making it run bright orange, just like the Wolgan River once did. Flows in Carne Creek will also become irregular. (Colong Foundation)**

**Emergence of near surface groundwater with elevated levels of salt or metal precipitate in Carne Creek must be prevented. (Colo Committee)**

Approximately 2 km of Carne Creek is directly above the proposed longwalls LW416- LW419. The section of creek located above the proposed longwalls is generally confined within Sunnyside East Swamp. The predicted tilt of 0.25 mm/m, is less than the typical natural grade of Carne Creek, which ranges from 25 mm/m to 300 mm/m and therefore no significant ponding, flooding, scouring is predicted and is unlikely to have any adverse effect, apart from the potential for small sections of grade reversal where natural channel grades are very low immediately upstream of chain pillars.

It is expected that Carne Creek will experience compressive strains due to valley related movements between 5 mm/m and 15 mm/m. The greatest compressive strains are expected to occur where the creek is located near the centrelines of the proposed longwalls, and less where the creek is located near the chain pillars.The maximum predicted valley related movements, due to the extraction of the proposed longwalls only, are 65 mm upsidence and 75 mm closure. It has also been predicted that the river has already experienced valley related movements up to 270 mm upsidence and 330 mm closure due to the extraction of the existing longwalls at Angus Place and Springvale Collieries. No significant fracturing or surface water flow diversions have been observed along the river due to the existing mining. It is unlikely, therefore, that the extraction of the proposed longwalls would result in any significant fracturing resulting in surface water flow diversions or water quality impacts.

Existing baseflows to Carne Creek already occur from the near surface aquifers. The water quality from these aquifers that flow into Carne Creek will remain unchanged as a result of the Project and as such there will be no impacts to the operations of the Emirates eco resort. There is no scientific evidence to suggest that the underground mining operations of Angus Place Colliery and Springvale Mine have previously resulted in impacts to water quality within Wolgan River.

**There are the construction works (new bore holes, power lines, pipelines and access roads) being undertaken at the moment in the area of Sunny Ridge Road (off Blackfellows Hand Road).**

**This activity resulted from recent approvals for long wall mining expansions into the Carne Creek catchment area. This is our water supply and the lifeline of the Wolgan further down. (Emirates)**

The construction works being undertaken in the area of Sunnyside Ridge Road, off Mayingu Marragu Trail (the former Blackfellows Hand Road), are associated with the construction of the Angus Place Ventilation Shaft Facility Project, approved as modification 2 to the Angus Place Colliery's current project approval 06_0021 (http://majorprojects.planning.nsw.gov.au/index.pl?action=view_job&job_id=5122). While this modification also approved trial mining and construction of gateroads from the existing mining area towards the ventilation facility and development of mains headings and gateroads to the proposed LW1001 and LW1003 within the Angus Place East mining area the mining component of the project has not commenced as yet.

The surface water assessment undertaken by GHD for the Ventilation Shaft Facility Project, appended to the EIS as Appendix 9.2, noted that while the surface run-off from the project area has the potential to impact on Carne Creek, Wolgan River and Marrangaroo Creek catchments, these potential impacts could be mitigated such that there will not be a significant impact on the Wolgan River, Carne Creek or Marrangaroo Creek. The wide range of mitigation measures recommended by GHD, including the development of site-specific sediment control plans for each area of work, has been adopted in the project. With the mitigation measures in place the impact (water quality and water quantity) is predicted to be within the natural variability of the existing water quality data and flow data in the Carne Creek, Wolgan River and Marrangaroo Creek catchments.

While a clarification on the surface water assessment outcomes for the Angus Place Ventilation Shaft Facility Project has been provided above as a response to the issue raised by Emirates it should be noted that project is not the subject of the current RTS.

**This development application involves plans to pump up to 43 million litres of contaminated water a day into the same river, which feeds into the Lake Burragorang, an important part of Sydney's drinking water supply. Under the current proposal, the mine water would apparently be released into the river untreated, despite having elevated salt and heavy metal levels. The specific route is via Sawyers Swamp Creek into the Coxs River. (BMCS)**

**The discharge to be made under the current application, of to 43.8ML/day of untreated eco-toxic mine effluent, would flow to the Coxs River via the Springvale Delta Water Transfer Scheme (SDWTS). Such an inappropriate discharge is inconsistent with the SCA Sydney Drinking Water Audit 2010 Recommendations. (BMCS)**

A Regional Water Quality Impact Assessment has been undertaken as part of the RTS process and is attached as **Appendix 2**. This report assesses the impact (water quality and quantity) of the proposal to discharge all mine water from Springvale and Angus Place MEPs into Coxs River via Sawyers Swamp Creek, i.e. the report assesses the scenario where no mine water is transferred to Wallerawang Power Station. The potential impacts on the Coxs river catchment have been quantified, including Lake Burragorang.

Following public exhibition of the EIS, a review of the EPA Direct Toxicity Assessment on Springvale's LDP009 discharge was undertaken by GHD (**Appendix 9** to this RTS). Following the review, an additional Direct Toxicity Assessment, provided as **Appendix 10** to this RTS, was carried out on discharge water from LDP001 at Angus Place and LDP009 at Springvale. The methodology for the Direct Toxicity Assessment was approved by the EPA in August 2014. The results of the Direct Toxicity Assessment show that there is no toxicity associated with the Discharge water from LDP001. Although toxicity has been observed at LDP009, it has been demonstrated that neither the EC or bicarbonate concentrations have any effect on the toxicity of the water. Lowering the EC may have a detrimental effect on the system as shown by the high toxicity at sites upstream of LDP001. The chemistry of water quality discharged through LDP009 does not point to any source in particular that is leading to the toxicity being observed. As such, Centennial proposes to undertake further investigations into the toxicity of LDP009 water discharge to identify the cause of the toxicity. Without knowing what is causing the toxicity, the application of a treatment system is premature as you won't know what you are treating for. As such, no additional treatment of mine water is considered necessary at this stage.

**There is considerable concern on the figures quoted by the company, specifically the water discharge amounts. We are led to believe that the 43 million litres per day (max) for the life of the mine (5 times the mine's current discharge) will come only from the seam and not from nearer surface aquifers. This requires an apparently unreasonably large volume of produced water from the seam and no breaching of aquicludes above the seam being mined. This appears inaccurate and should be verified by an independent study. In this regard, the Society supports the establishment of a system of truly independent consultants to conduct all environmental impact assessments. (BMCS)**

The mine inflows arise from the Lithgow Seam (Illawarra Coal Measures) being mined at Angus Place Colliery and Springvale Mine. This aquifer, referred to as AQ1 in the EIS and the Groundwater Impact Assessment (Appendix E) is hydraulically connected with the Berry Siltstone and Marrangaroo Formations beneath and the Long Swamp Formation and Irondale Coal Seam above, the location of which within the regional hydrostratigraphy is shown in the EIS Table 2.5. This aquifer, along with aquifers AQ2 – AQ6, represents one of the major aquifers in the regional hydrogeological system,

The regional hydrostratigraphic system is divided into three groundwater systems denoted as perched, shallow and deep groundwater systems, described in detail in Section 2.6.2.5 of the EIS. The regional hydrogeology encompassing the Angus Place and Springvale Project Application Areas was studied extensively by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) between 2004 and 2008, and is described in ACARP reports C14033 and C18016. The most recent and detailed groundwater and aquifer modelling was conducted by CSIRO, Palaris (Palaris 2013a and Palaris 2013b) and RPS between 2011 and 2013. This modelling is based on the latest groundwater and geological data, which has been significantly improved since the initial CSIRO reports were published. The geological model includes data from 501 exploration boreholes (refer Figure 2.11 of the EIS). The groundwater model includes data from 142 piezometers in 31 boreholes over a period of up to 10 years and mine water inflow data which has been recorded over a period of 20 years.g

The AQ1 aquifer, along with aquifers AQ2 and AQ3, is part of the deep groundwater system, located in the strata underlying the Mount York Claystone. The Mount York Claystone is the major aquitard in the region, and separates the deep groundwater system from the shallow/perched groundwater systems located above it. The deep groundwater system generally lies at a depth of 200 m to 500 m below the ground surface. The aquifer zones within the deep groundwater system are typically fractured rock aquifers or jointed coal seams. It is this system which produces the mine water inflows when groundwater in this system is drained into the goaf following coal extraction.

The hydrostratigraphic sequence discussed briefly above, and presented in Table 2.5 of the EIS, has been incorporated into the hydrogeological model developed by CSIRO (attached as Appendix K to the Groundwater Impact Assessment prepared by RPS (Appendix E) to understand the groundwater impacts of the Angus Place and Springvale MEP. The predicted mine inflows, from the projects, deduced from the CSIRO's hydrogeological model, are presented in Figure 10.11 in the EIS.

The geological modelling and identification of the major aquifers (AQ 1-6), aquicludes and semi-permeable horizons (SP1-4) in the hydrogeological system, the hydrostratigraphic sequence that was incorporated into the hydrogeological model, and the development of the hydrogeological model was undertaken by a group of truly independent researchers/consultants comprising CSIRO, Palaris and

RPS. The Hydrogeological Model was peer-reviewed by Dr. Noel Merrick of Heritage Computing Pty Ltd as part of the NSW Aquifer Interference Policy requirement.

**Appendix E, part 1 of The Groundwater Impact Assessment for the proposal, asserts that ground cracking under the swamps would be temporary due to the cracks being filled by sediment. This presupposes that loose sandy sediment would have low permeability, a dubious contention that the Society rejects. For a start, it would depend on the size distribution of the particular sediment. It is instructive to reflect that coal seam gas extraction from fracking is enabled by the injection of sand into microfractures, yet in a curious twist the gentle washing of sand into the cracks under these swamps supposedly inhibits fluid flow. (BMCS)**

As detailed in Section 5.12 of the Subsidence Assessment provided as Appendix D to the EIS and Section 7.2 of the Groundwater Assessment provided as Appendix E to the EIS, the shrub swamps develop in the bases of natural valleys and are formed from the accumulation of sediments along relatively flat sections of the drainage lines. These swamps have dense peat layers which overlie the shallow surface soils derived from the Triassic Narrabeen Sandstone group. Some swamps have bedrock outcropping at the downstream end which helps retain the soil and peat. The vegetation types within the swamp include grasses, ferns and shrubs, with trees rarely growing within the swamps. The peat layers in the shrub swamps retain water derived from the shallow groundwater aquifers, surface runoff and rainfall. The water retention is high due to the relatively flat grades and, hence, the substrate is generally permanently waterlogged. In some locations the swamps have been observed to grow and extend over highly cracked and porous rock platforms where the moisture within the swamp appeared to be maintained by the dense and tightly packed matted root structure of the swamp plants.

The surface cracking across the mining area is expected to be generally isolated and minor in nature, due to the reasonable depths of cover which typically vary between 270 metres and 450 metres, and due to the plasticity of the surface soils which allows them to more readily absorb the ground strains. Surface crack widths are expected to be similar to those observed above the previously extracted longwalls at Angus Place and Springvale Collieries, which were typically between 5 mm and 25 mm, but with isolated surface cracking in some locations greater than 50 mm.

The shrub swamps have peat layers which overlie the shallow natural surface soils and underlying bedrock along the alignments of the drainage lines. In most cases, cracking would not be visible at the surface within these swamps, except where the depths of bedrock are shallow or exposed. The shrub swamps comprise significant quantities of sediment and, therefore, fracturing of shallow bedrock beneath these swamps are likely to be filled with soil during subsequent flow events along the drainage lines.

These predictions of impacts are based on years of experience, detailed modelling and a comprehensive understanding of the environment in which the mine operates. Predictions are based on scientific, robust and reliable data made by highly qualified consultants respected in their field of expertise.

**The East Wolgan swamp demonstrated a rather perverse endless loop of increasing toxicity. Water from the mine was discharged above the swamp, damaging the downstream section until the water disappeared into the ground. Despite the undemonstrated assertion from the mine consultants that the water would resurface further downstream, due to the streambed cracking being attributed by the company to upsidence, the clear fate of the water would be to re-enter the mine workings via the broken, collapsed sequence above the long wall panel. The water**

**would then have to be pumped and discharged again, presumably collecting more toxic components from successive trips through the coal seams. (BMCS)**

Water from shrub swamps cannot enter the mine workings because of the presence of the aquitard, Mount York Claystone, with an average thickness of approximately 22 m that exists throughout the Angus Place Colliery, Springvale Mine and Clarence Colliery lease areas. The aquitard underlies the the Banks Wall Sandstone and Burralow Formation (refer Figure 2.6, Figure 2.10 and Table 2.10 in the EIS) which support the Shrub Swamps (Figure 2.10 of the EIS).

The Burralow Formation consists of medium- to coarse-grained sandstones interbedded with frequent sequences of fine-grained, clay-rich sandstones, siltstones, shales and claystones. These fine-grained units can be several metres in thickness and their presence differentiates the Burralow Formation from the underlying Banks Wall Sandstone. Several of the claystone horizons, together with clay-rich, fine-to-medium grained sandstones and shales were found to be acting as aquitards, or semi-permeable layers. These aquitards retard the vertical movement of groundwater into underlying strata. For this reason water is more likely to re-surface further downstream than infiltrate into the underlying strata.

**The aquifer interference policy requires that a proponent demonstrates variability to lawfully take water within the limits of their licence and the water sharing plan. The Society notes that there appears to be a discrepancy (deficit) between the extraction licence and the estimated inflow in 2023. That deficit is in relation to what is required for the Richmond groundwater source, and is approximately 7 GL. Furthermore, the society is of the opinion that there is insufficient water to allow this level of extraction. (BMCS)**

Centennial Coal met with the NSW Office of Water on 13 June 2014 to discuss the water licensing requirements for the Project. Centennial's western operations as a whole are not predicted to require additional water entitlements until 2018. Centennial acknowledges that it is legally obligated to hold the necessary entitlements to undertake its operations. Centennial acknowledges that a review of recharge studies may not result in a change to the licensing requirements for Springvale and Angus Place's future water need. Centennial acknowledges that this may present a compliance risk beyond 2020.

The following strategy will be adopted by Springvale Coal to secure water licenses required for the Project:

- Trade, within the constraints of the relevant Water Sharing Plan, with other Centennial Coal water license holders.
- Obtain, when available through controlled allocation orders under the relevant Water Sharing Plan, additional allocations.
- Review the hydrogeological model and predicted water inflows for the Project on a 6 monthly basis to ensure adequate accounting for water take and license requirements.
- Contribute to the 2016 Water Sharing Plan review process, as agreed with the NSW Office of Water.

The Statement of Commitments contained in **Section 5.0** of this RTS has been updated to include this commitment.

**Centennial Coal claims that much of the water disappearing from fractured streambeds may re-emerge further downstream. There is evidence to the contrary for East Wolgan Swamp. Such re-emergent surface water is often heavily contaminated with groundwater polluted with salt and metals. This re-emergent, potentially eco-toxic water could not help a swamp or affected stream reach upstream that had suffered water loss. Any downstream sensitive instream environments and riparian environments, such as some shrub swamps and the Greater Blue Mountains World Heritage Area, could be impacted by eco-toxic groundwater effluent. (Colong Foundation)**

Centennial Angus Place and Springvale Coal confirm that no emergency discharges into Wolgan River occur currently or is proposed in the future. No discharges into Wolgan River have occurred since 10 April 2010.

Angus Place Colliery's EPL 467 was varied on 29 July 2013 to remove LDP006 as the emergency discharge point on Newnes Plateau. No new LDPs have been proposed in the Angus Place MEP (refer Section 4.11.3 of the Angus Place MEP EIS).

While Springvale Mine's EPL 3607 still has provisions for two emergency discharge points (LDP004 and LDP005) on Newnes Plateau no emergency discharges have been proposed via these LDPs in the Springvale MEP. Instead it has been proposed (refer Section 4.10.1 of the Springvale MEP EIS) that these LDPs be relinquished post-approval when infrastructure required to re-direct emergency discharge water from the SDWTS back underground to the Angus Place Colliery's 900 water storage area has been installed.

Given that there are no emergency discharges proposed on Newnes Plateau Colong Foundation's concerns that the " …downstream sensitive instream environments and riparian environments, such as some shrub swamps and the Greater Blue Mountains World Heritage Area, could be impacted by eco-toxic groundwater effluent." are unfounded.

A Regional Water Quality Impact Assessment has been undertaken as part of the RTS process and is attached as **Appendix 2**. This report assesses the impact (water quality and quantity) of the proposal to discharge all mine water from Springvale and Angus Place MEPs into Coxs River via Sawyers Swamp Creek, i.e. the report assesses the scenario where no mine water is transferred to Wallerawang Power Station. The potential impacts on the Coxs river catchment have been quantified, including Lake Burragorang.

**The consultants for Centennial Coal make assertions that there is no net loss of water from stream catchments and that 'Any diverted surface water is likely to re-emerge into the catchment further downstream'. The consultants for Centennial conclude 'It is unlikely, however, that this would result in adverse impacts on the overall quality and quantity of water flowing from the catchment.' This statement is misleading. It is more likely that what has happened previously to the Wolgan River and to Kangaroo Creek will be repeated in the streams above the proposed longwall mining area. In these areas, water was lost downstream as well as within the mining area. Even if this was not the case, the water diverted into the near-surface groundwater does not assist the natural functioning of swamps undermined, even if the water does emerge downstream. (Colong Foundation)**

The impacts to the East Wolgan Swamp mostly attributable to the mine water discharges that occurred between early 2007 and April 2010, however, Centennial Angus Place and Springvale Coal concede that subsidence impacts were also observed at East Wolgan Swamp and Kangaroo Creek Swamp. This finding is supported by Goldney et al (2010), an independent investigation undertaken on behalf of the then Commonwealth Department of, Environment, Water, Heritage and the Arts (DEWHA), who agreed that impacts at East Wolgan Swamp were caused by a combination of subsidence-related ground movements, mine water discharge and erosion, with the particular contribution of subsidence impacts unable to be quantified. In the case of Kangaroo Creek Swamp, impacts were wholly attributable to subsidence.

In both of the Kangaroo Creek Swamp and East Wolgan Swamp cases investigations have revealed that mine design was a primary causative factor for the observed subsidence impacts. The ratio of longwall mining void width to depth of cover for LW940 and LW950 underlying was Kangaroo Creek Swamp identified to be in the critical subsidence behaviour range. Following this investigation, the mine design was modified for all future proposed mining areas in the vicinity of Newnes Plateau Shrub Swamps to ensure that the ratio of longwall mining void width to depth of cover over mine workings was in the sub-critical subsidence behaviour range. No subsidence effects to swamp hydrology or flora communities have been identified in areas where sub-critical mine design has been used in the past.

**The extensive sandstone fracturing under headwater swamps associated with longwall mining will release high levels of metals, notably manganese and iron, polluting Carne Creek and making it run bright orange, just like the Wolgan River did once. (Colong Foundation)**

Approximately 2 km of Carne Creek is directly above the proposed longwalls LW416- LW419. The section of creek located above the proposed longwalls is generally confined within Sunnyside East Swamp. The predicted tilt of 0.25 mm/m, is less than the typical natural grade of Carne Creek, which ranges from 25 mm/m to 300 mm/m and therefore no significant ponding, flooding, scouring is predicted and is unlikely to have any adverse effect, apart from the potential for small sections of grade reversal where natural channel grades are very low immediately upstream of chain pillars.

It is expected that Carne Creek will experience compressive strains due to valley related movements between 5 mm/m and 15 mm/m. The greatest compressive strains are expected to occur where the creek is located near the centrelines of the proposed longwalls, and less where the creek is located near the chain pillars.The maximum predicted valley related movements, due to the extraction of the proposed longwalls only, are 65 mm upsidence and 75 mm closure. It has also been predicted that the river has already experienced valley related movements up to 270 mm upsidence and 330 mm closure due to the extraction of the existing longwalls at Angus Place and Springvale Collieries. No significant fracturing or surface water flow diversions have been observed along the river due to the existing mining. It is unlikely, therefore, that the extraction of the proposed longwalls would result in any significant fracturing resulting in surface water flow diversions or water quality impacts.

Existing baseflows to Carne Creek already occur from the near surface aquifers. The water quality from these aquifers that flow into Carne Creek will remain unchanged as a result of the Project.

There is no scientific evidence to suggest that the underground mining operations of Angus Place Colliery and Springvale Mine have previously resulted in impacts to water quality within Wolgan River and “making it run bright orange”.

**Centennial alleged that Area 300 can store water ‘at an average rate of approximately 4.7 megalitres of water per day. This underground water storage appears to be the source of water emerging nearby at Lambs Creek which was subjected to longwall mining several decades ago. The Colong Foundation has observed a large amount of water welling up from the ground into a wetland on Lambs Creek near where the creek emerges onto private land. Upstream of this swamp, the creek is dry due to longwall mining operations at a shallow depth of cover. This water re-emergence appears to be an unlicensed discharge from the underground water storage, Area 300, Angus Place Colliery. This discharge was not considered in the Water Balance**

**provided in the Environmental Assessment for modification of the Project Approval. The emergence of water make into Lambs Creek should be investigated to confirm that it has water make characteristics. If it has, then the applicant should be asked to explain why it has not notified authorities of this source of mine effluent for the last three decades. (Colong Foundation)**

The claim that the Angus Place 300 Underground Storage Area is "...the source of water emerging nearby at Lambs Creek which was subjected to longwall mining several decades ago" is false. The claim has not been corroborated with any scientific evidence linking the "… large amount of water welling up from the ground into a wetland on Lambs Creek." and water stored within the 300 Underground Storage Area. The storage area below Lambs Creek has a depth of cover of at least 150 m. It is not possible for the stored mine water in the workings to "well up" from this depth to discharge into Lambs Creek. It is not possible for the water to emerge further downstream of Lambs Creek on the west and discharge into it as the coal seam / existing workings where water is stored dips to the east and mine water flows in that direction. No pumping of mine water from the storage area to the surface using a seam to surface pumping system occurs currently or is proposed in the Angus Place and Springvale MEPs.

**The Emirates Wolgan Valley Resort & Spa, Newnes Hotel and Cabins, local farmers, graziers and residents depend on this water for survival. Centennial must be required to enter into compensation arrangements in the event that Carne Creek or the Wolgan River either cease flowing, or become polluted to the point of being unfit for human consumption due to emergency mine water discharges. (LEG)**

Centennial Angus Place and Springvale Coal confirm that no emergency discharges into Wolgan River occur currently or is proposed in the future. No discharges into Wolgan River have occurred since 10 April 2010. There has never been any mine water discharges into Carne Creek and neither is there any proposal to do discharge into that catchment as part of the project.

Angus Place Colliery's EPL 467 was varied on 29 July 2013 to remove LDP006 as the emergency discharge point on Newnes Plateau. No new LDPs have been proposed in the Angus Place MEP (refer Section 4.11.3 of the Angus Place MEP EIS).

While Springvale Mine's EPL 3607 still has provisions for two emergency discharge points (LDP004 and LDP005) on Newnes Plateau no emergency discharges have been proposed via these LDPs in the Springvale MEP. Instead it has been proposed (refer Section 4.10.1 of the Springvale MEP EIS) that these LDPs be relinquished post-approval when infrastructure required to re-direct emergency discharge water from the SDWTS back underground to the Angus Place Colliery's 900 water storage area has been installed.

**The conclusion of the EIS after hydraulic investigation and modelling is that after cracking the ground of 1000's of hectares and subsequently pumping away 43.8 ML/day will have "…minimal impact on the shallow and perched aquifer systems across Newnes Plateau ". Given the volume of water to be pumped out from the mine as well as the undoubted effect this will have on underground aquifers (which it is impossible to predict), any normal person would agree that conclusion defies scientific evidence and logical argument. (LEG)**

The mine inflows arise from the Lithgow Seam (Illawarra Coal Measures) being mined at Angus Place Colliery and Springvale Mine. This aquifer, referred to as AQ1 in the EIS and the Groundwater Impact

Assessment (Appendix E) is hydraulically connected with the Berry Siltstone and Marrangaroo Formations beneath and the Long Swamp Formation and Irondale Coal Seam above, the location of which within the regional hydrostratigraphy is shown in the EIS Table 2.5. This aquifer, along with aquifers AQ2 – AQ6, represents one of the major aquifers in the regional hydrogeological system.

The regional hydrostratigraphic system is divided into three groundwater systems denoted as perched, shallow and deep groundwater systems, described in detail in Section 2.6.2.5 of the EIS. The regional hydrogeology encompassing the Angus Place and Springvale Project Application Areas was studied extensively by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) between 2004 and 2008, and is described in ACARP reports C14033 and C18016. The most recent and detailed groundwater and aquifer modelling was conducted by CSIRO, Palaris (Palaris 2013a and Palaris 2013b) and RPS between 2011 and 2013. This modelling is based on the latest groundwater and geological data, which has been significantly improved since the initial CSIRO reports were published. The geological model includes data from 501 exploration boreholes (refer Figure 2.11 of the EIS). The groundwater model includes data from 142 piezometers in 31 boreholes over a period of up to 10 years and mine water inflow data which has been recorded over a period of 20 years.

The AQ1 aquifer, along with aquifers AQ2 and AQ3, is part of the deep groundwater system, located in the strata underlying the Mount York Claystone. The Mount York Claystone is the major aquitard in the region, and separates the deep groundwater system from the shallow and perched groundwater systems located above it. The deep groundwater system generally lies at a depth of 200 m to 500 m below the ground surface. The aquifer zones within the deep groundwater system are typically fractured rock aquifers or jointed coal seams. It is this system which produces the mine water inflows when groundwater in this system is drained into the goaf following coal extraction.

Removal of mine inflows from the deep groundwater system is unlikely to impact the shallow/perched groundwater systems as there is no hydraulic connectivity.

The hydrostratigraphic sequence discussed briefly above, and presented in Table 2.5 of the EIS, has been incorporated into the hydrogeological model developed by CSIRO (attached as Appendix K to the Groundwater Impact Assessment prepared by RPS (Appendix E)) to understand the groundwater impacts of the Angus Place and Springvale MEPs. The predicted mine inflows, from the projects, deduced from the CSIRO's hydrogeological model, are presented in Figure 10.11 in the EIS.

## 3.3 Response to Community Individual Submissions

### 3.3.1 Air Quality

**Centennial claims only a small contribution to the amount of State and Federal GHG emissions, but omit the Scope 3 emissions about which they say the greatest emission sources associated with the Project are those related to the downstream combustion of the coal (Scope 3), the management of which is not in Centennial Angus Place's control. (SV160)**

An Air Quality and Greenhouse Gas Assessment were prepared by SLR Consulting to support the Project and are provided as Appendix M to the EIS. The Greenhouse gas assessment includes calculation of all Scope 3 greenhouse gas emissions associated with the Project.

As shown in Table 10.40 of the EIS, Scope 3 emissions will remain unchanged for the Project when compared to the current operations.

**Centennial argue that GHG emissions of all machinery required in the operations and all clearing of forest required for above ground supporting infrastructure is "negligible". However the entire purpose of this project is to sell for combustion 4.5 million tons of the thermal coal p.a. for 13 years. (SV280)**

An Air Quality and Greenhouse Gas Assessment for the Project was undertaken by SLR Consulting to support the Project and provided as Appendix M to the EIS.

The GHG assessment has been performed with reference to the Australian Department of Climate Change and Energy Efficiency document "National Greenhouse Accounts Factors" (July, 2011), the NSW Department of Energy, Utilities and Sustainability document "Guidelines for Energy Savings Action Plans" (2005), the National Greenhouse and Energy Reporting Act 2007 (NGER Act), the Centennial Coal Greenhouse Gas Assessment Guidance Notes (Centennial Coal, 2010) and Climate Change Response Policy (Centennial Coal, 2012b).

The Air Quality and Greenhouse Gas Assessment accounts for all Scope 1, Scope 2 and Scope 3 emissions over the life of the Project. The total lifetime direct (scope 1) emissions from the Project are estimated to be approximately 22,697 t CO2-e per annum, which is relatively small as this represents approximately 0.01% of NSW GHG emissions and 0.004% of Australia's total GHG emissions.

### 3.3.2 Consultation

**The Springvale and adjoining Angus Place mine extension proposals must be subject to a Planning Assessment Commission review with concurrent Public Hearings. (Various)**

**This proposal and the adjoining Angus Place extension proposal should be subject to a stringent planning assessment and PAC review process. (SV096, SV165, SV189, SV226)**

Determination of the Angus Place MEP and the Springvale MEP will be by the NSW Planning and Assessment Commission following public hearings for both projects. The Planning and Assessment Commission will determine how these public hearings are structured.

**Chapter 7 states that: "The public, including community groups and adjoining and affected landowners were identified and consulted with as part of the consultation and engagement strategy "(p201). None of the Wolgan Valley residents were contacted by Centennial including Emirates Wolgan Resort and Spa. Nor were The Blue Mountains Conservation Society, the Colong Foundation for Wilderness or the Lithgow Environment group. (SV280)**

As noted in Section 7.4.2 of both the Angus Place and Springvale MEP EISs three information sessions were held in March 2013 (2 – 4pm 6 March; 6 – 8 pm, 9 March; 10 am – 2 pm, 9 March) and two session in September 2013 (6 – 7.30 pm, 26 September; 1 – 2.30 pm, 28 September) in Wallerawang to discuss the proposed projects. The March 2013 sessions were held prior to the completion of the technical assessments being undertaken to support the EISs so that any concerns raised at the consultation sessions could be addressed in those technical assessments. The September 2013 sessions were held to provide outcomes of the technical assessments. In addition, a structured technical presentation was organised on 5 October 2013 at the Mines Rescue Station in Lithgow. This session was a means of informing the community formally the outcomes of the technical assessments, including how issues raised at the information sessions had been addressed in the EISs.

All information sessions and the technical session were advertised in Lithgow Mercury ahead of the session dates in March 2012, February 2013 and September 2013 inviting community members, including Wolgan Valley residents, Emirates Wolgan Resort and Spa, The Blue Mountains Conservation Society, the Colong Foundation for Wilderness and the Lithgow Environment group, to participate in the consultation process.

**After requesting to make a presentation to the Centennial Community Consultation Committee meeting of 8 April, 2014 I was refused by the Chairman, Howard Fisher. However my written presentation was read out during that meeting through committee member Ian Coates. Apparently, there was no discussion and he was told that I would receive a response from Centennial. I have not heard from them. (SV280)**

A letter from Thomas Ebersoll was tabled at the Angus Place Colliery and Springvale Mine Community Consultative Consultation (CCC) Meeting of 8 April 2014 by Ian Coates, one of the community members on the committee. The letter was discussed and an action was developed at the meeting. This is reflected in the minutes of that meeting available from the Angus Place Colliery website:

http://www.centennialcoal.com.au/Operations/OperationsList/Angus-Place.aspx#Community-Consultative-Committee-Minutes

The Chairman of the CCC, Howard Fisher, wrote to Thomas Ebersoll on 14 May 2014 acknowledging his letter and advised him to make a formal submission on the Angus Place MEP on the Department of Planning and Environment's website. Thomas Ebersoll was advised the closing date for submissions was 26 May 2014. Additionally to the above-noted communication, Thomas Ebersoll had contacted Angus Place Colliery to ask to speak with the person coordinating the preparation of the EIS for the Angus Place MEP. Iain Hornshaw (Environmental Projects Coordinator) called Thomas Ebersoll on 11 March 2014 and provided him with information on the MEPs.

### 3.3.3 Cultural Heritage

**The Garden of Stone area has profound cultural and physical heritage values that should be preserved. (SV230, SV232)**

Section 6.7.4 of the Flora and Fauna Impact Assessment includes an assessment of impacts from the Project on the Gardens of Stone National Park which is part of the Greater Blue Mountains Area (GBMA). The GBMA is a World Heritage Property and National Heritage Place which occurs approximately 6 km to the east of the Study Area and approximately 7 km to the north.

DoE (2013) provides Significant Impact Assessment criteria for World Heritage Properties and National Heritage Places. The Flora and Fauna Impact Assessment includes an assessment of the potential impacts from the Project against the DoE criteria. In summary, the proposed surface disturbance areas are surrounded by large areas containing contiguous forest, woodland, heath, swamp and rocky habitats. These habitats continue throughout the Newnes State Forest and into the Gardens of Stone National Park, Blue Mountains National Park and Wollemi National Park. For those more mobile species, including the threatened birds, bats, arboreal mammals and terrestrial mammals, which are likely to be impacted upon by the Project, local populations of these species would extend into these adjacent protected habitats. Those less mobile fauna, such as threatened frogs and the Blue Mountains Water Skink, have specific habitat niches important for their survival, which are not represented within the defined environmental study areas for the Project and therefore no impacts are expected to these species.

The proposed clearing of 11.4 hectares is unlikely to reduce the diversity or modify the composition of plant and animal species within the GBMA. However, habitats for fauna species that may occupy both the Project Application Area and the GBMA as part of their home range will be subject to a minor reduction in habitat due to proposed clearing.

As is detailed in Section 5.15 of the Subsidence Assessment prepared by MSEC and provided as Appendix D to the EIS, the Gardens of Stone National Park is located more than 7 kilometres north of the proposed longwalls. At this distance, the National Park will not experience any measurable subsidence movements resulting from the extraction of the proposed LW416 to LW432 and LW501 to LW503.

**The project will hamper tourism therefore destroying the opportunity for local Aboriginal people to benefit in a positive way as tour guides of the many local art sites. (SV192)**

Centennial Springvale acknowledge in Section 6.1 of the EIS that the Newnes Plateau is identified as being an important feature of the Lithgow LGA by the local, regional and State stakeholders who access the area for various activities. Consultation was undertaken as part of the development of the Social Impact Assessment prepared by James Marshall & Co and provided as Appendix N to the EIS, with users of the Plateau including adventure visitors (mountain bike riders, motor bikers and four wheel drivers) and passive visitors (include bushwalkers, families visiting a particular destination point). The consultation was undertaken at various times throughout 2013 and found that many visitors who live in the area are aware of mining under the Newnes Plateau. It was generally their opinion that mining has not changed their experience when visiting the area and will not change their experience as long as access to the area was permitted. Many of these visits were for adventure type tourism. Passive visitors, for example, families visiting the area to visit a particular destination point (for example the Glow Worm Tunnels) and bushwalkers generally stated that they did not want their experience changed. The amenity of the area was important to these types of visitors and key words used to describe the area are: quiet, nature, features (pagodas and cliffs) and views from lookouts.

It is identified in Section 5.3 of the Social Impact Assessment that the mine design and other mitigating factors have minimised the extent of change to the physical environment to an extent that the Project will not adversely impact on the existing land use, its physical characteristics including surface features and the manner in which the public utilise / access the area for recreation.

As is detailed in Section 10.4.7 of the EIS, in regards to Aboriginal heritage sites, there have been a number of surveys that have identified 34 Aboriginal cultural sites within the Project Application Area, of which three are at risk of harm by subsidence. The remaining sites are 'unlikely' or 'very unlikely' to be impacted by the extraction of the proposed longwalls.

Of the three sites, subsidence at site 45-1-0002 may cause the sandstone where the grinding groove is or was located to fracture. The recent survey was unable to find any evidence remaining of the site, probably due to the extensive vehicle traffic.

The predicted subsidence at site 45-1-0005 and 45-1-0065 is 50 mm and 25 mm, respectively. Tilts, curvatures or strains are predicted to be negligible and are not expected to damage these two sites.

As such, the Project is unlikely to impact the opportunity for local Aboriginal people to benefit in a positive way as tour guides of the many local art sites within the area.

### 3.3.4 Ecology

**Important terrestrial and stream environments in this significant part of the Gardens of Stone region must not be damaged by long wall mining but instead protected in a state conservation area. (Various)**

**The project is not to go ahead in the Gardens of Stone which has been recommended by the Office of Environment and Heritage to be protected in a conservation reserve. (SV247)**

1,860 hectares of land is within the potential subsidence impact area. As detailed in Section 6.5 of the flora and fauna impact assessment, provided as Appendix H to the EIS, flora and fauna monitoring undertaken at Angus Place Colliery since 2005 has not recorded any losses to threatened species populations or EECs as a result of subsidence. This is due to appropriate mine design to limit subsidence to acceptable levels.

The mining layout for the Project has been designed to minimise the potential for impacts and so the majority of the cliffs and pagoda complexes are located outside the 26.5 degree angle of draw line from the extents of the proposed longwalls. No impacts are expected to these features and, subsequently, no impacts would be expected to potential habitats of those threatened species that may utilise these habitats.

No significant impacts to the dry woodland and forest habitats are predicted as a result of subsidence. Destabilisation of slopes is unlikely to be substantial such that it would significantly affect threatened flora o fauna that may occupy woodland environments.

Section 6.7.4 of the Flora and Fauna Impact Assessment includes an assessment of impacts on the Projects impacts on the Gardens of Stone National Park which is part of the Greater Blue Mountains Area (GBMA). The GBMA is a World Heritage Property and National Heritage Place which occurs approximately 6 km to the east of the Study Area and approximately 7 km to the north.

DoE (2013) provides Significant Impact Assessment criteria for World Heritage Properties and National Heritage Places. The Flora and Fauna Impact Assessment includes an assessment of the potential impacts from the Project against the DoE criteria. In summary, the proposed surface disturbance areas are surrounded by large areas containing contiguous forest, woodland, heath, swamp and rocky habitats. These habitats continue throughout the Newnes State Forest and into the Gardens of Stone National Park, Blue Mountains National Park and Wollemi National Park. For those more mobile species, including the threatened birds, bats, arboreal mammals and terrestrial mammals, which are likely to be impacted upon by the Project, local populations of these species would extend into these adjacent protected habitats. Those less mobile fauna, such as threatened frogs and the Blue Mountains Water Skink, have specific habitat niches important for their survival, which are not represented within the defined environmental study areas for the Project and therefore no impacts are expected to these species.

The proposed clearing of 11.4 ha is unlikely to reduce the diversity or modify the composition of plant and animal species within the GBMA. However, habitats for fauna species that may occupy both the Project Application Area and the GBMA as part of their home range will be subject to a minor reduction in habitat due to proposed clearing.

As is detailed in Section 5.15 of the Subsidence Assessment prepared by MSEC and provided as Appendix D to the EIS, the Gardens of Stone National Park is located more than 7 km north of the proposed longwalls. At this distance, the National Park will not experience any measurable subsidence movements resulting from the extraction of the proposed LW416 to LW432 and LW501 to LW503.

Due to the above considerations, the Project is not expected to lead to indirect impacts from clearing, be significantly affected by subsidence or be affected by changes in water quality. Therefore, the Project is unlikely reduce the diversity or modify the composition of plant and animal species within any part of the GBMA.

No direct or indirect impacts are expected that would fragment, isolate or substantially damage habitat for rare, endemic or unique animal populations or species, or habitat that is important for the conservation of biological diversity within the GBMA.

Consequently, the Project is not expected to cause a long-term reduction in rare, endemic or unique plant or animal populations or species within the GBMA.

**Centennial Coal must not be allowed to simply replicate the damage it has already caused to nationally threatened upland swamps on the Newnes Plateau for which it was required by the Commonwealth Government to pay $1.45 million in reparations. (Various)**

Springvale Coal acknowledges in Section 2.6.2.7 of the EIS the historical impacts to Swamps as a result of previous mining and mining related activities. Longwalls have been extracted directly or partially beneath 13 shrub swamps and 26 hanging swamps. Surface impacts have been observed at five swamps including Kangaroo Creek Swamp, Narrow Swamp North, Narrow Swamp South, East Wolgan Swamp and Junction Swamp. These have been investigated and where impacts have been observed, these have been identified as largely the result of mine water discharge.

Investigations have identified that erosional and flora dieback impacts at Narrow Swamp North, Narrow Swamp South, East Wolgan Swamp and Junction Swamp were caused by changes to swamp hydrology related to mine water discharge and were not related to subsidence. As a result of this finding, future mine dewatering systems have been designed to ensure that discharge of mine water to Newnes Plateau Shrub Swamps is avoided.

Subsidence effects to aspects of swamp hydrology have been noted at two swamps (Kangaroo Creek Swamp and East Wolgan Swamp). In both of these cases investigations have revealed that mine design was a primary causative factor. The ratio of longwall mining void width to depth of cover over mine workings was identified to be in the critical subsidence behaviour range. Following this investigation, the mine design was modified for all future proposed mining areas in the vicinity of Newnes Plateau Shrub Swamps to ensure that the ratio of longwall mining void width to depth of cover over mine workings was in the sub-critical subsidence behaviour range. No subsidence effects to swamp hydrology or flora communities have been identified in areas where sub-critical mine design have been used in the past.

Section 2.8.4 of the EIS details the cause and outcomes of an Enforceable Undertaking under section 486DA of the EPBC Act. Centennial acknowledged that its operations had a significant impact on THPSS, a federally listed endangered ecological community and as such Springvale Coal and Angus Place Pty Limited undertook to pay $1,450,000 for a four year research program.

The objectives of this research program are to:

- Provide the necessary knowledge to conserve, manage and restore THPSS;
- Use that knowledge to promote best management practices for these areas;
- Transfer knowledge gained in the program to agencies, land managers and relevant stakeholders; and
- Maximise the educational and training opportunities of the Program.

The research themes under the program are:

- Understanding the THPSS which includes detailed mapping, location, distribution and extent of the swamps, including those under threat.
- Understanding swamp systems, including water balance and dynamics, the functionality of peatland swamps, environmental history and origins, ecology/biodiversity of major structural species and contribution of THPSS to the landscape.
- Understanding land management and impacts, including condition status mapping and trends.
- Application of understanding, including monitoring of reference sites and thresholds for recovery and resilience.

In 2012, approximately $900,000 of the research fund had been allocated to five projects, with additional funding set aside to support swamp hydrology research when a suitable project was identified by the Steering Committee. The Committee meets twice annually and holds an annual workshop to review the status of the research findings and outcomes.

**The sandstone strata supporting the 41 nationally endangered swamps, including the 11 shrub swamps affected by the proposal must not be fractured. (Various)**

Section 5.12 of the Subsidence Assessment, provided as Appendix D to the EIS, provides a detailed assessment of the potential impacts to shrub swamps and hanging swamps as a result of the Project.

The mining layout has also been designed so as to reduce the potential impacts on the shrub swamps resulting from mine subsidence movements, in particular, the proposed longwalls in the Project Application Area which lie beneath Newnes Plateau Shrub swamps (LW416 – LW432) are designed to have sub-critical W/H ratios and chain pillars at least 55 m wide.

Predicted post mining grades are similar to the natural grades within the shrub swamps. There are no predicted significant reductions or reversals of grade. The hanging swamps are located on the sides of the valleys and, therefore, that natural gradients are greater than those shown for the shrub swamps. It is not expected, therefore, that there would be any adverse changes in ponding or scouring within the swamps resulting from the predicted mine subsidence movements. It is also not anticipated that there would be any significant changes in the distribution of the stored surface waters within the swamps as a result of the mining induced tilt or vertical subsidence.

Fracturing of the uppermost bedrock has been observed in the past, as a result of longwall mining, where the tensile strains have been greater than 0.5 mm/m or where the compressive strains have been greater than 2 mm/m.

The swamps which are located outside the extents of the proposed longwalls, including Sunnyside Swamp and Nine Mine Swamp, are predicted to experience tensile strains less than 0.5 mm/m and compressive strains less than 2 mm/m due to the proposed mining. It is unlikely, therefore, that the bedrock beneath these swamps would experience any significant fracturing.

The swamps which are located directly above the proposed longwalls are predicted to experience tensile strains greater than 0.5 mm/m and compressive strains greater than 2 mm/m. It is expected, therefore, that fracturing would occur in the top most bedrock beneath these swamps.

The surface cracking across the mining area is expected to be generally isolated and minor in nature, due to the reasonable depths of cover which typically vary between 350 metres and 400 metres, and due to the plasticity of the surface soils which allows them to more readily absorb the ground strains. Surface crack widths are expected to be similar to those observed above the previously extracted longwalls at Angus Place and Springvale Collieries, which were typically between 5 mm and 25 mm, but with isolated surface cracking in some locations greater than 50 mm.

The shrub swamps have peat layers which overlie the shallow natural surface soils and underlying bedrock along the alignments of the drainage lines. In most cases, cracking would not be visible at the surface within these swamps, except where the depths of bedrock are shallow or exposed. The shrub swamps comprise significant quantities of sediment and, therefore, fracturing of shallow bedrock beneath these swamps are likely to be filled with soil during subsequent flow events along the drainage lines.

The hanging swamps have soft soil or peat layers which overly the bedrock on the valley sides. It is expected that the potential for fracturing in these locations would be less when compared to the bases of the valleys, where higher compressive strains occur due to the valley related movements, and due to the higher depths of cover along the valley sides.

Whilst some minor surface cracking could occur in the swamps resulting from the extraction of the proposed longwalls, the previous experience of mining beneath swamps at Angus Place, Springvale and in the Southern Coalfield indicate that the likelihoods and extents of these impacts are very small.

The dilated strata beneath the drainage lines, upstream of the swamps, could result in the diversion of some surface water flows beneath parts of the shrub swamps. It is noted, however, that the drainage lines upstream of the swamps are generally ephemeral and, therefore, surface water flows occur during and shortly after rainfall events. Any diverted surface water flows are expected to remerge short distances downstream, due to the limited depth of fracturing and dilation and due to the high natural stream gradients.

The incidence of impacts on swamps due to mine subsidence ground movements is very low and, in some of these cases, the impacts that were observed were associated with natural events or mining related surface activities. It is expected, therefore, that the incidence of impacts on the swamps within the Extension Area resulting from mining induced ground movements will also be low.

Previous longwalls at Angus Place and Springvale Collieries have been extracted directly beneath or partially beneath 13 shrub swamps and 26 hanging swamps. Surface impacts have been observed at four swamps which were directly mined beneath by the previously extracted longwalls at Angus Place and Springvale Collieries. Centennial has recognised that past mining related surface activities, i.e. the discharge of high quantities of mine water and construction of various roads and access paths, have resulted in surface impacts to some swamps. Centennial has developed management plans to minimise the potential for future impacts resulting from these mining related surface activities.

An environmental monitoring program was established to assess the effects of longwall mining on the groundwater systems associated with the swamps at Angus Place and Springvale Collieries. The monitoring comprised swamp piezometers, shallow aquifer piezometers and multi-level vibrating wire piezometers at Junction, Sunnyside, Sunnyside West and West Wolgan Swamps. The monitoring results were reviewed by RPS which found that the monitoring results provided no evidence that longwall mining had affected the groundwater systems for these swamps.

The groundwater Impact Assessment prepared by RPS to support the Project and provided as Appendix E to the EIS determined that the most significant reductions to average standing groundwater levels are predicted in Twin Gully Swamp.

This swamp has a projected drop in average standing water levels from 12.4 cm to 10.6 cm above the soil surface. The post mining values predicted at Twin Gully Swamp therefore suggest that soil saturation would persist, maintaining water availability for flora and fauna, as well as soil anoxia, allowing for continued peat formation. All other monitored swamps have smaller projected decreases in average standing water levels and monitored swamps are projected to maintain average standing water levels above the surface.

Additionally, highly organic peat soils with low bulk density capillary forces are likely to be saturated for some distance above the water table itself. Natural decreases in water levels, in addition to the small predicted decreases from the CSIRO model are still likely to enable capillary forces to saturate the peat layer. Therefore, a possible reduction in the average standing water levels, by the magnitudes predicted is unlikely to result in drying of the peat layer.

The Project is not expected to have a significant impact upon the hydrology of any hanging swamps. The reliance of these areas on perched aquifer systems effectively isolate them from any hydrological changes that may occur to the regional water table as a result of mining operations.

**The proposed clearing of 14 hectares of forest for an additional ventilation facility is excessive and its proposed location close to the Wolgan River is unacceptable. (Various)**

**The 11.44 ha of land clearance should not occur. (SV239)**

Springvale Coal is seeking approval for the construction of new proposed which include:

- Extension of the existing SDWTS scheme to the proposed Bores 9 and 10 dewatering facilities to be established on Newnes Plateau; and
- Duplication of the existing scheme at sections to a maximum capacity of 50 ML/day to allow for the management of mine inflows from both Springvale Mine and Angus Place Colliery.

Two new dewatering facilities are proposed to be established in the Project on Newnes Plateau. Bore 9 and Bore 10 will be installed sequentially as mining progresses to the east and then the southeast of the existing workings. Bore 9, will be established when the current dewatering facility (Bore 8) will no longer function effectively. Bore 9 will manage mine inflows from LW420 to LW423. Bore 10 will manage mine inflows from LW424 – LW432 and LW501 – LW503.

The timing of the construction, operation and rehabilitation of Bore 9 and Bore 10 will be staged and contingent upon the progression of underground workings. A proposed infrastructure footprint of 11.44 ha is required for the construction of new infrastructure.

Dewatering bore facility sites have been identified based upon mine design requirements, and environmental constraints from a desktop analysis. The preferred options for the final placement of the dewatering boreholes will balance dewatering needs with potential environmental impacts. It is identified in Section 5.3 of the Social Impact Assessment that the mine design and other mitigating factors have minimised the extent of change to the physical environment to an extent that the Project will not adversely impact on the existing land use, its physical characteristics including surface features and the manner in which the public utilise / access the area for recreation.

The dewatering infrastructure is critical for Springvale Mine's ability to continue to operate in a safe, efficient and environmentally sensitive manner underground as well as above ground.

**Carne and Bungleboori Creeks, pagodas, cliffs and the many nationally endangered swamps must not be damaged. (Various)**

**Carne Creek, pagodas, cliffs and the many nationally endangered swamps that the current proposal puts at risk must not be damaged. (SV024, SV035, SV104, SV183, SV196, SV210, SV231, SV288)**

**A number of threatened species and endangered ecological communities will be compromised by the proposed extension. (SV205, SV275)**

**The project will cause destruction of our natural environments that protect our flora and fauna that also provide clean water, air, a carbon sink, link to our cultural heritage and a tourist attraction. (SV001, SV096, SV102)**

**Longwall mining under the endangered ecological communities and rock pagodas and cliffs will cause subsidence damage. (SV138, SV140, SV142, SV143, SV209, SV226)**

**Ben Bullen State Forest is unique and must be protected. (SV247)**

1,860 hectares of land is within the potential subsidence impact area. As detailed in Section 6.5 of the flora and fauna impact assessment, provided as Appendix H to the EIS, flora and fauna monitoring undertaken at Angus Place Colliery since 2005 has not recorded any losses to threatened species populations or EECs as a result of subsidence. This is due to appropriate mine design to limit subsidence to acceptable levels.

The mining layout for the Project has been designed to minimise the potential for impacts and so the majority of the cliffs and pagoda complexes are located outside the 26.5 degree angle of draw line from the extents of the proposed longwalls. No impacts are expected to these features and, subsequently, no impacts would be expected to potential habitats of those threatened species that may utilise these habitats.

The Project will remove approximately 11.44 ha of potential habitat for a number of threatened fauna species. Consideration of potential impacts under the TSC Act and EPBC Act has been considered with regard to the proposed clearing. As a consequence of the available surrounding habitat, the comparatively small habitat losses, as well as the avoidance and mitigation measures proposed, the Project is unlikely to have a significant impact on threatened species or EECs as a result of proposed vegetation clearing.

No significant impacts to the dry woodland and forest habitats are predicted as a result of subsidence. Destabilisation of slopes is unlikely to be substantial such that it would significantly affect threatened flora or fauna that may occupy woodland environments. To compensate for the clearing required for new surface infrastructure, Centennial Coal has developed a Regional Biodiversity Strategy (revised September 2014) that that takes into consideration both the direct impacts of clearing potential habitat and indirect impacts to the Temperate Highland Peat Swamps on Sandstone, incorporating Newnes

Plateau Shrub Swamps and Newnes Plateau Hanging Swamps. Details of the Biodiversity Strategy proposed to be implemented are detailed in the revised Regional Biodiversity Offset Strategy provide as **Appendix 4** of this RTS.

As a result of impacts identified to swamps in the past, Springvale Coal has modified the mine design to minimise the potential risk of these impacts occurring into the future.

Whilst some minor surface cracking could occur in the swamps resulting from the extraction of the proposed longwalls, the previous experience of mining beneath swamps at Angus Place, Springvale and in the Southern Coalfield indicate that the likelihoods and extents of these impacts are very small.

No significant changes in surface water flows, vegetation composition or habitats are anticipated as a result of the Project.

**The project will negatively impact the Great Barrier Reef (SV213)**

The Project will not impact on the Great Barrier Reef given the distance of the Great Barrier Reef and the location of the Project. There are no reefs identified within the Project Application Area.

**The impacts of past mining have been dealt with cursorily in the EIS which essentially argues that there have been no direct impacts on swamps by subsidence. There have clearly been impacts. (SV004)**

**Both East Wolgan and Narrow have now been severely degraded by mining impacts and acknowledged in the imposition of Enforceable Undertaking, though the impacts of the excess mine water is conveniently used as the cause of the damage, damage which has left the drainage line of East Wolgan in particular a 30 m wide stretch of bare dry earth with no evidence of recovery after nearly 6 years. (SV004)**

**Kangaroo Swamp, Lambs Creek Swamp, Junction Swamp and East Wolgan Swamp have all been lost, although each was supposed to be protected under both State TSC Act and EPBC Act for Endangered Ecological Communities. (SV030)**

**The Commonwealth Department of the Environment has found that Centennial's longwall mining activities on the Newnes Plateau caused a loss of ecosystem function shown by loss of peat, erosion, vegetation dieback and weed invasion in 3 swamps (East Wolgan Swamp, Junction Swamp, Narrow Swamp). This shows they are not capable of protecting the environment and must not happen again. (SV032, SV115 ,SV151, SV205, SV221, SV244)**

**The mine water discharges into East Wolgan Swamp caused scalding in a narrow line down the valley axis. It did not support the vegetation over most of the swamp but killed it along the line of maximum discharge, encouraging erosion. (SV226)**

Centennial acknowledges in Section 2.6.2.7 of the EIS the historical impacts to Swamps as a result of previous mining and mining related activities. Longwalls have been extracted directly or partially beneath 13 shrub swamps and 26 hanging swamps. Surface impacts have been observed at five swamps including Kangaroo Creek Swamp, Narrow Swamp North, Narrow Swamp South, East Wolgan Swamp and Junction Swamp. These have been investigated and where impacts have been observed, these have been identified as largely the result of mine water discharge.

Investigations have identified that erosional and flora dieback impacts at Narrow Swamp North, Narrow Swamp South, East Wolgan Swamp and Junction Swamp were caused by changes to swamp hydrology related to mine water discharge. Impacts related to subsidence, however, were observed at East Wolgan Swamp and Kangaroo Creek. As a result of this finding, future mine dewatering systems have been designed to ensure that discharge of mine water to Newnes Plateau Shrub Swamps is avoided and the longwalls under shrub swamps are sub-critical panels.

Subsidence effects to aspects of swamp hydrology have been noted at two swamps (Kangaroo Creek Swamp and East Wolgan Swamp). In both of these cases investigations have revealed that mine design was a primary causative factor. The ratio of longwall mining void width to depth of cover over mine workings was identified to be in the critical subsidence behaviour range. Following this investigation, the mine design was modified for all future proposed mining areas in the vicinity of Newnes Plateau Shrub Swamps to ensure that the ratio of longwall mining void width to depth of cover over mine workings was in the sub-critical subsidence behaviour range. No subsidence effects to swamp hydrology or flora communities have been identified in areas where sub-critical mine design has been used in the past.

Chapter 8 of the EIS details the evolution of the mine design at Springvale Colliery and how the mine design proposed for the Project has been developed taking into consideration safety, geological and environmental features.

Springvale Mine has applied a risk based approach to the Project to identify, quantify and reduce risks of environmental consequences wherever feasible. Previous subsidence monitoring has been used to develop and validate a predictive model of subsidence for the proposed mining area. This model has a high level of confidence in its predictions and is built upon a significant dataset comprising geological and geotechnical data. The mine has been designed to avoid, to the largest extent possible, sensitive surface features. Where a sensitive surface feature has not been avoided, a sub-critical void width has been applied in the mine design.

The primary objective of mine design is safety, underground and on the surface. By managing safety, the mine manages subsidence impacts on the surface and in turn manages environmental and social consequences. At Angus Place Colliery, the application of risk based planning, has driven mine planning, mine design and subsidence management, based on the geological and geotechnical constraints, and the overlying sensitive features.

There are two management strategies for avoiding or minimising the impacts to sensitive surface features as a result of mining. These are:

- Avoid mining under the sensitive surface feature; or
- Mine design under the sensitive surface feature has a sub-critical void width.

The following controls have been applied to the Project:

- proposed longwalls LW501 to LW503 have been positioned between clusters of cliffs. LW419 to LW422 have been shortened to avoid cliffs and pagodas;
- the proposed longwalls in the Project Application Area which lie beneath Newnes Plateau Shrub Swamps (LW416 – LW432) are designed to have sub-critical W/H ratios and chain pillars at least 55 m wide.

Potential environmental constraints have already been taken into account during the mine design process to ensure the Project is undertaken safely and in the most environmentally sensitive manner feasible. Where impacts are predicted, monitoring management and where appropriate, offset strategies, have been proposed to be implemented.

**In total 73 nationally endangered swamps will be damaged by cracking of the underlying sandstone causing the swamps to dry out by the groundwater level falling by 10 m. This will increase bushfire risk and lead to dried out swamps being replaced by dry land floral communities. (SV010, SV084, SV091, SV098, SV111, SV161, SV168, SV189, SV246, SV277, SV281)**

**The peat soils that supported the swamps will decompose and over a period of years eucalypts and banksias will migrate into the dying swamps as they evolve into dryland communities. (SV084, SV091, SV107, SV246, SV280)**

**Impacts to swamps will result in many threatened plants and animals supported by them being killed, including the giant dragonfly. (SV029, SV084, SV091, SV130, SV246, SV281)**

**Centennial "admits its mining will fracture iconic Birds Rock, a Flora Reserve, and the sandstone beds under 73 nationally endangered swamps". (SV044, SV067)**

**The Angus Place and Springvale extension proposals are a direct threat to core of the shrub swamp area in the headwaters of Carne Creek. The EEC listed endangered ecological community of Newnes Plateau Shrub Swamps should not be mined under. (SV160, SV215, SV225)**

**The sandstone rock supporting the 41 nationally endangered swamps, and particularly the 11 shrub swamps affected by the proposal, will also develop a large number of fractures. Centennial predicts these cracks to be 5 to 50mm wide and 10 to 15 metres deep. (SV088, SV107)**

**This project has the potential to lead to the irrevocable degradation and potential destruction of several Newnes Plateau Shrub Swamps (NPSS), an Endangered Ecological Community (EEC), which forms part of the Commonwealth listed Temperate Highland Peat swamps on Sandstone (THPSS) EEC, with resultant negative impacts upon their associated groundwater dependent species. These species may include threatened flora and fauna, such as the endangered Giant Dragonfly (Petalura gigantea), endangered Blue Mountains Water Skink (Eulamprus leuraensis), and vulnerable Dean's Boronia (Boronia deanei deanei), all of which are obligate mire (peat swamp) dwelling species. (SV149)**

As detailed in Section 5.4 of the Subsidence Impact Assessment (Appendix D to the EIS), the surface cracking across the mining area is expected to be generally isolated and minor in nature, due to the reasonable depths of cover which typically vary between 270 m and 450 m, and due to the plasticity of the surface soils which allows them to more readily absorb the ground strains. Surface crack widths are expected to be similar to those observed above the previously extracted longwalls at Angus Place and Springvale Collieries, which were typically between 5 mm and 25 mm, but with isolated surface cracking in some locations greater than 50 mm.

The swamps which are located directly above the proposed longwalls are predicted to experience tensile strains greater than 0.5 mm/m and compressive strains greater than 2 mm/m. It is expected, therefore, that fracturing would occur in the top most bedrock beneath these swamps.

The Groundwater Impact Assessment prepared by RPS to support the Project and provided as Appendix E to the EIS determined that the most significant reductions to average standing groundwater levels are predicted in Twin Gully Swamp within the Angus Place mining area, however will not be directly undermined.

This swamp has a projected drop in average standing water levels from 12.4 cm to 10.6 cm above the soil surface. The post mining values predicted at Twin Gully Swamp therefore suggest that soil saturation would persist, maintaining water availability for flora and fauna, as well as soil anoxia, allowing for continued peat formation. All other monitored swamps have smaller projected decreases in average standing water levels and monitored swamps are projected to maintain average standing water levels above the surface.

Additionally, highly organic peat soils with low bulk density capillary forces are likely to be saturated for some distance above the water table itself. Natural decreases in water levels, in addition to the small predicted decreases from the CSIRO model are still likely to enable capillary forces to saturate the peat layer. Therefore, a possible reduction in the average standing water levels, by the magnitudes predicted is unlikely to result in drying of the peat layer.

The Project is not expected to have a significant impact upon the hydrology of any hanging swamps. The reliance of these areas on perched aquifer systems effectively isolate them from any hydrological changes that may occur to the regional water table as a result of mining operations.

The mining layout has also been designed so as to reduce the potential impacts on the shrub swamps resulting from mine subsidence movements. Predicted post mining grades are similar to the natural grades within the shrub swamps. There are no predicted significant reductions or reversals of grade. The hanging swamps are located on the sides of the valleys and, therefore, that natural gradients are greater than those shown for the shrub swamps and, in addition to this, the predicted mining induced tilts are less.

It is not expected, therefore, that there would be any adverse changes in ponding or scouring within the swamps resulting from the predicted mine subsidence movements. It is also not anticipated that there would be any significant changes in the distribution of the stored surface waters within the swamps as a result of the mining induced tilt or vertical subsidence.

**The current surface works are involving extensive clearing. The forests need to be maintained for the future, enough land has been taken from nature. (SV066)**

**The amount and scale of the infrastructure will be increased, including: a 14ha clearing for one mine vent, seven more dewatering sites (for Angus Place) with power, pipelines and tracks and clearings 90m x 110m, and two additional borehole sites (for Springvale). Exploration drill holes and groundwater monitoring holes, as well as subsidence monitoring activities will also occur. (SV160)**

Springvale Coal is seeking approval for the construction of new proposed which include:

- Extension of the existing SDWTS scheme to the proposed Bores 9 and 10 dewatering facilities to be established on Newnes Plateau; and

- Duplication of the existing scheme at sections to a maximum capacity of 50 ML/day to allow for the management of mine inflows from both Springvale Mine and Angus Place Colliery.

Two new dewatering facilities are proposed to be established in the Project on Newnes Plateau. Bore 9 and Bore 10 will be installed sequentially as mining progresses to the east and then the southeast of the existing workings. Bore 9, will be established when the current dewatering facility (Bore 8) will no longer function effectively. Bore 9 will manage mine inflows from LW420 to LW423. Bore 10 will manage mine inflows from LW424 – LW432 and LW501 – LW503.

The timing of the construction, operation and rehabilitation of Bore 9 and Bore 10 will be staged and contingent upon the progression of underground workings. A proposed infrastructure footprint of 11.44 ha is required for the construction of new infrastructure.

The proposed installation of surface facilities will require the removal of vegetation and habitats potentially suitable for threatened flora and fauna species. Those threatened species and communities recorded or expected in the impact area have been assessed by way of 7 part tests of significance under the TSC Act and/or the assessment of significance under the EPBC Act with the result of these assessments summarised in Section 10.3.5 of the EIS and included in detail in Appendices 1 and 2 of the Flora and Fauna Impact Assessment (Appendix H of the EIS). The results of these assessments show that the Project is unlikely to have significant direct or indirect impacts on threatened species or communities such that the populations of the species and the occurrence of the communities are likely to be placed at risk of extinction.

To compensate for the clearing required for new surface infrastructure, Centennial Coal has developed a Regional Biodiversity Strategy (revised September 2014) and attached as **Appendix 4** of this RTS that that takes into consideration both the direct impacts of clearing potential habitat and indirect impacts to the Temperate Highland Peat Swamps on Sandstone, incorporating Newnes Plateau Shrub Swamps and Newnes Plateau Hanging Swamps. Details of the Biodiversity Strategy proposed to be implemented are detailed in Section 10.3.7 of the EIS.

Further measures to mitigate the impacts of vegetation clearing required for new surface infrastructure are detailed in Section 10.3.8 of the EIS.

**Sound from mine ventilation has seen a decline in native animal activity in the area. (SV201)**

A Noise Impact Assessment was prepared by SLR Consulting and provided as Appendix L to the EIS. The Noise Impact Assessment identifies and assesses the potential noise impacts of the Project (including construction, operational, cumulative and off-site transport noise impacts). The Noise Impact Assessment has referenced and addressed relevant guidelines and assessment criteria as noted within the DGRs. The NIA has been prepared with reference to Australian Standard AS1055:1997 “Description and Measurement of Environmental Noise” (Parts 1, 2 and 3) and in accordance with:

- EPA (1999) “NSW Industrial Noise Policy” (INP);
- EPA (2009) “Interim Construction Noise Guideline” (ICNG);
- EPA (2011) “NSW Road Noise Policy” (RNP);
- EPA (2006) “Environmental Noise Management – Assessing Vibration: A Technical Guideline; and
- ANZECC (1990) “Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration”.

As detailed in Section 10.6.7 of the EIS, modelling of the Project components shows that the predicted construction noise levels are significantly below the construction noise goals in accordance with ICNG at the nearest sensitive receiver and therefore the potential construction noise impacts of the Project are negligible.

There is no evidence to suggest that noise from the mine ventilation fan has resulted in a decline in animal activity in the area.

**The evidence shows that the protection of the Burralow Formation aquitard AQ6 is critical to swamp protection but that AQ6 will drop well below root depth and by up to 10m, if mining is permitted. (SV226)**

**Piezometric traces have been impossible to interpret. The multiple traces on Fig 2.14 and 2.15 make them unreadable. Colour differentiation is indistinct, the traces overlap and the data is unclear. The depths of sediment are not given, nor are the times when the swamps were undermined or the longwalls involved. (SV226)**

**The Report notes (p 82 and Fig 2.27), Kangaroo Creek1 hydrograph dropped after mining nearby at Angus Place in 2008 and has not recovered. As it is a small swamp, the impacts may not be dramatic, but it shows clearly that undermining does lead to long-term loss of water from the swamp sediments. (SV226)**

**Reduced groundwater availability as a result of subsidence from the longwall mining will result in long-term degradation and contraction of the NPSS, compounding predicted effects of climate change. This will result in reduced spatio-temporal distribution of suitable breeding habitat for Petalura gigantea (Pg), and will threaten the persistence of other groundwater dependent species, including Boronia deanei, Eulamprus leuraensis (El), Euastacus australasiensis, and other organisms such as stygofauna. (SV149)**

**Monitoring data in the EIS indicate that there will be drawdown in all the swamps with a maximum drop of 36 cm in Gang Gang Southeast Swamp, though the EIS does not think this will cause any impact, though if the ecological dynamics in the swamp are considered t is evident that a permanent water level drop will cause major drying out of surface substrate and dislocation of swamp species. It is likely that these water level changes will be permanent and result in reduction in size of the swamps over time as swamps gradually dry out and are invaded by woodland species. Certainly the East Wolgan drainage line has been completely dry for the last 5 years and is showing no sign of recovery. (SV004)**

**The predicted lowering of the water table in identified NPSS, as a result of mining, is claimed to be not significant. The predicted lowering of water tables will be significant, with a possibility that the extent of lowering will exceed the model results. The proponent acknowledges that there will be a lowering of water levels. Based upon previous evidence, it can be assumed that the actual lowering of water table will be more, and possibly much more. Any lowering of water tables in the long term will affect the ecological functioning of these swamps and negatively affect their suitability for individual species, such as Pg. (SV149)**

The Groundwater Impact Assessment prepared by RPS to support the Project and provided as Appendix E to the EIS determined that the most significant reductions to average standing groundwater levels are predicted in Twin Gully Swamp within the Angus Place mining area. This swamp has a projected drop in average standing water levels from 12.4 cm to 10.6 cm above the soil surface. The post mining values predicted at Twin Gully Swamp therefore suggest that soil saturation would persist, maintaining water availability for flora and fauna, as well as soil anoxia, allowing for continued peat formation. All other monitored swamps have smaller projected decreases in average standing water levels and monitored swamps are projected to maintain average standing water levels above the surface.

Detailed investigations of the relationship between the groundwater and surface water movements, the underlying geology and the proposed mining layout has concluded, through empirical modelling, that the proposed longwall mining would not create interconnected fracturing between the aquifer supporting swamps and the longwalls. This is primarily due to the large vertical distance between extracted coal seam and the swamps, resulting in these swamps being located significantly higher than the predicted fracturing zone. The predicted change to baseflow and average water level is within the expected capillary forces of peat swamps such that the magnitudes of water table decline predicted is unlikely to result in drying of the peat layer.

Assessments of impacts have been undertaken for those species that are dependent upon the swamp habitats. These species include *B. deanei*, Giant Dragonfly and Blue Mountains Water Skink. Assessment of impacts have concluded that the predicted changes in baseflow and average standing water levels are not of a magnitude that would cause the swamp habitats to become unsuitable for these species. Consequently, the Project is unlikely to significantly impact upon those threatened species that rely on the swamp habitats.

**Hanging swamps are the forgotten swamps in the EIS. Section 2.8.3.5 deals with impacts of past undermining - all examples are of valley floor swamps, although Kangaroo Creek could perhaps be described as a hanging swamp. While recognising the importance of the hanging swamps, the Report does not address the impacts of mining on them. Yet they are clearly at least as vulnerable to diversion of water via bedrock cracking as valley floor swamps. (SV226)**

The potential impacts to hanging swamps as a result of the Project are considered throughout the EIS and supporting technical reports.

The hanging swamps develop on the sides of valleys where groundwater seepage occurs from perched aquifers, downslope of sandstone layers which overlie less permeable claystone or shale layers. Figure 10.1 of the EIS shows the locations of the hanging swamps relative to the proposed longwalls at Springvale Mine and handing swamps which are located outside the proposed longwalls but are within the Project Application Area.

Subsidence predictions for Hanging Swamps within the Project Application Area are contained in Table 5.5, Section 5.12.2 of the Subsidence Assessment prepared by MSEC and provided as Appendix D to the EIS. Give the locations of the hanging swamps on the sides of the valleys, are not expected to experience significant valley related upsidence movements or compressive strains due to closure movements, which occur near the bases of the valleys.

Section 7.3.5 of the Groundwater Impact Assessment prepared by RPS Australia and provided as Appendix E to the EIS identifies that the hanging swamps present within the Project Application Area are associated with the perched aquifer system and not the regional water table. As a result, these systems are heavily reliant on rainfall recharge to the perched aquifer system and are independent of changes to groundwater table levels and associated baseflow modifications.

**The conclusion that there will not be a significant impact in relation to the KTP in relation to subsidence from longwall mining is incorrect. (SV149)**

As detailed in Section 6.5 of the Flora and Fauna Impact Assessment provided as Appendix H to the EIS, the Project is likely to incrementally contribute to the KTP ‘Alteration of habitat following subsidence due to longwall mining’. A number of threatened species potentially occurring within the Study Area are listed within this KTP as being at risk. These include Boronia deanei, Blue Mountains Water Skink, Giant Dragonfly and Stuttering Frog. Newnes Plateau Shrub Swamp is also listed within the final determination of this KTP.

Subsidence monitoring within Springvale has shown that nearly all measurements are less than those predicted. Based on the monitoring data, there is an approximate 95% confidence level that the maximum observed total subsidence will be less than the maximum predicted total subsidence. Flora and fauna monitoring since 2005 has not recorded any losses to threatened species populations or EECs as a result of subsidence. This is due to appropriate mine design to limit subsidence to acceptable levels. However, conservative predictions for maximum baseflow and standing water level changes in several shrub swamps as a result of subsidence have determined that potential low-scale changes to swamp hydrology is possible.

The magnitude of these changes have, however, been considered against the likely capillary forces of the peat to maintain saturation. The predicted change to average water level is within the expected capillary forces such that the magnitudes of water table decline predicted in Adhikary and Wilkins (2013), is unlikely to result in drying of the peat layer. The conversion of perched water table flows into subsurface flows through voids is unlikely. Cracks may divert some water temporarily from swamps, but will initially fill with water before eventually filling with silt/peat from within the swamp, so that there should be no long-term or permanent impact on flows in the swamp. Therefore, the minor alterations to the hydrological regime predicted are unlikely to modify the vegetation communities present in the short or long term.

**An additional impact on peat swamps, associated with a drying of surface peats, is the increased combustion of the organic component of the soil during fire events. A long term lowering of water tables will result in significant cumulative effects of subsequent fires, which will be further compounded by predicted climate change scenarios. (SV149)**

Fracturing of bedrock due to mine subsidence does not necessarily imply that there will be loss of surface or standing water. Bedrock contains natural joints and discontinuities due to erosion and weathering processes.

Whilst some minor surface cracking could occur in the swamps resulting from the extraction of the proposed longwalls, the previous experience of mining beneath swamps at Angus Place, Springvale and in the Southern Coalfield indicate that the likelihoods and extents of these impacts are very small.

The dilated strata beneath the drainage lines, upstream of the swamps, could result in the diversion of some surface water flows beneath parts of the shrub swamps. It is noted, however, that the drainage lines upstream of the swamps are generally ephemeral and, therefore, surface water flows occur during and shortly after rainfall events. Any diverted surface water flows are expected to remerge short distances downstream, due to the limited depth of fracturing and dilation and due to the high natural stream gradients.

The Project is unlikely to impact on access to visitors to public areas within the Project Application Area as a result of subsidence impacts. Regardless, Springvale Mine has an approved Public Safety Management Plan (refer Table 3.7 in the EIS) to manage public safety. This plan includes controls that should subsidence pose a potential public safety risk, warning signs will be erected and subsidence repairs completed as soon as practicable. A review of the Public Safety Management Plan will be undertaken on a regular basis.

The Project is considered unlikely to increase the risk of Bushfire within the Project Application Area.

**EIS Main Document Volume 2 p.334, Table 10.9: Incorrectly states that Pg could not potentially occur, when in fact there are multiple records for this species in NPSS in the project area, including new records by I.R.C. Baird in January 2014. (SV149)**

**The Endangered shrub, Persoonia hindii, should be added to list of threatened flora which could potentially be affected by this project. (SV149)**

**The Endangered giant dragonfly, Petalura gigantea (Pg) should be added to the list of threatened fauna which could potentially be affected by this project. This is a significant omission. (SV149)**

**Assessment for Boronia deanei ssp. deanei is flawed. Any NPSS population of this species, which is subjected to medium to long term lowering of the water table, will be at risk of a reduction and potentially loss of that population in the long term. (SV149)**

**Fauna surveying was inadequate for the EIS, if they did not at least find swamp rats Rattus lutreolus (evidence observed by I.R.C. Baird in most NPSS) and Antechinus spp. And Eulamprus leuraensis in NPSS. The lack of observation of small terrestrial mammals in these swamps is also a serious deficiency. (SV149)**

**Assessment for P. gigantea is flawed. The requirement for moist to saturated substrate for successful oviposition and larval burrow establishment is the critical factor in the persistence of this species in swamps. Because of the long larval stage, some late stage larvae in established burrows may be able to persist until emergence, even after some lowering of water tables; however, successful reproduction, and thus persistence of populations, will be limited by the availability of suitable wet substrate for ovipositing and larval establishment. (SV149)**

**Assessment of Eulamprus leuraensis is flawed. The report states that El occurs in non-swamp habitat, however, any records for this species in non-swamp habitats are likely to be of wandering or foraging individuals temporarily outside their core swamp habitat. The assessment of no significant impact upon this species is based on the flawed presumption that there will be no significant lowering of the water table in a particular swamp. A relatively minor loss of groundwater could have a deleterious effect on a local swamp population of this species. (SV149)**

Flora and fauna surveys were undertaken as part of the Flora and Fauna Impact Assessment prepared by RPS to support the Project and provided as Appendix H to the EIS. In addition to the flora and fauna surveys undertaken by RPS and as detailed in Section 2.6 of the Flora and Fauna Impact Assessment, annual fauna monitoring has been occurring at Springvale Mine lease area since 2004. Fauna monitoring has been undertaken by MKES (2004 - 2009) and BMS (2010 -2012).

Monitoring has occurred at four locations, with three additional monitoring sites being included in 2011. All sites are located within wetland habitat (shrub swamps), but the surrounding woodland habitat is also surveyed. Six fauna monitoring sites occur within the Springvale Mine lease area.
A total of 27 monitoring plots have been established within the lease area. These swamp monitoring sites are permanently marked with 20 m x 20 m quadrats within which vegetation abundance and condition is measured.

The high level of effort of targeted surveys over the proposed surface infrastructure has enabled those easily detectable threatened species to be assessed for their likelihood of occurrence and subsequent potential impact. For those species that are less easily detected, the combined results from surveys and desktop analysis, including nine years of fauna monitoring have been used to assess the likelihood of a certain species occurring. Where any uncertainty has arisen due to any of the limitations identified in the flora and Fauna Impact Assessment, the precautionary principle has been adopted, thus assuming it has potential for presence where potentially suitable habitat exists.

For all known and potential species identified within the Project Application Area, an assessment of potential impact has been undertaken as part of the Flora and Fauna Impact Assessment (Appendix H to the EIS). This assessment has used other technical assessments undertaken for the Project, namely, Subsidence Impact Assessment (Appendix D to the EIS), Groundwater Impact Assessment (Appendix E to the EIS), Surface Water Impacts Assessment (Appendix F to the EIS) to draw conclusions on the potential impacts of the project on the biodiversity within the Project Application Area and the locality.

**A comprehensive, systematic pre-mining stygofauna survey must be implemented across the project area, with finer resolution taxonomic identification of stygofauna, to ensure that the diversity of stygofauna is properly assessed and potential risks of the project determined. (SV149)**

**The recommendation to undertake more comprehensive, and better designed pre-mining surveying, and finer resolution taxonomic identification of stygofauna, must be implemented if this project proceeds to ensure that the diversity of stygofauna is properly assessed and potential risks of the project determined. (SV149)**

No significant impacts are predicted on aquatic habitats, aquatic flora or aquatic fauna and or stygofauna. As is included in the Statement of Commitment contained in Section 11 of the EIS, because the aquifer systems across the Newnes Plateau are consistent, stygofauna will be monitored using standing water levels within one borehole in each aquifer where stygofauna are known to occur (AQ4 to AQ6). Where available, monitoring of the deep aquifer system, AQ1 to AQ3 will be undertaken to establish presence of stygofauna.

Additionally, Centennial Coal will commit to undertaking a regional stygofauna assessment which will:

- Collate existing available information on groundwater bores, water quality and characteristics in Centennial Coal’s area of operations throughout the Western Coalfield.
- Use this information to form a prioritisation list of likely areas for GDE to occur.
- Use the prioritisation protocol to identify bores that can be sampled to provide data on the presence and significance of fauna both within and outside mine areas.
- Identify any stygofauna found to a minimum of Family level.
- Advise on the significance of the findings.
- Examine relationship between bore characteristics and presence of stygofauna.

The Statement of Commitments contained in **Section 5.0** of this RTS has been updated to include this commitment.

**The Newnes Plateau Swamps proposed to be undermined support a population stronghold of the Blue Mountains Water Skink in this region, and a significant alteration in hydrology of the swamps, such as a loss of groundwater through subsidence, would negatively affect the suitability of the habitat. This in turn may cause a substantial reduction in abundances within swamps, and an overall reduction in populations of skinks throughout that region. The ability of individuals and populations of the Blue Mountains Water Skink to recover from such an event is unknown. (S Gorissen, R Shine, Shine Laboratory, The University of Sydney)**

A review of the potential impacts to the Shrub Swamp EEC discussed in the Subsidence Impact Assessment (Appendix D to the EIS), Groundwater Impact Assessment (Appendix E to the EIS) and Surface Water Impact Assessment (Appendix F to the EIS) was undertaken within the Flora and Fauna Impact Assessment (Appendix H to the EIS) to assess the impact of the Project on the biodiversity of the Project Application Area. Given that:

- there is unlikely to be significant reductions or reversals of grade that could otherwise cause ponding or scouring

- the limited depth of fracturing above the Mount York Claystone aquitard and lack of dilation of bedrock of shrub swamp or upstream drainage lines would not result in losses of infiltrated water and minimal divergence of surface water would occur

the Flora and Fauna Impact Assessment (Appendix H of the EIS) concluded it is unlikely that the effects of subsidence would have an adverse effect on shrub swamps or hanging swamps such that the ecological functioning of these swamps would be impaired.

RPS completed a study in November 2012 (RPS, 2012) to assess whether any impacts attributable to the undermining of the swamps could be ascertained based on swamps hydrographs and groundwater level trends. All of the swamps which were included in this study have a significant history of water level monitoring, are located away from licensed discharge points (to minimise potential for conflicting information), and have all been either undermined by longwall extraction or were in very close proximity to extracted longwall panels.

The results of (RPS, 2012) showed that no water level impacts that could be attributed to past or present mining operations (subsidence-related impact or depressurisation) were observed. Rather, the water levels in the swamps showed a strong correlation to cumulative rainfall trends, and this was found to be the driving factor.

As no mining influenced water level fluctuations can be identified in any of the monitored swamps (both undermined and baseline) it is accurate to say that mining at Springvale Mine and the adjoining Angus Place Colliery has not led to any identifiable water level impacts on the monitored swamps, and that all undermined swamps continue to display baseline water levels.

As part of the Flora and Fauna Impact Assessment (Appendix H of the EIS), 7 part test of significance under the TSC Act was conducted for Blue Mountains Water Skink. The results of the assessment is provided in full in Appendices 1 of the Flora and Fauna Assessment (Appendix H of the EIS) and summarised in Table 10.14 in the EIS. The conclusion drawn from the 7-part test is that the Project will not or unlikely to have an adverse effect on the population of Blue Mountains Water Skink to such an extent that its local occurrences are likely to be placed at risk of extinction (TSC Act).

Given the outcome of the 7 part test of significance assessment and the fact that the Project is not expected to have a significant impact upon any shrub swamps, such that their ecosystem functioning may be compromised, any alterations to potentially important habitats from subsidence, will not affect the long-term survival of the Blue Mountains Water Skink in the locality.

### 3.3.5 General

**The scenic western edge of the Newnes Plateau must be protected from further scarring by new roads, pipeline and electricity easements. (Various)**

**Centennial Coal has already extensively and severely damaged parts of the Newnes Plateau by blighting the landscape with a network of roads, pipes, survey lines and power lines. (SV105)**

**The amenity of the Newnes Plateau will be spoilt by the great amount of mining surface infrastructure by the three mines operating there side by side. (SV138, SV139, SV140, SV160)**

**Centennial has a bad track record with polluting creeks and streams, plus the ugly scars on the Newnes Plateau area which are made to provide infrastructure to support the mine operation. (SV032, SV160, SV282, SV288)**

**Centennial must be made to fix previous serious environmental damage done by the pre-existing coal mine and provide evidence that they are capable of working in an environment without damaging it before any further extensions can be considered. (SV111)**

**The Springvale mine has already caused subsidence and pollution and the extension will markedly increase the damage and pollution. (SV052, SV122)**

Springvale Coal is seeking approval for the construction of new proposed which include:

- Extension of the existing SDWTS scheme to the proposed Bores 9 and 10 dewatering facilities to be established on Newnes Plateau; and
- Duplication of the existing scheme at sections to a maximum capacity of 50 ML/day to allow for the management of mine inflows from both Springvale Mine and Angus Place Colliery.

Two new dewatering facilities are proposed to be established in the Project on Newnes Plateau. Bore 9 and Bore 10 will be installed sequentially as mining progresses to the east and then the southeast of the existing workings. Bore 9, will be established when the current dewatering facility (Bore 8) will no longer function effectively. Bore 9 will manage mine inflows from LW420 to LW423. Bore 10 will manage mine inflows from LW424 – LW432 and LW501 – LW503.

Dewatering bore facility sites have been identified based upon mine design requirements, and environmental constraints from a desktop analysis. The preferred options for the final placement of the dewatering boreholes will balance dewatering needs with potential environmental impacts. It is identified in Section 5.3 of the Social Impact Assessment that the mine design and other mitigating factors have minimised the extent of change to the physical environment to an extent that the Project will not adversely impact on the existing land use, its physical characteristics including surface features and the manner in which the public utilise / access the area for recreation.

As detailed in Section 5.12.5 of the Subsidence Assessment prepared by MSEC and provided as Appendix D to the EIS, the surface cracking across the mining area is expected to be generally isolated and minor in nature, due to the reasonable depths of cover which typically vary between 270 m and 450 m, and due to the plasticity of the surface soils which allows them to more readily absorb the ground strains. Surface crack widths are expected to be similar to those observed above the previously extracted longwalls at Angus Place and Springvale Collieries, which were typically between 5 mm and 25 mm, but with isolated surface cracking in some locations greater than 50 mm.

The Project is assessed to have significance of visual effects of none or minor at receptor locations with the exception being the mine services borehole compound due to the woodland clearing required during construction and its proximity to motorists on Old Bells Line of Road. However, placed in the context of being a transient viewpoint within a much larger area that commonly has larger clearings of pine plantation, Old Bells Line of Road not having direct line of site to this receptor and combined with the proposed appropriate dismantling and rehabilitation during decommissioning of this infrastructure, there will be no long term visual impact.

Springvale Mine has adopted a progressive approach to rehabilitation to reduce and mitigate potential environmental impacts. Exploration sites, ventilation and dewatering facilities and access tracks are rehabilitated promptly with periodic inspections and maintenance as necessary based upon evidence of endemic regrowth, weeds and soil disturbance. Rehabilitation acceleration techniques are undertaken, if required following approval from the Forestry Corporation of NSW.

The success of progressive rehabilitation activities is monitored against appropriate performance indicators identified within the Angus Place EMS framework and relevant legislative requirements.

The new infrastructure components of the Project will require rehabilitation as a result of surface disturbance during construction. The progressive approach to rehabilitation will continue to be applied.

The success of existing and future rehabilitation will be monitored against appropriate performance indicators identified within the rehabilitation strategy and MOP.

**Centennial must revise the proposal to improve environmental outcomes. (Various)**

**The Springvale mine has already caused subsidence and pollution and the extension will markedly increase the damage and pollution. (SV052, SV122)**

**Any future mine expansions in the Newnes Plateau region of the Blue Mountains should not be allowed as they will irreversibly damage the unique and fragile environments through cumulative impacts from subsidence, pollution, and water quality threats to ecology, water, air, noise, cultural heritage and local residents. (SV001, SV010, SV031, SV066, SV151, SV154, SV057, SV160, SV168, SV194, SV197, SV205, SV209, SV225, SV263, SV301)**

Springvale Coal acknowledges that previous mining has resulted in some localised impacts to the environment as a result of its operations. The impacts are largely a result of subsidence and water discharges.

In 2002, Springvale Mine commenced intensive monitoring, investigations and research to better understand the surface environment. These investigations have included groundwater, surface water, ecological aspects and the interplay of these aspects on swamps. The data collected and analysed over the past 11 years has been critical to proving that the technologies and engineering methodologies for longwall mining will minimise impacts to sensitive surface features

At Springvale Mine, the application of risk based planning, has driven mine planning, mine design and subsidence management, based on the geological and geotechnical constraints, and the overlying sensitive features.

Chapter 8 of the EIS details the evolution of the mine design at Springvale Colliery and how the mine design proposed for the Project has been developed taking into consideration safety, geological and environmental features.

Springvale Mine has applied a risk based approach to the Project to identify, quantify and reduce risks of environmental consequences wherever feasible. Previous subsidence monitoring has been used to develop and validate a predictive model of subsidence for the proposed mining area. This model has a high level of confidence in its predictions and is built upon a significant dataset comprising geological and geotechnical data. The mine has been designed to avoid, to the largest extent possible, sensitive surface features. Where a sensitive surface feature has not been avoided, a sub-critical void width has been applied in the mine design (for example LW416 to LW432).

The geological and geotechnical constraints to mining, combined with the extensive knowledge of the hydrogeological environment has resulted in a mine design that is reflective of decades of mining experience at the Angus Place Colliery and Springvale Mine.

Significant effort has been invested to evaluate the available coal resource and to avoid or minimise potential impacts that could be associated with the Project.

Potential environmental constraints have already been taken into account during the mine design process to ensure the Project is undertaken safely and in the most environmentally sensitive manner feasible.

**The price of coal is dropping globally. Once the global coal price drops below $60 per tonne, which will happen by the end of the decade on current trends, the industry is over in Australia. (SV051, SV065)**

**Coal is an outdated fuel so any jobs created are short term. (SV122)**

**In this era when we need to focus on renewable sources of energy, there are no viable reasons for extending this mine. (SV099, SV051, SV052, SV065, SV075, SV115 , SV145, SV220, SV237, SV263, SV268)**

**Coal is currently over supplied and thus Centennial should not damage the region for minimal profit. (SV189)**

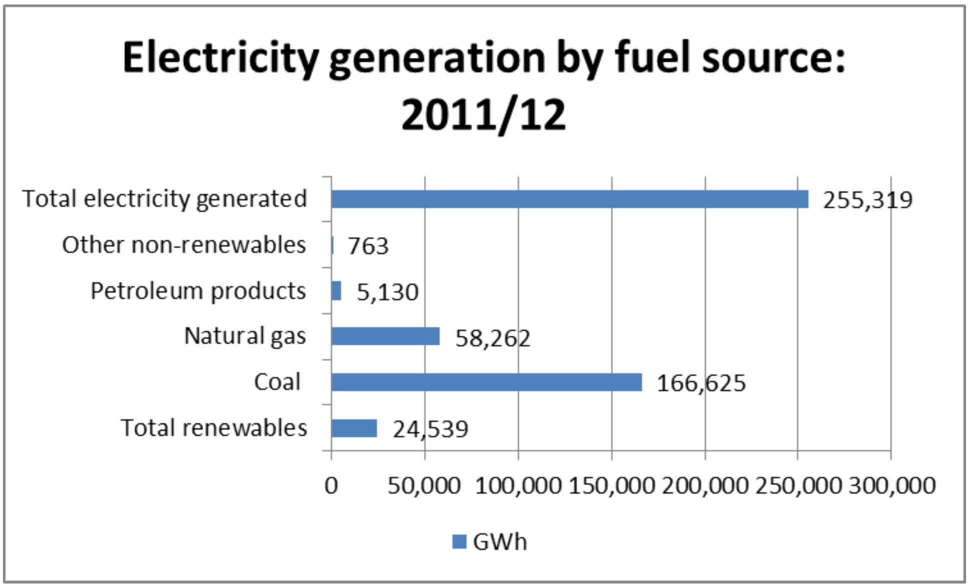
Coal mining in Australia is still warranted as the electricity generation industry remains heavily reliant on coal-fuelled generation. Recent research by Pitt & Sherry (2014) demonstrate that black coal demand for electricity generation has been declining in recent years while alternative fuel sources such as gas, wind and other renewable have been on the rise. However, their research shows that to date black coal is still the highest fuel source used for electricity generation, and they provide the following statistics:

‘Shares of total generation in the year ended June 2014 were black coal 50.7%, brown coal 22.3%, gas 12.7%, hydro 9.6% and wind 4.7%. These are the lowest shares of both black and brown coal, and the highest shares of wind, since Cedex® data starts in 2006, and in fact, almost certainly ever’.

The observations of Pitt and Sherry (2014) are supported by data from the Australian Bureau of Statistics (ABS). **Figure 42** provides data on electricity generation by fuel type for the period 2011/2012, and shows that coal represents the highest fuel source for electricity generation in the period 2011/2012. Approximately 65% of the total electricity generated in Australia was from coal while natural gas provided approximately 23% of the total demand. In comparison the combined renewable fuel sources met less than 10% of Australia’s fuel source demand for electricity generation.

While it can be anticipated, based on research by Pitt and Sherry (2014), that use of alternative and renewable sources will continue to increase, the transition to a point where these sources supplant coal as the predominant fuel source in the future will clearly take a significant period of time. This is especially the case given the availability of coal resources, the simplistic methods of mining of coal and conversion to electricity compared to renewables, and the extensive investment already sunk into coal-fired generation capacity in Australia.

**Figure 42 - Electricity Generation by Fuel Source 2011/2012**



**The Development Consent must be subject to periodic third party reviews to ensure that adjoining conservation areas are not adversely affected. (SV244)**

**The proposed Springvale mine extension should not be granted development consent unless Development consent is staged, with a review every five years and is subject to performance standards triggers that ensure the health and integrity of receiving waters and heritage values. (SV149)**

**This project must not be allowed to go ahead without sufficient environmental protections to the fragile ecosystems. (SV105)**

As is detailed in Section 3.12.4 of the EIS, the various Springvale Mine management plans are supported by an environmental monitoring network, monitoring noise, dust, groundwater, surface water and subsidence The results of the monitoring programmes are reported in:

- Annual Reviews (formerly Annual Environmental Management Reports);
- Annual Returns for EPL 3067;
- Subsidence Management Status Reports;
- Longwall End of Panel Reports;
- National Pollutant Inventory reports; and
- National Greenhouse Gas Emissions Report.

These reports are provided to various government agencies and are made publicly available.

In addition, Internal and independent external audits are completed periodically with a focus on ensuring compliance with approval conditions. The outcomes of these audits are provided to the relevant government agencies and identify continuous improvement strategies to be implemented where feasible.

The consent period of 13 years is required to ensure the sustainable operations at Springvale Mine and provide a level of certainty to the company to ensure the continued ongoing employment the Springvale Mine provides.

**The EIS tends to only be a theoretical document and have little credence in terms of impacts and mitigation actions. (SV111)**

**The EIS mentions everything that supports the application but leaves out aspects which might speak against it. (SV280)**

The EIS has been prepared by various independent technical consultants who are experts in their field. The impacts predicted in the Environmental Impact Statement are based on extensive monitoring data, robust modelling and a comprehensive understanding of the environment in which the Project operates. Springvale Coal acknowledges throughout the EIS the impacts experienced as a result of previous mining and mining related activities and have adopted an adaptive management approach to minimise the potential risk of these impacts occurring in the future through a detailed mine design process. It has been determined that the impacts experienced in the past are unlikely to occur as a result of the Project and any impacts would not be significant. Should impacts be identified, an adaptive management approach will be developed to manage impacts into the future.

### 3.3.6 Groundwater

**Approximately 1.5 m subsidence and cracking caused by the project will destroy the water table. (SV066)**

**Longwall mining affects groundwater as groundwater will find its way through cliff cracks into the mine affecting the aquifers. (SV280)**

A Subsidence Impact Assessment was undertaken for the Springvale MEP by MSEC and provided as Appendix D to the EIS. Mining is predicted to cause maximum of 1.7 m of conventional subsidence above longwall extraction areas. Based on the predicted maximum strains calculated by the subsidence study it is likely that some fracturing will occur in the uppermost bedrock, beneath the surface soils/regolith. It has been observed in previous studies, that the depth of fracturing and dilation of the surficial lithologies, resulting from longwall mining, is generally less than 10 to 15 m.

This shallow fracturing will, in general terms, enhance shallow permeability, favouring infiltration of rainfall and surface water to the ground, and recharging the shallow aquifers hence reducing available runoff during rain events. In no case, is it expected that the infiltrated water will be lost to deeper aquifers since the fracturing will be only superficial (upper most 10 to 15 m) and is isolated from the deeper zones of connective vertical fracturing. It is likely that any infiltrated flow will re-emerge to the surface further downstream and with some degree of delay, contributing to prolong the base flow contribution to the watercourses

The groundwater impact model predicts that some minor impacts to the shallow groundwater and baseflow will occur. However, it is considered that the groundwater modelling results are conservative, particularly in respect to the predicted impacts to baseflows. The model assumes dilation of horizontal ‘plies’ will occur through to ground surface, however, this has not been observed in the field. In any regard, the model is not able to replicate the self-healing nature of the creeks and swamps and as such, it is conservative, over-predicting the magnitude of potential impacts.

**It is misleading and inaccurate to argue that mining has not caused a drop in the water tables of the undermined swamps above the Springvale and Angus Place mines. (SV266)**

Numerous specialist hydrogeological studies have been undertaken at Angus Place with the aim of quantifying mine water inflow and subsidence impacts, groundwater drawdown and depressurisation, and addressing other geotechnical and hydrogeological issues over the past number of years.

RPS completed a study in November 2012 (RPS, 2012) to assess whether any impacts attributable to the undermining of the swamps could be ascertained based on swamps hydrographs and groundwater level trends

All of the swamps which were included in this study have a significant history of water level monitoring, are located away from licensed discharge points (to minimise potential for conflicting information), and have all been either undermined by longwall extraction or were in very close proximity to extracted longwall panels.

The results of the 2012 study showed that no water level impacts that could be attributed to past or present mining operations (subsidence-related impact or depressurisation) were observed. Rather, the water levels in the swamps showed a strong correlation to cumulative rainfall trends, and this was found to be the driving factor.

As no mining influenced water level fluctuations can be identified in any of the monitored swamps (both undermined and baseline) it is accurate to say that mining at Angus Place has not led to any identifiable water level impacts on the monitored swamps, and that all undermined swamps continue to display baseline water levels.

**The Springvale mine expansion proposes to increase the pumping out of mine water from 20.9 Mega (= million) litres per day to a potential 29.9 ML/d (p.305). The EIS, suggests that after cracking the ground and pumping that much water out from the lowest point there will be "...minimal impact on the shallow and perched aquifer systems across Newnes Plateau "(p.479). In contrast chapter 7.3.1 of Appendix E p.76, states that: "From the piezometric and water table contours presented on Figures 26 to 30, and with reference to Section 5.2.5, it is apparent that the initial groundwater levels are considerably impacted by current and historical mining operations." Given the volume of water to be pumped out from the mine as well as the undoubted effect this volume of water will have on underground aquifers (which it is impossible to predict), this conclusion defies scientific evidence and logical argument. (SV280)**

The mine inflows arise from the Lithgow Seam (Illawarra Coal Measures) being mined at Angus Place Colliery and Springvale Mine. This aquifer, referred to as AQ1 in the EIS and the Groundwater Impact Assessment (Appendix E) is hydraulically connected with the Berry Siltstone and Marrangaroo Formations beneath and the Long Swamp Formation and Irondale Coal Seam above, the location of which within the regional hydrostratigraphy is shown in the EIS Table 2.5. This aquifer, along with aquifers AQ2 – AQ6, represents one of the major aquifers in the regional hydrogeological system,

The regional hydrostratigraphic system is divided into three groundwater systems denoted as perched, shallow and deep groundwater systems, described in detail in Section 2.6.2.5 of the EIS. The regional hydrogeology encompassing the Angus Place and Springvale Project Application Areas was studied extensively by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) between 2004 and 2008, and is described in ACARP reports C14033 and C18016. The most recent and detailed groundwater and aquifer modelling was conducted by CSIRO, Palaris (Palaris 2013a and Palaris 2013b) and RPS between 2011 and 2013. This modelling is based on the latest groundwater and geological data, which has been significantly improved since the initial CSIRO reports were published. The geological model includes data from 501 exploration boreholes (refer Figure 2.11 of the EIS). The groundwater model includes data from 142 piezometers in 31 boreholes over a period of up to 10 years and mine water inflow data which has been recorded over a period of 20 years.

The AQ1 aquifer, along with aquifers AQ2 and AQ3, is part of the deep groundwater system, located in the strata underlying the Mount York Claystone. The Mount York Claystone is the major aquitard in the region, and separates the deep groundwater system from the shallow and perched groundwater systems located above it. The deep groundwater system generally lies at a depth of 200 m to 500 m below the ground surface. The aquifer zones within the deep groundwater system are typically fractured rock aquifers or jointed coal seams. It is this system which produces the mine water inflows when groundwater in this system is drained into the goaf following coal extraction.

Removal of mine inflows from the deep groundwater system is unlikely to impact the shallow/perched groundwater systems as there is no hydraulic connectivity.

The hydrostratigraphic sequence discussed briefly above, and presented in Table 2.5 of the EIS, has been incorporated into the hydrogeological model developed by CSIRO (attached as Appendix K to the Groundwater Impact Assessment prepared by RPS (Appendix E)) to understand the groundwater impacts of the Angus Place and Springvale MEPs. The predicted mine inflows, from the projects, deduced from the CSIRO's hydrogeological model, are presented in Figure 10.11 in the EIS.

**The Burralow Formations perched aquifers are described as discontinuous (Main Report pt 1), surficial and independent of regional groundwater. However the mapping such as in Fig. 2.8 shows the brown isopachs of the aquitards (denoted as YS or SP semi-permeable layers in the discussions) as laterally continuous. Hence they are of regional and not local importance. (SV266)**

Figure 2.8 in the EIS is a 3D image of Carne Creek, and swamps Carne West, Gang Gang South West, Gang Gang South West and Carne Central, located to the northeast of the Project Application Area. The brown isopachs are continuous over the area covered in Figure 2.8. Additionally, the Burralow Formation isopachs are continuous over a much larger area (refer Figure 2.9 in the Springvale EIS and Figure 2.10 in Angus Place EIS) comprising the Angus Place and Springvale Project Application Areas. Whether the isopachs extend over areas beyond that mapped cannot be confirmed from the available mapping data. Further mapping of the Burralow Formation over a larger area is required to determine if it is of regional importance.

### 3.3.7 Mine Design

**Mining intensity should be reduced. (SV149)**

**The proponent’s justification for the currently proposed panel widths under the swamps is not substantiated. (SV149)**

**There should be no mining under the swamps as has protected Sunnyside Swamp, or if not possible to reduce the width of the long walls which are proposed to be up to 261 m to between 115-160m as used elsewhere to reduce subsidence. (SV004)**

**Centennial says that due to a weak roof and a high stress environment longwall mining is the only option, however Clarence Colliery successfully uses bord & pillar mining methods and the Airly mine in the Capertee Valley operates to depth of 405 metres underground in the same geology, with bad mine roof conditions, including many structural defects. (SV149, SV160)**

**Shortening longwalls 432, 431, 430 and 429 must be done to prevent damage to the Marrangaroo swamps, and shortening longwalls 425 and 426 must be done to prevent damage to Paddys Creek Swamp. (SV149)**

**Longwalls should be shortened to avoid undermining THPSS: All discussion in the EIS Main Document Volume 2, of the option of shortening longwalls to avoid undermining NPSS, related to existing longwalls, but did not address the option of shortening longwalls in the proposed extension project to avoid undermining NPSS. The fact that such a modification may reduce the economic feasibility of the entire project should not be a justification for allowing these swamps to be undermined, with the associated risk of damage. (SV149)**

**In the event that the longwall panels are not shortened to avoid mining under the NPSS, then all longwall panels that pass under swamps should be further reduced in width, with wider pillar widths, to further minimise risk of subsidence that may result in significant lowering of swamp water tables. (SV149)**

**Longwall LW501 should be shortened to protect cliffs and pagodas. (SV149)**

As is detailed in Section 8.2.2 of the EIS, the combination of a weak roof and a high stress environment means that longwall mining in the Lithgow seam at Angus Place Colliery is the only viable and safe mining method. Strata Engineering Pty. Ltd (Australia) in Report No. 03-123-AGP-33 identify that in

Australia there is no known precedent for safe and viable partial extraction (i.e. bord and pillar) operation in the geotechnical environment under consideration within the Project Application Area.

The geological and geotechnical constraints to mining, combined with the extensive knowledge of the hydrogeological environment has resulted in a mine design that is reflective of decades of mining experience at the Angus Place Colliery and Springvale Mine and there has been significant effort to prioritise avoidance and reduction of potential impacts and constraints of surface features and geological and geotechnical issues, while considering mine safety, feasibility and optimisation. The mine has been designed to avoid, to the largest extent possible, sensitive surface features. Where a sensitive surface feature has not been avoided, a sub-critical void width has been applied in the mine design.

Springvale Mine has applied a risk based approach to the Project to identify, quantify and reduce risks of environmental consequences wherever feasible. Previous subsidence monitoring has been used to develop and validate a predictive model of subsidence for the proposed mining area. This model has a high level of confidence in its predictions and is built upon a significant dataset comprising geological and geotechnical data. The mine has been designed to avoid, to the largest extent possible, sensitive surface features. Where a sensitive surface feature has not been avoided, a sub-critical void width has been applied in the mine design.

The geological and geotechnical constraints to mining, combined with the extensive knowledge of the hydrogeological environment has resulted in a mine design that is reflective of decades of mining experience at the Angus Place Colliery and Springvale Mine.

The approach of Springvale Mine to the MEP has been to apply a best practice system of environmental management: that is a hierarchy of avoiding, minimising, mitigating and finally, offsetting residual impacts.

Significant effort has been invested to evaluate the available coal resource and to avoid or minimise potential impacts that could be associated with the Project.

The primary objective of mine design is safety, underground and on the surface. By managing safety, the mine manages subsidence impacts on the surface and in turn manages environmental and social consequences. At Angus Place Colliery, the application of risk based planning, has driven mine planning, mine design and subsidence management, based on the geological and geotechnical constraints, and the overlying sensitive features.

There are two management strategies for avoiding or minimising the impacts to sensitive surface features as a result of mining. These are:

- Avoid mining under the sensitive surface feature; or
- Mine design under the sensitive surface feature has a sub-critical void width.

The following controls have been applied to the Project:

- proposed longwalls LW501 to LW503 have been positioned between clusters of cliffs. LW419 to LW422 have been shortened to avoid cliffs and pagodas;
- the proposed longwalls in the Project Application Area which lie beneath Newnes Plateau Shrub Swamps (LW416 – LW432) are designed to have sub-critical W/H ratios and chain pillars at least 55 m wide.

Potential environmental constraints have already been taken into account during the mine design process to ensure the Project is undertaken safely and in the most environmentally sensitive manner feasible. Where impacts are predicted, monitoring management and where appropriate, offset strategies, have been proposed to be implemented.

To avoid directly undermining the shrub swamps overlying the proposed longwalls, is not economically feasible for Springvale Mine, and is not necessary based on the predicted impacts to the swamps based on the mine design proposed.

### 3.3.8 Monitoring

**Monitoring of surface flow and near-surface groundwater monitoring must create a comprehensive picture of the sub-catchments affected by mining. (SV149)**

**Monitoring guidelines must clearly specify how the condition of groundwater dependent indicator plant species and the general condition of groundwater dependent ecosystems will be performed. (SV149)**

**Representative sites for the piezometers to monitor groundwater in swamps and streams must be chosen by a third party agency. (SV149)**

As is detailed in Section 3.12.4 of the EIS, the various Springvale management plans are supported by an environmental monitoring network, monitoring noise, dust, groundwater, surface water and subsidence. Springvale Coal has undertaken extensive monitoring of its operations for a number of years now and has collected a large amount of information. The results of the monitoring programmes are reported in:

- Annual Reviews (formerly Annual Environmental Management Reports);
- Annual Returns for EPL 3067;
- Subsidence Management Status Reports;
- Longwall End of Panel Reports;
- National Pollutant Inventory reports; and
- National Greenhouse Gas Emissions Report.

These reports are provided to various government agencies and are made publicly available.

Monitoring is carried out by various independent experts in accordance with any relevant guidelines.

The Project proposes to update the existing management plans as part of the Project. These management plans will detail the monitoring proposed to be undertaken and the methodologies to be used. The management plans to be prepared and updated will be developed in consultation with various government agencies and submitted to the Secretary of the Department of Planning and Environment for approval.

### 3.3.9 Noise

**Centennial states the noise of the dewatering pumps can only be heard up to 100m away, however the noise can travel much further across valleys, up to 1km, and the pumps run non-stop most of the time. (SV160)**

**Mine ventilation is capable of producing sound energy at frequencies able to cause the population to feel effects from low frequency sound or infrasound. These effects are already being seen in the population. (SV201)**

All currently operational dewatering facilities and the mine ventilation facility (Vent Shaft 3) and the associated submersible pumps (Springvale Bores 6 and 8) are located on Newnes Plateau. The proposed Bores 9 and 10 will also be located on Newnes Plateau. The Noise Impact Assessment (NIA) (Appendix L of the EIS) assessed the impacts of Newnes Plateau infrastructure (dewatering bore facilities and the Ventilation Shaft 3) on nine sensitive receptors identified on Newnes Plateau, referred to as NF1 to NF9 in the EIS and the NIA and classed as non-residential/recreational receptors (refer Table 2.3 of the EIS), the results of which are discussed in Section 10.6.4.2 of the EIS.

The NIA has referenced and addressed relevant guidelines and assessment criteria as noted within the DGRs. The NIA has been prepared with reference to Australian Standard AS1055:1997 "Description and Measurement of Environmental Noise" (Parts 1, 2 and 3) and in accordance with:

- EPA (1999) "NSW Industrial Noise Policy" (INP);
- EPA (2009) "Interim Construction Noise Guideline" (ICNG);
- EPA (2011) "NSW Road Noise Policy" (RNP);
- EPA (2006) "Environmental Noise Management – Assessing Vibration: A Technical Guideline; and
- ANZECC (1990) "Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration".

A comparison of the modelled operational noise at these receptors against the project specific noise goal of 50 dB, being the acceptable amenity criterion for a passive recreational area in accordance with the INP are included in Table 10.28 of the EIS. Predicted noise at NF1 <30 dB and for NF2 to NF9 are <20 dB, while under temperature inversion conditions 33 dB is predicted for NF1. All predicted noise levels due to operations of infrastructure on Newnes Plateau are significantly less than the 50 dB criterion.

The predicted construction noise levels at Newnes Plateau receptors NF1 to NF9 are presented in Table 10.27 of the EIS, and show the predicted levels are significantly below the project specific noise goal, being 60 dB in accordance with ICNG for passive recreation areas.

### 3.3.10 Rehabilitation

**All past tracks and trails created by Centennial Coal and its consultants, including those established by trail bikes, need to be recorded and plans set in place to rehabilitate these trails on an on-going basis and as soon as practicable as part of the on-going rehabilitation program for this mine. (SV149)**

As detailed in Section 3.13 of the EIS, the current approved MOP for Springvale Mine details the proposed rehabilitation objectives to ensure the final landform is commensurate with the surrounding topography and relevant zoning requirements of the time.

Springvale Mine has adopted a progressive approach to rehabilitation to reduce and mitigate potential environmental impacts. Exploration sites, ventilation and dewatering facilities and access tracks are rehabilitated promptly with periodic inspections and maintenance as necessary based upon evidence of endemic regrowth, weeds and soil disturbance. Rehabilitation acceleration techniques are undertaken, if required following approval from the Forestry Corporation of NSW.

The success of progressive rehabilitation activities is monitored against appropriate performance indicators identified within the Springvale EMS framework and relevant legislative requirements.

### 3.3.11 Socio-Economic

**This area is a tourist attraction for national and international visitors. The project would destroy NSW's reputation to these tourists by destroying a prestige destination spot now and for future generations. (SV008, SV160, SV168, SV188)**

Springvale Coal acknowledges in Section 6.1 of the EIS that the Newnes Plateau is identified as being an important feature of the Lithgow LGA by the local, regional and State stakeholders who access the area for various activities. Consultation was undertaken as part of the development of the Social Impact Assessment prepared by James Marshall & Co and provided as Appendix N to the EIS, with users of the Plateau including adventure visitors (mountain bike riders, motor bikers and four wheel drivers) and passive visitors (include bushwalkers, families visiting a particular destination point). The consultation was undertaken at various times throughout 2013 and found that many visitors who live in the area are aware of mining under the Newnes Plateau. It was generally their opinion that mining has not changed their experience when visiting the area and will not change their experience as long as access to the area was permitted. Many of these visits were for adventure type tourism. Passive visitors, for example, families visiting the area to visit a particular destination point (for example the Glow Worm Tunnels) and bushwalkers generally stated that they did not want their experience changed. The amenity of the area was important to these types of visitors and key words used to describe the area are: quiet, nature, features (pagodas and cliffs) and views from lookouts.

It is identified in Section 4.3 of the Social Impact Assessment that the mine design and other mitigating factors have minimised the extent of change to the physical environment to an extent that the Project will not adversely impact on the existing land use, its physical characteristics including surface features and the manner in which the public utilise / access the area for recreation.

The Project may have a slight impact on those who use the area for bushwalking, photography etc if they are impacted upon by noise, or long term visual impacts from the surface facilities. However any risk in this regard will be minor and as such no additional mitigation strategy is identified.

Based on the review of specialist consultants reports, it was determined that the extent of long term social change arising from the Project is minimal and will not adversely impact on how people use the area. There will be no long term change to the social amenity of the area arising from this Project brought about by noise, dust and visual impacts.

**Damage to Carne Creek will have serious consequences for local tour operators such as the 4 x 4 and adventure recreation companies. (SV109)**

**Damage to Carne Creek will have serious consequences for the Emirates Wolgan Valley Resort and Spa. (SV088, SV107, SV109, SV130)**

Approximately 2 km of Carne Creek is directly above the proposed longwalls LW416- LW419. The section of creek located above the proposed longwalls is generally confined within Sunnyside East

Swamp. The predicted tilt of 0.25 mm/m, is less than the typical natural grade of Carne Creek, which ranges from 25 mm/m to 300 mm/m and therefore no significant ponding, flooding, scouring is predicted and is unlikely to have any adverse effect, apart from the potential for small sections of grade reversal where natural channel grades are very low immediately upstream of chain pillars.

It is expected that Carne Creek will experience compressive strains due to valley related movements between 5 mm/m and 15 mm/m. The greatest compressive strains are expected to occur where the creek is located near the centrelines of the proposed longwalls, and less where the creek is located near the chain pillars.The maximum predicted valley related movements, due to the extraction of the proposed longwalls only, are 65 mm upsidence and 75 mm closure. It has also been predicted that the river has already experienced valley related movements up to 270 mm upsidence and 330 mm closure due to the extraction of the existing longwalls at Angus Place and Springvale Collieries. No significant fracturing or surface water flow diversions have been observed along the river due to the existing mining. It is unlikely, therefore, that the extraction of the proposed longwalls would result in any significant fracturing resulting in surface water flow diversions or water quality impacts.

Existing baseflows to Carne Creek already occur from the near surface aquifers. The water quality from these aquifers that flow into Carne Creek will remain unchanged as a result of the Project and environmental consequences will not result. No impacts on local tours or the Emirates Wolgan Valley Resort will occur.

**Any jobs created by the project are false economies based on short term gains, damaging future prospects for generations. (SV263)**

The Project will secure employment for up to 310 direct employees and contractors. As detailed in Section 6.0 of the EIS, the continuation of employment of the workforce is a positive social impact of the Project. Employee surveys undertaken for the Project have found that mine related employment directly contributes to the local financial and social economy. Employment in the mining industry provides flow-on effects for local support services via direct and indirect employment opportunities across a range of sectors.

The NSW Department of Trade, Investment, Regional Infrastructure and Services (Division of Resources and Energy) has previously identified output and employment multipliers for mining and related services. The relatively large gross value added multiplier value (4.099) demonstrates the importance of incomes generated by the Project. Benefits associated with the Project include the broad social benefit gained as a consequence of the continued operations at Springvale Mine in terms of the royalties and taxes that are provided to the State. These are subsequently redistributed across Local Government Areas, including Lithgow LGA. Similarly, the existing workforce at Springvale Mine will be sustained by the Project with the incomes received by employees resulting in further direct and indirect benefits across the regional community. The continued operation of Springvale Mine has provided substantial socio-economic benefits throughout the region. Although there will be no increase in employment numbers as a result of the Project, it will enable continuation of the existing benefits during the period of active mining at Springvale Mine. This is key to the socio-economic wellbeing of Lithgow LGA with the Project providing a net benefit to the community with regard to social, economic and environmental impacts and benefits.

### 3.3.12 Subsidence

**As a result of subsidence movements, the surface sandstone rock will be cracked to a depth of 15 to 20 metres over the entire area mined. Bird Rock will be fractured. (SV088, SV107, SV246)**

**The possibility of subsidence from longwall mining in these areas and the inevitable impact on the environment from cracking the underlying sandstone layers which support the lakes, stream beds, swamps, pagodas, rock outcrops, walking tracks and cliffs should not be allowed. This subsidence will also increase bushfire risk. (SV009, SV025, SV149, SV189, SV215, SV216, SV225, SV256)**

**The Heritage section of the SoEI offers the description of the historic site of a grinding stone at site 45-1-0002. After stating that "no spoiling or cracking is predicted" (p. 479) for cliffs and pagodas "the sandstone where the grinding groove is or was located" can be expected "to fracture and damage the site should it still remain." (p480). Therefore all the cliffs and pagodas will be fine but the grinding stone will fracture and vanish. (SV280)**

**Fracturing of the rock underneath the surface will occur as a result of the longwall mining and the use of tentative language in the EIS statement is an attempt to minimize the potential for this serious damage to the cliff and pagoda landscape to occur. (SV280)**

**Mining should not be allowed at the thinnest points of access where pagodas have developed their most advanced forms. This is seen in longwall panel LW501 which is approximately 40% overlain by a rocky spur. (SV192, SV262)**

**From the project, steep slopes are predicted to experience tension cracking at the top and sides, and compression ridges at the bottom. (SV160)**

**The project will cause some cliffs, pagodas and other rock formations are likely to experience fracturing and spalling to 1% to 3% of total exposed rock face areas which are located above longwalls. (SV160)**

As detailed in Section 10.1.3 of the EIS, approximately 2 km of Carne Creek is directly above the proposed longwalls LW416- LW419. Wolgan River is located to the west of the proposed longwalls, outside the mining area, above the previously extracted longwalls at the mine. The Wolgan River is located 460 m west of LW416, at its closest point to the proposed longwalls. The total length of the Wolgan River located within a distance of 600 m from the extents of the proposed longwalls is approximately 0.9 km.

No significant ponding, flooding, scouring is predicted for the Wolgan River. The Wolgan River has previously experienced up to 270 mm subsidence and 330 mm closure due to previous extraction of longwalls at both Angus Place Colliery and Springvale Mine, which caused no significant fracturing or related surface water diversions. It is not predicted that any significant fracturing or water diversion will occur due to the Project.

Given that most channels in Carne Creek catchment have grades well in excess of 25 mm/m, the predicted tilt is not expected to reverse any grades nor cause significant changes in channel grade, and is unlikely to have any adverse effect. Accordingly there is no ponding or scouring predicted, apart from the potential for small sections of grade reversal where natural channel grades are very low immediately upstream of chain pillars. The predicted tilt of 0.25 mm/m, is less than the typical natural grade of Carne Creek, which ranges from 25 mm/m to 300 mm/m and therefore no significant ponding, flooding, scouring is predicted.

Impacts to watercourses have been avoided through eliminating extraction directly underneath fourth order watercourses and through narrowing the longwall width to sub-critical voids. As a result, monitoring of impacts to watercourses will be through the underground Strata Management Plan and will be limited to the section of Carne Creek within the 26.5 degree angle of draw.

The mining layout has been designed such that the majority of the cliffs and pagoda complexes are located outside the 26.5 degree angle of draw line from the extents of the proposed longwalls. There are some cliffs and pagoda complexes which have been identified within the 26.5 degree angle of draw however, they are all located outside the extents of the proposed longwalls. Whilst the cliffs and pagodas complexes could experience low levels of subsidence, they are not expected to experience any significant conventional tilts, curvatures or strains. These features are located along the valley sides and, therefore, are not expected to experience the valley related upsidence or compressive strains due to valley closure.

It is unlikely therefore that the cliffs and pagoda complexes would experience any adverse impacts resulting from the extraction of the proposed longwalls. This is supported by extensive experience from the NSW Coalfields, at depths of cover greater than 200 m, where no cliff instabilities have been observed where cliffs have been located wholly outside the extents of extracted longwalls.

As detailed in Section 5.12.5 of the Subsidence Assessment prepared by MSEC and provided as Appendix D to the EIS, the surface cracking across the mining area is expected to be generally isolated and minor in nature, due to the reasonable depths of cover which typically vary between 270 m and 450 m, and due to the plasticity of the surface soils which allows them to more readily absorb the ground strains. Surface crack widths are expected to be similar to those observed above the previously extracted longwalls at Angus Place and Springvale Collieries, which were typically between 5 mm and 25 mm, but with isolated surface cracking in some locations greater than 50 mm.

Fracturing of bedrock due to mine subsidence does not necessarily imply that there will be loss of surface or standing water. Bedrock contains natural joints and discontinuities due to erosion and weathering processes.

Subsurface monitoring by Mills (2003 and 2007) and Mills and Huuskes (2004) along the Waratah Rivulet found that the fracture network beneath the stream extended to a depth of 12 m and bed separation and dilation extended to a depth of 20 m. For subcritical longwalls with sufficient depth of cover to develop a constrained zone, the diverted surface water flows are confined in the shallow network which then re-emerges further downstream after sufficient fall of the stream bed elevation.

Examples of this include the Bargo River above Tahmoor LW14 to LW19 and the Waratah Rivulet at Metropolitan Colliery, where the surface water flows which were diverted into the fracture networks beneath these streams re-emerged further downstream of the impact site.

Southern Coalfield Inquiry (DoP, 2008) stated that there is “No evidence was presented to the Panel to support the view that subsidence impacts on rivers and significant streams, valley infill or headwater swamps, or shallow or deep aquifers have resulted in any measurable reduction in runoff to the water supply system operated by the Sydney Catchment Authority or to otherwise represent a threat to the water supply of Sydney or the Illawarra region. However, this does not discount the possibility that a reduction in runoff may be realised under certain conditions, including downwards leakage to mining operations, especially where a shallow depth of cover prevails or a structural feature provides a conduit for flow”.

The third order streams are located within and downstream of Tri Star, Twin Gully (Angus Place mining area), Gang Gang and Marrangaroo Creek Swamps (Springvale mining area). The potential for impacts on the sections of these streams within the swamps are assessed as part of the swamps. The sections of these streams located downstream of Tri Star Swamp and Twin Gully Swamp are located outside the extents of the proposed longwalls and adverse impacts are not anticipated.

There are short sections of the third order streams located downstream of Gang Gang and Marrangaroo Creek Swamps which are located directly above the longwalls. The potential impacts for these are the same as those assessed for the drainage lines.

**The subsidence caused by the project in large areas of the plateau will cause deep cracking and cause aquifers to drop by up to 10 m. This is irreversible. (SV160)**

**All 1,860 hectares affected by the proposed longwall mining will be subject to surface cracking. Surface groundwater aquifers will become more permeable and interconnected. (SV088, SV107)**

As detailed in Section 5.12.5 of the Subsidence Assessment prepared by MSEC and provided as Appendix D to the EIS, the surface cracking across the mining area is expected to be generally isolated and minor in nature, due to the reasonable depths of cover which typically vary between 270 m and 450 m, and due to the plasticity of the surface soils which allows them to more readily absorb the ground strains. Surface crack widths are expected to be similar to those observed above the previously extracted longwalls at Angus Place and Springvale Collieries, which were typically between 5 mm and 25 mm, but with isolated surface cracking in some locations greater than 50 mm.

**Areas close to the Angus Place Colliery's existing works and other existing mines already show prominent examples of cracking and collapse. This damage must not be allowed to extend to the Gardens of Stone. (SV111)**

The Gardens of Stone National Park is located more than 7 km north of the proposed longwalls at Springvale Mine (northern longwall block). The nearest conservation reserve, the Gardens of Stone National Park (part of the larger National Heritage Place and World Heritage Area) will not experience any measurable subsidence movements as a result of the Project.

**Subsidence monitoring should be by a third party agency, such as the Office of Environment and Heritage, and monitoring should be paid for by Centennial Coal. (SV149)**

Subsidence monitoring is undertaken by suitably qualified and certified surveyors registered with the Board of Survey and Spatial Information. Surveyors are required to keep their qualifications up to date to maintain their registration. All surveys are undertaken in accordance with relevant government guidelines. Subsidence monitoring is undertaken in accordance with agreed subsidence monitoring programmes detailed within an extraction plans and Subsidence Management Plan and within accuracy requirements determined by the NSW Division of Resources and Energy.

### 3.3.13 Surface Water

**The proposed discharge of up to 43.8ML/day of eco-toxic mine effluent must be treated using reverse osmosis technology to remove all metals and salts before discharge to the Cox's River. (Various)**

**The discharge from both mines of metal-rich salts will impact the Cox's river that supplies Sydney with drinking water, part of the Warragamba catchment. This will lead to possible contamination of Sydney's drinking water. (SV102, SV130, SV194, SV216, SV230, SV232, SV256, SV280, SV305)**

**The combined effluent from both mines will be 43.8ML/day in 2023. 30.8 tonnes/day of toxic effluent will be discharged into the Cox River which supplies Sydney' drinking water. This is unacceptable. (SV091, SV096, SV098, SV149, SV161, SV246, SV280)**

**No mining discharge water should be allowed to leave a mining site and flow into natural creeks and streams unless it equals the same natural background levels. These streams should be protected. (SV030)**

**Mining discharge water should be treated with desalination methods and not filtration dams. Mining discharge water from this particular area is over 1000µs/cm which is breaching the ANZECC guidelines. (SV030)**

**Carne Creek and other waterways in the area must not be permanently despoiled by reduced water flows and the discharge of toxic effluent. (SV096, SV215)**

**This proposal plans to pollute Sydney's water supply. (SV066)**

**The mine effluent discharged into the Cox River will lead to negative impacts on the surrounding environment and local recreational fishing. (SV096)**

**More information on the mitigation of increased concentrations of heavy metals into the Cox's River and Sydney's water supply plus potential health impacts mediated through water quality and security is urgently required. (SV111)**

**The SoEI states "The consequence of increased discharge to the Cox's River is not significant since there is excess demand for this water resource in this catchment." (p.479). This argument neglects the fact that the mine discharge water is contaminated with heavy metals and is of high salinity. (SV280)**

**The eco-toxic mine effluent currently running at 12.5ML/day has unacceptably high levels of turbidity, heavy metals and salinity. (SV280)**

**Before discharge, the mine water must be treated to a standard that protects undisturbed aquatic ecosystems using reverse osmosis technology to remove metals and salts. (SV280)**

**Discharge of what is effectively untreated, highly contaminated mine water to Kangaroo Creek via LDP001, and subsequently to the Cox's River, is inappropriate. The measures proposed to mitigate the ongoing and increasing damage to these aquatic ecosystems are inadequate. (SV149)**

**A complete redesign of the waste water management system is essential, ensuring Centennial is held accountable for ensuring the water management system is designed to cope with all scenarios and ensure that no waste water is ever transferred to watercourses. (SV149)**

**The effective doubling of discharge via the water transfer scheme (the SDWTS), with flow of saline ground water to the Cox's River catchment will have a detrimental effect on the aquatic biota. (SV160)**

A Regional Water Quality Impact Assessment (**Appendix 2** to this RTS) has been undertaken to assess the impact of direct discharge at Angus Place LDP001 and Springvale LDP009. This assessment has quantified the impact (water quality and water quantity) of the proposed discharges from Angus Place Colliery and Springvale Mine into the Coxs River catchment, including Lake Burragorang.

Springvale Coal has undertaken SSTV assessment for Springvale Mine's LDP009. Results of the SSTV analysis indicate that current water quality at LDP009 exceeds the data for electrical conductivity, aluminium, zinc and copper concentrations meets ANZECC 95% protection of aquatic ecosystems except for copper and zinc concentrations but fall below the adopted trigger value (**Appendix 3**).

Following public exhibition of the EIS, a review of the EPA Direct Toxicity Assessment on Springvale's LDP009 discharge was undertaken by GHD (**Appendix 9** to this RTS). Following the review, an additional Direct Toxicity Assessment, provided as **Appendix 10** to this RTS, was carried out on discharge water from LDP001 at Angus Place and LDP009 at Springvale. The methodology for the Direct Toxicity Assessment was approved by the EPA in August 2014. The results of the Direct Toxicity Assessment show that there is no toxicity associated with the Discharge water from LDP001. Although toxicity has been observed at LDP009, it has been demonstrated that neither the EC or bicarbonate concentrations have any effect on the toxicity of the water. Lowering the EC may have a detrimental effect on the system as shown by the high toxicity at sites upstream of LDP001. The chemistry of water quality discharged through LDP009 does not point to any source in particular that is leading to the toxicity being observed. As such, Centennial proposes to undertake further investigations into the toxicity of LDP009 water discharge to identify the cause of the toxicity. Without knowing what is causing the toxicity, the application of a treatment system is premature as you won't know what you are treating for. As such, no additional treatment of mine water is considered necessary at this stage.

**Carne Creek is currently in a pristine state, and its waters that flow through the Greater Blue Mountains World Heritage Area are of the highest standard. This creek must not run bright orange or suffer reduced flows, just like the Wolgan River after Centennial Coal wrecked it. (Various)**

**The project will impact on Carne Creek, the Wolgan River, Marrangaroo Creek, Bunglebouri Creek, Wolgan River and Rocky Creek headwaters and catchments. These impacts will be unable to be mitigated. (SV049, SV098, SV111, SV160, SV189, SV246)**

**The Wolgan River is dry, where it once ran into the valley as a magnificent waterfall. This must not happen to Carne Creek. (SV142)**

**There should be no emergence of near surface groundwater with elevated levels of salt or metal precipitate in Carne Creek. (SV149)**

No significant ponding, flooding, scouring is predicted for the Wolgan River. The Wolgan River has previously experienced up to 270 mm subsidence and 330 mm closure due to previous extraction of longwalls at both Angus Place Colliery and Springvale Mine, which caused no significant fracturing or related surface water diversions. It is not predicted that any significant fracturing or water diversion will occur due to the Project.

Approximately 2 km of Carne Creek is directly above the proposed longwalls LW416- LW419. The section of creek located above the proposed longwalls is generally confined within Sunnyside East Swamp. The predicted tilt of 0.25 mm/m, is less than the typical natural grade of Carne Creek, which ranges from 25 mm/m to 300 mm/m and therefore no significant ponding, flooding, scouring is predicted and is unlikely to have any adverse effect, apart from the potential for small sections of grade reversal where natural channel grades are very low immediately upstream of chain pillars.

It is expected that Carne Creek will experience compressive strains due to valley related movements between 5 mm/m and 15 mm/m. The greatest compressive strains are expected to occur where the creek is located near the centrelines of the proposed longwalls, and less where the creek is located near the chain pillars.The maximum predicted valley related movements, due to the extraction of the proposed longwalls only, are 65 mm upsidence and 75 mm closure. It has also been predicted that the river has already experienced valley related movements up to 270 mm upsidence and 330 mm closure due to the extraction of the existing longwalls at Angus Place and Springvale Collieries. No significant fracturing or surface water flow diversions have been observed along the river due to the existing mining. It is unlikely, therefore, that the extraction of the proposed longwalls would result in any significant fracturing resulting in surface water flow diversions or water quality impacts.

Existing baseflows to Carne Creek already occur from the near surface aquifers. The water quality from these aquifers that flow into Carne Creek will remain unchanged as a result of the Project and environmental consequences will not result.

Lastly, Springvale Coal and Centennial Angus Place have not, as yet, been provided with any scientific evidence that their mining operations caused the impacts in Wolgan River that caused it to run “bright orange”. The claim that Centennial Coal wrecked Wolgan River is not validated with evidence.

**The proposal will cause creek flows and swamp waters to move many meters underground and pretend that nothing has happened. (SV009)**

The Groundwater Impact Assessment prepared by RPS to support the Project and provided as Appendix E to the EIS determined that the most significant reductions to average standing groundwater levels are predicted in Twin Gully Swamp. This swamp has a projected drop in average standing water levels from 12.4 cm to 10.6 cm above the soil surface. The post mining values predicted at Twin Gully Swamp therefore suggest that soil saturation would persist, maintaining water availability for flora and fauna, as well as soil anoxia, allowing for continued peat formation. All other monitored swamps have smaller projected decreases in average standing water levels and monitored swamps are projected to maintain average standing water levels above the surface.

Detailed investigations of the relationship between the groundwater and surface water movements, the underlying geology and the proposed mining layout has concluded, through empirical modelling, that the proposed longwall mining would not create interconnected fracturing between the aquifer supporting swamps and the longwalls. This is primarily due to the large vertical distance between extracted coal seam and the swamps, resulting in these swamps being located significantly higher than the predicted fracturing zone. The predicted change to baseflow and average water level is within the expected capillary forces of peat swamps such that the magnitudes of water table decline predicted is unlikely to result in drying of the peat layer.

Shrub swamps which are located directly above the proposed longwalls are predicted to experience tensile strains greater than 0.5 mm/m and compressive strains greater than 2 mm/m. It is expected, therefore, that fracturing would occur in the top most bedrock beneath these swamps.

The surface cracking across the mining area is expected to be generally isolated and minor in nature, due to the reasonable depths of cover which typically vary between 270 metres and 450 metres, and due to the plasticity of the surface soils which allows them to more readily absorb the ground strains. Surface crack widths are expected to be similar to those observed above the previously extracted longwalls at Angus Place and Springvale Collieries, which were typically between 5 mm and 25 mm, but with isolated surface cracking in some locations greater than 50 mm.

The shrub swamps have peat layers which overlie the shallow natural surface soils and underlying bedrock along the alignments of the drainage lines. In most cases, cracking would not be visible at the surface within these swamps, except where the depths of bedrock are shallow or exposed. The shrub swamps comprise significant quantities of sediment and, therefore, fracturing of shallow bedrock beneath these swamps are likely to be filled with soil during subsequent flow events along the drainage lines.

The hanging swamps have soft soil or peat layers which overly the bedrock on the valley sides. It is expected that the potential for fracturing in these locations would be less when compared to the bases of the valleys, where higher compressive strains occur due to the valley related movements, and due to the higher depths of cover along the valley sides.

Whilst some minor surface cracking could occur in the swamps resulting from the extraction of the proposed longwalls, the previous experience of mining beneath swamps at Angus Place, Springvale and in the Southern Coalfield indicate that the likelihoods and extents of these impacts are very small.

The dilated strata beneath the drainage lines, upstream of the swamps, could result in the diversion of some surface water flows beneath parts of the shrub swamps. It is noted, however, that the drainage lines upstream of the swamps are generally ephemeral and, therefore, surface water flows occur during and shortly after rainfall events. Any diverted surface water flows are expected to remerge short distances downstream, due to the limited depth of fracturing and dilation and due to the high natural stream gradients.

The incidence of impacts on swamps due to mine subsidence ground movements is very low and, in some of these cases, the impacts that were observed were associated with natural events or mining related surface activities. It is expected, therefore, that the incidence of impacts on the swamps within the Extension Area resulting from mining induced ground movements will also be low.

**The Wallerawang Power Plant has shut down, possibly permanently. The current SDWTS proposal to provide water to this plant is not viable. (SV280)**

Springvale Coal and Centennial Angus Place have undertaken additional water balance modelling to assess potential water quality impacts in light of the recent change in status of the Wallerawang Power Station and reduced water demand. This assessment is attached as **Appendix 2** to this RTS.

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**The impact of subsidence on surface water in Appendix F, Chapter 6.4 p.98 investigates impacts on Marrangaroo Creek, Wolgan River and as far as the Colo River. Carne Creek which will be directly undermined is left out. (SV280)**

Section 5.3 of the Subsidence Assessment prepared by MSEC and provided as Appendix D to the EIS as well as Section 5.3.2 of the Surface Water Impact Assessment prepared by RPS and provided as Appendix F to the EIS addresses predicted subsidence impacts to Carne Creek.

As detailed in Section 10.1.3 of the EIS, approximately 2 km of Carne Creek is directly above the proposed longwalls LW416- LW419.

Given that most channels in Carne Creek catchment have grades well in excess of 25 mm/m, the predicted tilt is not expected to reverse any grades nor cause significant changes in channel grade, and is unlikely to have any adverse effect. Accordingly there is no ponding or scouring predicted, apart from the potential for small sections of grade reversal where natural channel grades are very low immediately upstream of chain pillars. The predicted tilt of 0.25 mm/m, is less than the typical natural grade of Carne Creek, which ranges from 25 mm/m to 300 mm/m and therefore no significant ponding, flooding, scouring is predicted.

Impacts to watercourses have been avoided through eliminating extraction directly underneath fourth order watercourses and through narrowing the longwall width to sub-critical voids. As a result, monitoring of impacts to watercourses will be through the underground Strata Management Plan and will be limited to the section of Carne Creek within the 26.5 degree angle of draw.

**Any malfunction of the SDWTS, such as following a bushfire, must not result in emergency discharges to the World Heritage Area via Wolgan River or Carne Creek. These discharges must be properly treated and reinserted underground into the mine instead. (SV149)**

The SDWTS pipeline network, covering Angus Place Colliery's dewatering bores 930 (not operational) and 940 (in service) and Springvale Mine's bores 6 and 8 and licensed discharged point LDP009 (EPL 3607) and Energy Australia's Wallerawang Power Station, are predominantly trenched and hence the risk of bushfire destroying the network is minimal. In the event a bushfire destroyed the short exposed section of the SDWTS, the mine water would cascade down Newnes Plateau and will be captured within the Sawyers Swamp Creek Ash Dam, owned by Energy Australia.

Centennial Angus Place and Springvale Coal confirm that no emergency discharges into Wolgan River occur currently or is proposed in the future. No discharges into Wolgan River have occurred since 10 April 2010. Angus Place Colliery's EPL 467 was varied on 29 July 2013 to remove LDP006 as the emergency discharge point on Newnes Plateau. No new LDPs have been proposed in the Angus Place MEP (refer Section 4.11.3 of the Angus Place MEP EIS).

While Springvale Mine's EPL 3607 still has provisions for two emergency discharge points (LDP004 and LDP005) on Newnes Plateau no emergency discharges have been proposed via these LDPs in the Springvale MEP. Instead it has been proposed (refer Section 4.10.1 of the Springvale MEP EIS) that these LDPs be relinquished post-approval when infrastructure required to re-direct emergency discharge water from the SDWTS back underground to the Angus Place Colliery's 900 water storage area has been installed.

There has never been any mine water discharges into Carne Creek and neither is there any proposal to do discharge into that catchment as part of the Project.

**Emergency discharge points in the Wolgan River and Carne Creek must be eliminated and those discharge licences voided. (SV149)**

Angus Place Colliery's EPL 467 was varied on 29 July 2013 to remove LDP006 as the emergency discharge point on Newnes Plateau. No LDPs have been proposed in the future through the Angus Place MEP (refer Section 4.11.3 of the Angus Place MEP EIS).

The Springvale MEP EIS (refer Section 4.10.1 of the Springvale MEP EIS) is proposing that its existing two emergency discharge points on EPL 3607 (LDP004 and LDP005) on Newnes Plateau be relinquished post-approval when infrastructure required to re-direct emergency discharge water from the SDWTS back underground to the Angus Place Colliery's 900 water storage area has been installed.

### 3.3.14 Traffic

**The project will lead to another increase in traffic on poor quality state forest roads 24 hours a day, 7 days a week. (SV160)**

As detailed in Section 10.5.4 of the EIS, construction vehicles will travel across two shifts (6.00 am to 6.00 pm and 6.00 pm to 6.00 am), seven days a week. Peak light vehicle movements will occur in relatively short periods around shift changes with construction staff generally travelling in groups to and from construction sites.

Considering the maximum of 16 vtpd predicted during construction and less than 10 vehicle trips per week during operation upon the existing Newnes Plateau road network, the consequences of road traffic impacts are low. Notwithstanding this the unsealed Newnes State Forest road network may require additional remediation works and general maintenance in accordance with the Forestry Act 2012, so as to appropriately provide for the traffic generated by the Project and other road users.

All heavy vehicle trips within the Newnes State Forest will be undertaken during daylight hours to maximise safety. These heavy vehicle movements will generally be between the hours of 6am and 6pm.

As detailed in Section 10.5.5 of the EIS, a Construction Traffic Management Plan will be prepared in consultation with the Forestry Corporation of NSW; This will include measures such as warning signs at appropriate locations on the main access roads to the infrastructure sites, advising public road users of when access tracks will be used by increased numbers of heavy vehicles and other construction traffic. Caution will be advised to all road users.

Springvale Coal will also commit to developing the Construction Traffic Management plan in consultation with Lithgow City Council and RMS.

### 3.3.15 Visual

**Centennial says there will be little visual impact at their test sites, but if you travel to say Birds Rock lookout (one of their test sites) you see numerous examples of their mining infrastructure along the way. (SV160)**

The Project is assessed to have significance of visual effects of none or minor at receptor locations with the exception being the mine services borehole compound due to the woodland clearing required during construction and its proximity to motorists on Old Bells Line of Road. However, placed in the context of being a transient viewpoint within a much larger area that commonly has larger clearings of pine plantation, Old Bells Line of Road not having direct line of site to this receptor and combined with the proposed appropriate dismantling and rehabilitation during decommissioning of this infrastructure, there will be no long term visual impact.

## 3.4 Positive Submissions

The Angus Place and Springvale Mine Extension Projects have received a substantial number of submissions in response to the projects being placed on exhibition. On review of the submissions that were written in support of these projects, it is found that mining brings about a direct and significant social and economic benefit to local communities which would be lost should the projects be refused. A review of submissions received in support of the projects has found:

- The majority of support submissions are from the local community (Lithgow LGA) or immediate surrounding LGA's.
- The submissions outline the risks to the local community if the projects are not approved, which include:
- The importance of ongoing secure employment.
- Reduction in flow-on effects to other business and subsequent negative impacts.
- The possible need for families to relocate should employment continue to decline across the sector.
- The loss of financial and in-kind sponsorship to local community events, charities and projects.
- The long history of mining in the LGA and also the multi-generational employment history amongst families will be lost.
- The environmental performance of the projects is important to the workforce and that local people (including the sector workforce) access and enjoy the areas where mining is undertaken for leisure and recreation.
- The mining sector is an important training resource for new employees and those wishing to pursue a career in the industry.
- Direct mine industry sector employment sits at 15% of Lithgow's workforce compared to 1.0% of the NSW workforce (2011 Census).
- The Lithgow Economic Development Strategy (Version 2) highlights the clear link between economic sustainability and population growth. Lithgow's current population is 20,161 (2011 census) and the projected population is forecast to be 20,650 people in 2036.
- A large proportion of Angus Place and Springvale's workforce reside in the Lithgow LGA, many of whom are long term residents and have been employed in the mining sector for many years. The workforce is more likely to own their own home and directly contribute to the social and financial economy of their community.
- For the 2013 – 2014 financial years Angus Place spent $64,923,494.15 on external contractors. Over 18% of this contribution was for contractors based in the Lithgow LGA and 80% for contractors based in other LGA's. For the same period, Springvale spent $78,887,424.62 on external contractors. 30% of this contribution was for contractors based in the Lithgow LGA and 70% for contractors based in other LGA's.
- The financial contribution to other LGA's does not represent lost income to the Lithgow economy as it generates spending in other non-mining related sectors (i.e. accommodation, food, fuel, engagement of additional contract support services etc.). This type of expenditure would not occur if funds remained within the LGA. Therefore the indirect spend is significant.

- Case studies over the last 2 – 3 years illustrate the importance of mining to the general economy. There are many stories that recognise the link between mine related employment and the broader economy.

A socio-economic analysis of the submissions received in support of Angus Place and Springvale MEPs has been provided as Attachment 1 of **Appendix 5** to this RTS.

# 4.0 CONSULTATION

Since the public exhibition of the EIS, Springvale Coal has continued to undertake consultation with the relevant government agencies regarding the Project. A summary of the consultation undertaken since the submission of the EIS for public exhibition is detailed below.

## 4.1 Commonwealth Department of the Environment

- 24 September 2014 – Meeting with the Department of Environment to discuss the issues raised by the IESC in regards to THPSS.

## 4.2 Department of Planning and Environment

- 24 September 2014 – Meeting with the Department of Planning and Environment to discuss the issues raised by the IESC in regards to THPSS.

## 4.3 Environment Protection Authority

- 26 June 2014 – Meeting with EPA regarding increase in discharge limits and inspection of the Springvale Delta Water Transfer Scheme.

- 27 June 2014 – Email from EPA seeking clarification on groundwater make and discharge volumes for Springvale and Angus Place. This issue has been addressed as part of this Response to Submissions.

- 2 July 2014 – Letter from the EPA seeking further information on mine water discharge toxicity and the EPA’s EPL variation expectations and requirements.

- 4 August 2014 – Draft EPL Licence Variation issued for EPL 3607

- 7 August 2014 – Letter to EPA in response to EPL 3607 variation and PRP

- 11 August 2014 – Phone call with EPA to discuss PRP on the draft Springvale EPL 3607 variation.

- 13 August 2014 – Email response to EPA providing a copy of the Springvale Direct Toxicity Assessment Methodology and Chemical Analysis program to satisfy the PRP on EPL 3607.

- 22 September 2014 – Meeting with the EPA to discuss the results of the additional water assessments.

## 4.4 NSW Office of Water

- 24 September 2014 - Meting with the NSW Office of Water to discuss the water licensing strategy for the Springvale and Angus Place MEPs.

## 4.5 Office of Environment and Heritage

- 23 September 2014 - Meeting with the OEH to discuss the revisions to the regional Biodiversity Strategy.

## 4.6 Emirates Wolgan Valley Resort

- 2 July 2014 – Meeting with representatives from the Emirates Wolgan Valley Resort to discuss the Project and concerns raised in the submission to the EIS.

# 5.0 REVISED STATEMENT OF COMMITMENTS

| Desired Outcome | Action |
|---|---|
| **1. General** | |
| All operations are undertaken in a manner that will minimise the environmental impacts associated with the Project. | Operations will be undertaken in accordance with the description provided in this EIS.<br>As the required exploration drill holes are determined, Centennial Angus Place will undertake a series of due diligence assessments to consider key impacts as relevant. The general approach of the due diligence assessments will be to conduct site investigations to ensure that significant impacts are avoided.<br>Centennial Springvale will develop Trigger Action Response Plans as part of the development of the certain management plans which will detail the response to be taken if mining induced impacts occur. |
| **2. Development Phase** | |
| All construction operations are appropriately undertaken to minimise potential impacts to the environment. | Six (6) months prior to construction of surface facilities on the Newnes Plateau, a Construction Environmental Management Plan will be developed in consultation with the Forestry Corporation of NSW. This plan will include noise management in accordance with the Project Specific Noise Criteria detailed in Section 10.6.3 of the EIS. A copy of the Construction Environmental Management Plan will be provided to Lithgow City Council for their consideration. |
| **3. Exploration** | |
| All exploration activities are appropriately undertaken to minimise potential impacts to the environment. | Proposed exploration activities will be notified to DRE and where applicable to the Forestry Corporation of NSW. All required approvals will be obtained prior to the commencement of any exploration activities. Copies of any due diligence assessments will also be provided to DRE and Forestry Corporation (where applicable). |
| **4. Hours of Operation** | |
| All operations are undertaken within the approved operating hours. | Operations will be undertaken 24 hours a day 7 days a week, 52 weeks per year. |
| **5. Surface Water, Groundwater, Geomorphology and Aquatic** | |
| All surface water groundwater and aquatic impacts are minimised to the greatest extent possible. | Within six (6) months of development consent, a Water Management Plan will be developed that includes the monitoring requirements identified in Section 10.2.5 of the EIS.<br>The Water Management Plan will be developed in consultation with the NSW Office of Water.<br>Groundwater models will be updated every 6 months and a review will be included in the Annual Review. Copies of the Annual Review will continue to be provided to NOW.<br>Flow monitoring on drainage lines within 800m of the longwall voids from LW1008 will be installed to measure far field effects.<br>Throughout the life of the Project, stygofauna will be monitored using standing water levels within one borehole in each aquifer where stygofauna are known to occur (AQ4 to AQ6). Where available, monitoring of the deep aquifer system, AQ |

| **Desired Outcome** | **Action** |
|---|---|
| | 1 to AQ3 will be undertaken to establish presence of stygofauna.<br>Centennial Coal will undertake a regional stygofauna assessment which will:<br>• Collate existing available information on groundwater bores, water quality and characteristics in Centennial Coal's area of operations throughout the Western Coalfield.<br>• Use this information to form a prioritisation list of likely areas for GDE to occur.<br>• Use the prioritisation protocol to identify bores that can be sampled to provide data on the presence and significance of fauna both within and outside mine areas.<br>• Identify any stygofauna found to a minimum of Family level.<br>• Advise on the significance of the findings.<br>• Examine relationship between bore characteristics and presence of stygofauna.<br>The following strategy will be adopted by Centennial Coal to secure water licenses required for the Project:<br>• Trade, within the constraints of the relevant Water Sharing Plan, with other Centennial Coal water license holders.<br>• Obtain, when available through controlled allocation orders under the relevant Water Sharing Plan, additional allocations.<br>• Review the hydrogeological model and predicted water inflows for the Project on a 6 monthly basis to ensure adequate accounting for water take and license requirements.<br>• Contribute to the 2016 Water Sharing Plan review process, as agreed with the NSW Office of Water.<br>Springvale Coal will commit to notify NSW Fisheries if any monitoring detects significant impacts to third order drainage lines as a result of subsidence.<br>Centennial Springvale will undertake further investigations into the toxicity of LDP001 water discharge to identify the cause of the toxicity. |
| **6. Terrestrial and Aquatic Ecology** | |
| | Within 12 months of development consent, the land to be used for offsetting the impacts of the Project, as identified in Chapter 10.3, will be implemented. Within 12 months of development consent a Research Strategy will be developed in consultation with the DOPI, Forestry Corporation of NSW, Office of Environment and Heritage, National Parks and Wildlife Service and Federal Environment Department. This research strategy will include the research and mitigation themes described in **Section 10.3**.<br>Within two (2) years of development consent, a Biodiversity Management Plan will be developed and implemented. The Plan will be developed in consultation with DOPI, OEH, DoE, Forestry Corporation of NSW, NPWS and will include the outcomes of the Research Strategy. |
| **7. Aboriginal Heritage Management** | |
| Ensure that identified and unidentified Aboriginal Sites are appropriately managed. | Aboriginal Heritage will be monitored and managed in accordance with Table 8.2 of this EIS.<br>Within 6 months of the date of approval, the Cultural Heritage Management Plan will be updated. |
| **8. Traffic and Transport** | |

| Desired Outcome | Action |
|---|---|
| Project-related impacts on the road network are limited. | Six months prior to the commencement of construction activities, a Construction Traffic Management Plan will be developed and implemented. The Plan will be developed in consultation with Lithgow City Council and Forestry Corporation of NSW. |
| **9. Noise and Vibration** | |
| All noise impacts are minimised to the greatest extent possible. | The existing Noise Management Plan will be updated to include the noise criteria for the Project and a noise monitoring programme for the sensitive receptors identified in **Figure 10.25** of the EIS. The noise monitoring programme will include continuous, unattended noise monitoring and operator attended quarterly noise monitoring. |
| **10. Air Quality and Greenhouse Gas** | |
| All air quality impacts are minimised to the greatest extent possible. | Within six (6) months of development consent, the Air Quality Management Plan will be updated to include the mitigation measures identified in **Section 10.7** of the EIS.<br>An additional TEOM will be installed as part of a regional air quality monitoring programme that is currently being developed by Centennial Coal. |
| **11. Soils and Land Capability** | |
| All soil and land impacts are minimised to the greatest extent possible | Soil stripping will be undertaken in accordance with the soil stripping depths in the Soils and Land Capability Report appended to this EIS.<br>The following topsoil management measures will be applied:<br>• topsoil will be stripped to depths in Table 10.44 of the EIS only when moist and stockpiled a maximum of 3 m high;<br>• topsoil stripping will immediately precede construction to minimise the time that bare subsoils are exposed;<br>• ameliorants for each soil type will be applied as per the Soils and Land Capability Report;<br>• topsoil that is to be stockpiled for longer than 3 months with be stabilised with an annual cover crop; and<br>• prior to re-spreading stockpiled topsoil, weeds will be removed. |
| **12. Life of Mine and Rehabilitation** | |
| Rehabilitation of the Springvale Coal Services Site is conducted in accordance with Industry Standards. | Progressive rehabilitation will be undertaken in accordance with the Rehabilitation Strategy appended to this EIS.<br>Within 6 months of approval, the Mining Operations Plan will be updated to include the rehabilitation requirements outlined in the Rehabilitation Strategy of this EIS, |
| **13. Hazards** | |
| Safety of the underground personnel from the underground strata will be maintained. | The existing Hazard Plan, being part of the Strata Failure Management System, will be maintained and updated on an ongoing basis as required, in accordance with the Clause 28b (ii) of the *Coal Mine Health and Safety Regulation 2006*. |

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# 7.0 APPENDICES

# Appendix 1 – Springvale Community Submission Reference Table

# Appendix 2 – Springvale and Angus Place Regional Water Quality Impact Assessment (RPS 2014a)

# Appendix 3 – Springvale LDP009 Site Specific Trigger Values (RPS 2014b)

# Appendix 4 – Revised Regional Biodiversity Offset Strategy (RPS 2014c)

# Appendix 5 – Springvale Response to TIA Submission (Aigis 2014)

# Appendix 6 – Springvale and Angus Place Height of Fracturing Report (DgS 2014)

# Appendix 7 – Springvale and Angus Place Height of Fracturing Peer Review (MSEC 2014)

# Appendix 8 - EPA Letter to Centennial Coal (25 July 2014)

# Appendix 9 - Springvale EPA Water Quality and Toxicity Assessment Interpretive Report (GHD 2014a)

# Appendix 10 – Coxs River Ecotoxicology Assessment (GHD 2014b)

# Appendix 11 - Kangaroo Creek Swamp Photo Monitoring

# Appendix 12 - Springvale Total Discharge Volumes (RPS 2014d)

# Appendix 13 – Centennial Response to IESC Report: Ecological Characteristics, Sensitivities to Change, and Monitoring and Reporting Techniques

# Appendix 14 – Centennial Response to IESC Report: Evaluation of Mitigation and Remediation Techniques

# Appendix 15 – Centennial Response to IESC Report: Longwall Mining Engineering Design – Subsidence Predictions, Buffer Distances and Mine Design Options

# Appendix 16 – Detailed Response to IESC Advice Water Issues (RPS 2014e)

# Appendix 17 – Springvale and Angus Place Height of Fracturing Estimation (Hydro Simulations (2014)

# Appendix 18 – Geology of Shrub Swamps within the Mine Extension Areas

Centennial Coal

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Centennial Coal
Environment Matters

| Springvale Community Submissions | |
|---|---|
| **Centennial ID** | **Department ID** |
| SV001 | 100394 |
| SV002 | 100405 |
| SV003 | 97411 |
| SV004 | 95515 |
| SV005 | 97322 |
| SV006 | 100402 |
| SV007 | 97440 |
| SV008 | 97211 |
| SV009 | 97444 |
| SV010 | 95700 |
| SV011 | 97634 |
| SV012 | 97640 |
| SV013 | 97448 |
| SV014 | 100309 |
| SV015 | 97419 |
| SV016 | 100307 |
| SV017 | 97509 |
| SV018 | 97348 |
| SV019 | 97470 |
| SV020 | 97298 |
| SV021 | 97305 |
| SV022 | 97484 |
| SV023 | 97520 |
| SV024 | 97507 |
| SV025 | 97539 |
| SV026 | 97482 |
| SV027 | 97492 |
| SV028 | 97553 |
| SV029 | 97559 |
| SV030 | 97497 |
| SV031 | 97578 |
| SV032 | 97565 |
| SV033 | 97531 |
| SV034 | 97588 |
| SV035 | 97580 |
| SV036 | 97474 |
| SV037 | 97472 |
| SV038 | 97486 |
| SV039 | 97535 |
| SV040 | 97584 |
| SV041 | 97501 |
| SV042 | 97686 |
| SV043 | 97642 |
| SV044 | 97706 |
| SV045 | 97667 |
| SV046 | 97688 |
| SV047 | 97690 |
| SV048 | 97602 |

| Springvale Community Submissions | |
|---|---|
| **Centennial ID** | **Department ID** |
| SV049 | 97654 |
| SV050 | 97679 |
| SV051 | 97644 |
| SV052 | 97675 |
| SV053 | 97673 |
| SV054 | 97656 |
| SV055 | 97696 |
| SV056 | 97694 |
| SV057 | 97682 |
| SV058 | 97620 |
| SV059 | 97618 |
| SV060 | 97600 |
| SV061 | 97596 |
| SV062 | 97734 |
| SV063 | 97799 |
| SV064 | 97801 |
| SV065 | 97750 |
| SV066 | 97718 |
| SV067 | 97706 |
| SV068 | 97746 |
| SV069 | 97722 |
| SV070 | 97773 |
| SV071 | 97762 |
| SV072 | 97789 |
| SV073 | 97758 |
| SV074 | 97730 |
| SV075 | 97726 |
| SV076 | 97791 |
| SV077 | 97781 |
| SV078 | 97769 |
| SV079 | 97785 |
| SV080 | 97741 |
| SV081 | 97728 |
| SV082 | 97720 |
| SV083 | 97807 |
| SV084 | 97801 |
| SV085 | 97889 |
| SV086 | 97819 |
| SV087 | 97881 |
| SV088 | 97933 |
| SV089 | 97846 |
| SV090 | 97901 |
| SV091 | 97883 |
| SV092 | 97873 |
| SV093 | 97848 |
| SV094 | 97893 |
| SV095 | 97815 |
| SV096 | 97811 |

**Springvale Community Submissions**

| Centennial ID | Department ID |
|---|---|
| SV097 | 97927 |
| SV098 | 97923 |
| SV099 | 97871 |
| SV100 | 97895 |
| SV101 | 97929 |
| SV102 | 97861 |
| SV103 | 97824 |
| SV104 | 97964 |
| SV105 | 98009 |
| SV106 | 100398 |
| SV107 | 97933 |
| SV108 | 97962 |
| SV109 | 98005 |
| SV110 | 98015 |
| SV111 | 100396 |
| SV112 | 98011 |
| SV113 | 97937 |
| SV114 | 97984 |
| SV115 | 97980 |
| SV116 | 98027 |
| SV117 | 98025 |
| SV118 | 97943 |
| SV119 | 97941 |
| SV120 | 97960 |
| SV121 | 97966 |
| SV122 | 97978 |
| SV123 | 97970 |
| SV124 | 98041 |
| SV125 | 98126 |
| SV126 | 98031 |
| SV127 | 98112 |
| SV128 | 98154 |
| SV129 | 98160 |
| SV130 | 98128 |
| SV131 | 98108 |
| SV132 | 98089 |
| SV133 | 98037 |
| SV134 | 98077 |
| SV135 | 98087 |
| SV136 | 98051 |
| SV137 | 98106 |
| SV138 | 98148 |
| SV139 | 98142 |
| SV140 | 98132 |
| SV141 | 98124 |
| SV142 | 98140 |
| SV143 | 98134 |
| SV144 | 98222 |

**Springvale Community Submissions**

| Centennial ID | Department ID |
|---|---|
| SV145 | 98218 |
| SV146 | 98162 |
| SV147 | 98262 |
| SV148 | 98264 |
| SV149 | 98184 |
| SV150 | 98188 |
| SV151 | 98194 |
| SV152 | 98214 |
| SV153 | 98230 |
| SV154 | 98210 |
| SV155 | 98256 |
| SV156 | 98244 |
| SV157 | 98176 |
| SV158 | 98250 |
| SV159 | 98238 |
| SV160 | 98226 |
| SV161 | 98204 |
| SV162 | 98198 |
| SV163 | 98166 |
| SV164 | 98292 |
| SV165 | 98288 |
| SV166 | 98290 |
| SV167 | 98302 |
| SV168 | 98358 |
| SV169 | 98324 |
| SV170 | 98332 |
| SV171 | 98278 |
| SV172 | 98284 |
| SV173 | 98300 |
| SV174 | 98350 |
| SV175 | 98320 |
| SV176 | 98338 |
| SV177 | 98286 |
| SV178 | 98308 |
| SV179 | 98304 |
| SV180 | 98314 |
| SV181 | 98312 |
| SV182 | 98346 |
| SV183 | 98340 |
| SV184 | 98412 |
| SV185 | 98400 |
| SV186 | 98480 |
| SV187 | 98448 |
| SV188 | 98454 |
| SV189 | 98426 |
| SV190 | 98374 |
| SV191 | 98462 |
| SV192 | 100409 |

**Springvale Community Submissions**

| Centennial ID | Department ID |
|---|---|
| SV193 | 98364 |
| SV194 | 98416 |
| SV195 | 98420 |
| SV196 | 98460 |
| SV197 | 98450 |
| SV198 | 98440 |
| SV199 | 98474 |
| SV200 | 98468 |
| SV201 | 98402 |
| SV202 | 98370 |
| SV203 | 98368 |
| SV204 | 98388 |
| SV205 | 98551 |
| SV206 | 98575 |
| SV207 | 98579 |
| SV208 | 98488 |
| SV209 | 98543 |
| SV210 | 98563 |
| SV211 | 98545 |
| SV212 | 98480 |
| SV213 | 98512 |
| SV214 | 98520 |
| SV215 | 98508 |
| SV216 | 98555 |
| SV217 | 98484 |
| SV218 | 98537 |
| SV219 | 98498 |
| SV220 | 98528 |
| SV221 | 98516 |
| SV222 | 98514 |
| SV223 | 98496 |
| SV224 | 98482 |
| SV225 | 98533 |
| SV226 | 98643 |
| SV227 | 98595 |
| SV228 | 98579 |
| SV229 | 98597 |
| SV230 | 98611 |
| SV231 | 98609 |
| SV232 | 98615 |
| SV233 | 98617 |
| SV234 | 98581 |
| SV235 | 98605 |
| SV236 | 98627 |
| SV237 | 98647 |
| SV238 | 98639 |
| SV239 | 98621 |
| SV240 | 98587 |

**Springvale Community Submissions**

| Centennial ID | Department ID |
|---|---|
| SV241 | 98657 |
| SV242 | 98635 |
| SV243 | 98629 |
| SV244 | 98651 |
| SV245 | 98659 |
| SV246 | 98603 |
| SV247 | 98755 |
| SV248 | 98661 |
| SV249 | 98707 |
| SV250 | 98771 |
| SV251 | 98691 |
| SV252 | 98747 |
| SV253 | 98739 |
| SV254 | 98767 |
| SV255 | 98689 |
| SV256 | 100400 |
| SV257 | 98695 |
| SV258 | 98757 |
| SV259 | 98737 |
| SV260 | 98765 |
| SV261 | 98709 |
| SV262 | 98701 |
| SV263 | 98727 |
| SV264 | 98713 |
| SV265 | 98659 |
| SV266 | 98681 |
| SV267 | 98671 |
| SV268 | 98825 |
| SV269 | 98789 |
| SV270 | 98771 |
| SV271 | 98839 |
| SV272 | 98902 |
| SV273 | 98904 |
| SV274 | 98793 |
| SV275 | 98813 |
| SV276 | 98785 |
| SV277 | 98898 |
| SV278 | 98791 |
| SV279 | 98894 |
| SV280 | 98875 |
| SV281 | 98896 |
| SV282 | 98892 |
| SV283 | 98900 |
| SV284 | 98777 |
| SV285 | 98807 |
| SV286 | 98803 |
| SV287 | 98801 |
| SV288 | 98799 |

| Springvale Community Submissions | |
|---|---|
| **Centennial ID** | **Department ID** |
| SV289 | 100268 |
| SV290 | 100270 |
| SV291 | 98908 |
| SV292 | 100276 |
| SV293 | 98906 |
| SV294 | 98910 |
| SV295 | 100260 |
| SV296 | 100262 |
| SV297 | 98936 |

| Springvale Community Submissions | |
|---|---|
| **Centennial ID** | **Department ID** |
| SV298 | 98904 |
| SV299 | 100274 |
| SV300 | 100266 |
| SV301 | 100272 |
| SV302 | 100296 |
| SV303 | 100264 |
| SV304 | 98989 |
| SV305 | 100298 |

RPS

# REGIONAL WATER QUALITY IMPACT ASSESSMENT - ANGUS PLACE AND SPRINGVALE MINE EXTENSION PROJECTS

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# REGIONAL WATER QUALITY IMPACT ASSESSMENT - ANGUS PLACE AND SPRINGVALE MINE EXTENSION PROJECTS

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| | Name | Position | Signature | Date |
|---|---|---|---|---|
| Author | Dr Justin Bell | Principal Modeller and Surface Water Engineer | | 10/09/2014 |
| | | | | |

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# EXECUTIVE SUMMARY

A daily water and salt balance model has been developed for the Coxs River and Wollondilly River catchments based on the Australian Water Balance Model (AWBM).

The objective of the model was a regional water quality impact assessment of proposed water strategies of the extensions at Angus Place Colliery and Springvale Mine within the Upper Coxs River on water quality and flow in the Coxs River and water quality and volume in Lake Burragorang.

The model was calibrated based on observed flow and salinity data within the Coxs River catchment during the period 1 January 1979 to 30 June 2014. Observation data comprised recent data from Centennial, flow and water quality data from NSW Office of Water gauging stations as well as historical water quality sampling from the period 1960 – 1992.

Modelling indicates that predicted salinity in the Coxs River between Lake Wallace and Lake Lyell will be elevated compared to the null condition, however, is well below historical observation. This is due to the closure of Wallerawang Power Station whom discharged Cooling Tower Blowdown to the Coxs River since its initial commissioning in 1957, until its closure in April 2014. Predicted salinity under the proposed water strategy is a median of 552mg/L compared to a median of 231mg/L in the null case, at the location, compared to historical average salinity of ~800mg/L. For the purpose of reference, the 95% ANZECC default trigger value for the protection of aquatic ecosystems is 235mg/L (assuming a 0.67 conversion factor on salinity, as Electrical Conductivity, of 350µS/cm).

The water quality model was constructed to encompass all catchments contributing to Lake Burragorang (Warragamba Dam). Modelling indicates the predicted salinity in Lake Burragorang will increase only slightly due to the proposal from a modelled median salinity of 85mg/L to a median salinity of 97mg/L. For the purpose of reference, the Australian Drinking Water Guideline (AWDG) is 600mg/L, based on aesthetics. The proposed water strategies have negligible impact on water volume in Lake Burragorang.

Water quality in Lake Burragorang is managed by the Sydney Catchment Authority to the ADWG for raw bulk water supply. The proposal meets this water quality standard. As well, there are site specific water quality characteristic requirements by Sydney Water for their Water Filtration Plant at Prospect. The proposal also meets these water quality requirements. The proposal therefore has a neutral impact to water quality since the predicted increase in salinity is small.

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# 1. Introduction

## 1.1 Purpose of this Report

This report was commissioned by Centennial Angus Place Pty Ltd (Angus Place) and Springvale Coal Pty Ltd (Springvale).

This work is a part of a package of works aimed at addressing queries arising from the public exhibition between 12 April 2014 and 26 May 2014 of the Environmental Impact Statements (EISs) of the proposed extensions of mining operations at Angus Place Colliery and Springvale Mine.

The objective of this report is to be a Technical Appendix to be used by Centennial during preparation of their responses to submissions made during the public exhibition period of the proposed extensions at Angus Place Colliery and Springvale Mine.

The model was constructed with view to be integrated with detailed site water balances prepared by GHD Pty Ltd, RPS and others at a later stage and to serve as a platform for water management by Centennial in the Coxs River catchment.

The model described within, will also address Conditions of Consent with respect to the Water Management Plan at the Centennial Western Coal Services Project, Condition 24 (c) (iv):

> *“to coordinate modelling programmes for validation, re-calibration and re-running of groundwater and surface water models”*

## 1.2 Layout of the Report

This report should be read in conjunction with the Surface Water Impact Assessment prepared for the Angus Place Mine Extension Project (RPS, 2014a) and Springvale Mine Extension Project (RPS, 2014b).

Chapter 1 – provides an introduction as to the purpose of this report

Chapter 2 – presents an extension of the description of the surface water environment to that presented in the Surface Water Impact Assessment, where relevant

Chapter 3 – presents a description of the water quality model, including construction, calibration, prediction and uncertainty analysis

Chapter 4 – presents an extension of the impact assessment to that presented in the Surface Water Impact Assessment, where relevant

Chapter 5 – presents relevant references.

# 2. Background

## 2.1 Study Area

The water quality model prepared for this impact assessment encompasses all contributing catchments to Lake Burragorang (Warragamba Dam). These catchments lie within the Upper Nepean and Upstream Warragamba Water Source of the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011 (*Water Management Act* 2000). The extent of the model is equivalent with the study area and is presented in Figure 2.1. Lake Burragorang is the primary drinking water storage dam of the Sydney Catchment Authority (SCA).

With respect to local scale, licensed discharge points of the Angus Place Colliery and Springvale Mine occur within the Wywandy Management Zone. The Wywandy Management Zone encompasses all catchments upstream of Lake Lyell, which is the lower water supply reservoir of Energy Australia's Wallerawang Power Station, now closed, and Mt Piper Power Station. Figure 2.2 presents the Wywandy Management Zone.

## 2.2 Surface Water Environment

As presented in the Surface Water Impact Assessment (RPS, 2014ab), the Coxs River catchment within the Wywandy Management Zone has a mixed land use comprising:

- natural vegetation
    - generally steep slopes and plateaus
- dryland farming / cleared pasture
- urban areas
    - townships of Blackmans Flat, Lidsdale, Lithgow and Wallerawang
- heavy industry
    - active and rehabilitated open cut mining areas
    - coal washery and reject emplacement areas
    - power generating facilities including dry ash placement facilities.

## 2.3 Water Use

The primary current and historical water use in the Wywandy Management Zone is heavy industry for power generating.

Wallerawang Power Station was commissioned in 1959, with Lake Wallace and Lake Lyell (Lilyvale Dam) commissioned in 1979. The most recent power generating units at Wallerawang Power Station, Wang C (Unit 7 and 8) were completed in 1976 and 1980. Unit 7 closed in January 2013 and Unit 8 closed in April 2014 due to dwindling energy demand. Sawyers Swamp Creek Ash Dam was constructed in about 1979 for Wallerawang Power Station. Wallerawang Power Station was converted to a dry process from a wet ash process in about 2002.

Mt Piper Power Station was built over two stages in 1992 and 1993 as well as Thompsons Creek Reservoir and associated pipeline.

It is understood that Reverse Osmosis plants (two 6ML/d plants) to treat Cooling Tower blowdown water at Mt Piper Power Station and Wallerawang Power Station were commissioned in April 2007.

The estimated demand at Wallerawang Power Station and Mt Piper Power Station was based on Water Management Licence reporting (Delta Electricity, 2006, 2007, 2008, 2009) and was 36.8ML/d at Wallerawang Power Station and is 38.9ML/d at Mt Piper Power Station. These averages were determined from average of daily take from monthly records between July 2007 and June 2009. Blowdown efficiency at Wallerawang Power Station was, on average, 32%, of daily demand. The assumed blowdown efficiency at Mt Piper Power Station is 30%.

From the 2008-09 Water Management Licence Compliance Report (Delta Electricity, 2009), accepted design efficiency was 1.65ML/GWh at Mt Piper Power Station and 1.75ML/GWh at

Wallerawang Power Station. In 2008/9, water use was 1.72ML/GWh at Mt Piper Power Station and was 1.81ML/GWh at Wallerawang Power Station.

Cooling Tower blowdown, low quality water that collates as a by-product of water use, at Wallerawang Power Station was discharged to Lake Wallace (Energy Australia LDP001 and LDP021) but the majority was discharged below Lake Wallace (Energy Australia LDP004). There is no direct discharge of Cooling Tower blowdown at Mt Piper Power Station to the surface water environment and it is understood that blowdown is recirculated on-site and ultimately disposed as brine to the adjacent Ash Placement Area.

## 2.4 Water Storages

There are four storages in the Wywandy Management Zone. They consist:

- Lake Wallace
    - fed by run-off from upstream catchment and pump-in from Lake Lyell
    - operational capacity of 2206ML (*modelled as 2240ML assuming full storage is 4221ML and minimum storage is 1981ML*)
    - spillway height is 871.4mAHD
    - pump-in when water level <870.5mAHD (*modelled to be 3106ML*) and pump-off at 870.8mAHD (*modelled to be 3521ML*)
    - daily environmental release requirement is 0.7ML/d from Lake Wallace, which can be met via discharge at Energy Australia LDP004 (*modelled as daily release from Lake Wallace only)*.
- Lake Lyell
    - fed by run-off from upstream catchment
    - pump-out to Lake Wallace or Thompsons Creek Reservoir
    - total capacity of 34192ML (*modelled as 34451ML*)
    - spillway height of 785.5mAHD
    - active storage capacity of 32109ML
    - minimum storage volume of 2083ML (*modelled as 2749ML*)
    - daily environmental release requirements are:
        - if total storage in Lake Wallace, Lake Lyell and Thompsons Creek Reservoir is <50,000ML for more than six months then daily release is 5ML/d (*not modelled*)
        - if total storage in Lake Wallace, Lake Lyell and Thompsons Creek Reservoir is <50,000ML (drought trigger) and daily inflow is <9ML/d then daily inflow is released (transparent flows – *modelled as described*)
        - if total storage in Lake Wallace, Lake Lyell and Thompsons Creek Reservoir is <50,000ML (drought trigger) and daily inflow is >9ML/d then 9ML/d is released (translucent flows – *modelled as described*)
        - if daily inflow <13.6ML/d then release equals daily inflows (transparent flows – *modelled as described*)
        - if daily inflow >13.6ML/d then 13.6ML/d plus 25% of daily flow greater than 13.6ML/d is released (translucent flows – *modelled as described*).
        - long term channel maintenance flow (*not modelled*).
- Thompsons Creek Reservoir
    - is an off-stream storage as very minor local catchment
    - pump-in from Lake Lyell
    - total capacity of 27,500ML (*modelled as 28,000ML*)
    - spillway height is 1032.5mAHD
    - minimum storage is 500ML (*modelled as 500ML*)
    - operationally maintained at full capacity.

- Sawyers Swamp Creek Ash Dam
  - built for wet ash disposal from Wallerawang Power Station and now operated with a negative water balance
  - total capacity of 8500L (*modelled as 8500ML*)
  - spillway height of 941.6mAHD
  - operational capacity of 1197ML (*modelled as 1197ML*).

Figure 2.3 presents the layout of the Energy Australia Coxs River Water Supply Scheme.

The pump-out capacity from Lake Lyell is 95ML/d and is understood to be able to be diverted to either Lake Wallace or the diversion value house below Thompsons Creek Reservoir.

## 2.5 Water Supply

There are several water sources used to meet demand at Wallerawang Power Station and Mt Piper Power Station for cooling. Energy Australia are a significant water user and therefore have a corporate licence from the NSW Office of Water. Their operating conditions are governed by their Water Access Licence Conditions including details such as environmental release requirements (NSW Office of Water, 2014ab).

The water sources for power generation comprise:

- direct supply by the Fish River Scheme from State Water Corporation
- extraction from the Coxs River (Lake Wallace, Lake Lyell and Thompsons Creek Reservoir)
- mine water make from the Springvale Delta Water Transfer Scheme (SDWTS), when operational

### 2.5.1 Fish River Scheme

The Fish River Water Supply Scheme was constructed in the 1950 - 60s and supplies water from Oberon Dam to several townships as well as directly to Energy Australia’s Wallerawang Power Station and Mt Piper Power Station. The Fish River Scheme is now administered under the *Water Management Act* 2000 via the Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources 2012. Energy Australia’s entitlement in this scheme is 8,184ML and the historical allocation is presented in Table 2.1 from July 2005. It is highlighted that there is an embargo on trading into the scheme as well as restrictions during times of drought insofar as supply to Oberon being first priority and Energy Australia and Sydney Catchment Authority (SCA) being last.

**Table 2.1: Energy Australia’s Historical Allocation (ML) from the Fish River Scheme**

| Water Year | Annual Allocation (ML) |
|---|---|
| 2005/06 | 6367 |
| 2006/07 | 6590 |
| 2007/08 | 4367 |
| 2008/09 | 3356 |
| 2009/10 | 2856 |
| 2010/11 | 4932 |
| 2011/12 | 4141 |
| 2012/13 | 5873 |

### 2.5.2 Coxs River

Historically there was direct extraction from Lake Wallace to Wallerawang Power Station and from Thompsons Creek Reservoir to Mt Piper Power Station. As indicated above, with respect to operation of the Lake Lyell storage reservoir, there is transfer from Lake Lyell to Lake Wallace or Lake Lyell to Thompsons Creek Reservoir.

### 2.5.3 SDWTS

The Springvale – Delta Water Transfer Scheme (SDWTS) was commissioned in February 2006 and transmitted mine water make from Springvale and Angus Place via Springvale Mine directly to Wallerawang Power Station. When not required at Wallerawang Power Station, mine water make from the SDWTS was directed to Sawyers Swamp Creek via Energy Australia LDP020. In August 2012, responsibility for Energy Australia LDP020 transferred to Springvale Mine. The new LDP became Springvale LDP009. Prior to the SDWTS, mine water make at Springvale was discharged to the Wolgan River via the Newnes Plateau. Historical discharge at Angus Place was via Kangaroo Creek. Between 2006 and 2012, when the SDWTS was offline, there were periods when there was discharge to the Wolgan River. This ceased in approximately 2010. Currently all flow within the SDWTS is being directed to Sawyers Swamp Creek via Springvale LDP009.

## 2.6 Historical Water Quality

There has been mining activity in the Upper Coxs River catchment since the late 1800s and in recent time, since 1979, major land use activities have consisted: open cut and underground mining, power generation, dryland agriculture as well as urban development.

There are two studies of historical water quality that are of relevance to the Coxs River catchment:

- a regional water quality review undertaken by Australian Water Technologies in 1992 (AWT, 1992)
- water management licence compliance reporting by Energy Australia (then Delta Electricity) (Delta Electricity, 2009).

Figure 2.4 presents the location of the AWT water quality sites and Figure 2.5 presents the location of Energy Australia monitoring stations.

Water quality monitoring observations were extracted at selected locations from the AWT (1992) study and are presented in Figure 2.6. Table 2.2 presents a summary of observed salinity.

**Table 2.2: Historical Salinity at Selected Locations (AWT, 1992).**

| Station ID | Easting[1] | Northing[1] | Description | Range in Salinity (mg/l) |
|---|---|---|---|---|
| E005 | 228689 | 6305288 | Coxs River below Kangaroo Creek | 87 (40 – 335, n = 8) |
| E015 | 226151 | 6305131 | Wangcol Creek above WCSLDP006 | 221 (134 – 302, n = 9) |
| E006 | 227998 | 6304334 | Wangcol Creek above Blue Lagoon | 503 (101 – 6700, n = 14) |
| E013 | 228658 | 6300675 | Coxs River above Lake Wallace | 268 (154 – 536, n = 23) |
| E037 | 228588 | 6297735 | Coxs River below Lake Wallace but above Energy Australia LDP004 | 281 (168 – 1005, n = 18) |
| E039 | 227015 | 6289786 | Coxs River above Farmers Creek | 121 (34 – 469, n = 9) |
| E070 | 230238 | 6285698 | Coxs River below Lake Lyell | 134 (67 – 389, n = 25) |
| E081 | 240375 | 6261223 | Coxs River above Little River | 24 (9 – 70, n = 21) |
| E083 | 246019 | 6248741 | Coxs River above Lake Burragorang | 107 (74 – 704, n = 25) |

1. Eastings and Northings are in Map Grid of Australia 1994, Zone 56.

Energy Australia undertakes compliance monitoring at a number of locations. Figure 2.7 presents time-series historical salinity. Table 2.3 presents a summary of these data.

**Table 2.3: Historical Salinity at Selected Locations (Delta Electricity, 2009).**

| Station ID | Easting[1] | Northing[1] | Description | Range in Salinity (mg/L) |
|---|---|---|---|---|
| WX9 | 228658 | 6300675 | Coxs River above Lake Wallace | 486 (302 – 687, n = unk) |
| COX3 | 228394 | 6297901 | Lake Wallace | 519 (218 – 771, n = unk) |
| WX13 | 228588 | 6297735 | Coxs River below Lake Wallace but above Energy Australia LDP004 | 519 (402 – 1206, n = unk) |

| Station ID | Easting[1] | Northing[1] | Description | Range in Salinity (mg/L) |
|---|---|---|---|---|
| COX5 | 227753 | 6291380 | Coxs River above Lake Lyell | 737 (168 – 1240, n = unk) |
| COX8A | 228880 | 6286559 | Lake Lyell | 427 (168 – 637, n = unk) |
| COX9 | 230238 | 6285698 | Coxs River below Lake Lyell | 402 (168 – 637, n = unk) |

1. Eastings and Northings are in Map Grid of Australia 1994, Zone 56.

It is noted that Figure 2.6 has units of mS/m. The conversion factor between salinity, as EC in µS/cm, to salinity as TDS (mg/L) was assumed to be 0.67.

From Figure 2.6, historical water quality in the Coxs River above Wangcol Creek / Blue Lagoon, site E005 in the AWT (1992) study, ranged between 6mS/m (40mg/L) in 1980 and 50mS/m (335mg/L) in 1989. Current salinity at that location from monitoring at AP_COXS_DOWNSTREAM on 5 March 2014 is 610mg/L. Within Wangcol Creek, at site E006, historical water quality was 1000mS/m (6700 mg/L) in 1980 due to mining within the watercourse. In 1990, salinity at site E006 was 30mS/m (200mg/L). Current salinity at WCS_WangcolFarDownstream is 1394mg/L on 19 December 2013. Upstream of Lake Wallace, the AWT site, E013, corresponds with current monitoring at NSW Office of Water gauge 212054, water quality monitoring by Energy Australia, WX9 and monitoring by Springvale at SV_COXS_UPSTREAM. In Figure 2.6, water quality at this location was 35mS/m (235mg/L) in 1980 and was 50mS/m (335mg/L) in 1991.

Water quality in the Coxs River below Lake Wallace was monitored at AWT site E037 and corresponds with NSW Office of Water gauge, 212008, monitoring by Energy Australia, WX13 and current monitoring by Springvale at SV_COXS_DOWNSTREAM. Salinity at this location was 50mS/m (335mg/L) in 1980 and was 50mS/m (335mg/L) in 1991.

There are several other monitoring locations in the AWT study between Lake Wallace and Lake Lyell as well as below Lake Lyell through to Lake Burragorang. AWT site E039 lies on the Coxs River above Farmers Creek and observed salinity was 5mS/m (34mg/L) in 1980 and 70mS/m (469mg/L) in 1982. AWT site E070 lies on the Coxs River below Lake Lyell. Site E081 lies on the Coxs River above Little River and site E083 is on the Coxs River above Lake Burragorang. The location of all monitoring stations used in the model calibration is presented in Section 3.2.3. Salinity below Lake Lyell is observed to decrease in a downstream direction below site E070, which corresponds with NSW Office of Water gauge 212011 and Energy Australia monitoring station COX9. Water quality was 58mS/m (389mg/L) in 1981 and was 15mS/m (101mg/L) in 1991. At site E081, water quality at equivalent times were 40mS/m (268mg/L) and 17mS/m (114mg/L). At site E083, water quality at equivalent times was 23mS/m (154mg/L) and 24mS/m (161mg/L).

From Figure 2.7, water quality above Lake Wallace, at monitoring station WX9, ranges between 450µS/cm (302mg/L) in 2000 to maximum of 1025µS/cm (687mg/L) in 2009. Within Lake Wallace itself, monitoring station COX3, ranges between 650µS/cm (436mg/L) in 2000 to maximum of 1,150µS/cm (771mg/L) in 2007. Below Lake Wallace, at site WX13, historical salinity ranges between 650µS/cm (436mg/L) in 2000 to maximum in 2007 of 1150µS/cm (771mg/L). The spike in salinity in late 2000 is presumed to reflect drought conditions / low volume and therefore was ignored.

From Figure 2.7, between Lake Wallace and Lake Lyell, historical water quality at monitoring station, COX5, ranged between 400µS/cm (268mg/L) in 2000 to maximum of 1850µS/cm (1,240mg/L) in 2007. Monitoring of Lake Lyell, COX8A, presents an increasing trend from 250µS/cm (168mg/L) in 2000 to maximum of 950µS/cm (637mg/L) in 2007, followed by a drop to ~650µS/cm (436mg/L). Water quality below Lake Lyell at COX9 matches water quality within Lake Lyell. For Thompsons Creek Reservoir, there is a steady increasing trend from 250µS/cm (168mg/L) in 2000 to 650µS/cm (436mg/L) in 2009.

Historical water quality analyses indicate that the Coxs River has been impacted by industrial activity in the past. As will be presented below, the proposed water management strategies for the extension of Angus Place Colliery and Springvale Mine will not result in predicted water quality being significantly outside of that experienced historically and / or ANZECC (2000) default trigger values for 95% protection of aquatic ecosystems.

# 3. Modelling

## 3.1 Model Setup

### 3.1.1 Model Approach

The water quality model presented here is based on the rainfall-run-off model AWBM by Boughton (2010). The AWBM has been used extensively within Australian and is based on saturated overland flow. i.e. excess rainfall after surface storage capacity has been replenished. The structure of the AWBM is presented below.

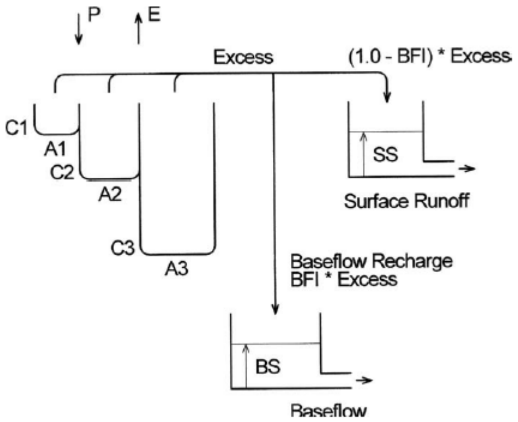

Figure: Structure of the AWBM (after Boughton, 2010).

There are three different capacities of surface storage used to represent partial areas of the catchment that runoff at different times during a storm. The surface catchment storages are depleted by evaporation and runoff is partitioned to surface runoff and baseflow based on parameter selection.

Research into the AWBM on ungauged catchments by Boughton (2010) has led to derivation of average surface storage capacity that are distributed using a fixed pattern throughout Australia. This was due to an outcome of Boughton's later research that areal distribution of rainfall was of much greater importance than variability in average surface storage capacity. As noted by Boughton (2010), small discrepancies in rainfall lead to significant variability in calibrated average surface storage capacity.

To facilitate use of the AWBM, Golder Associates Pty Ltd, the original authors of the generalised mass balance model, GoldSIM, translated the AWBM into GoldSIM and this module is available as a downloadable example from the GoldSIM website. That AWBM module was then adapted for use in this study by taking into account areal distribution of rainfall and land use through sub-catchment delineation. In total there are 281 sub-catchments in the model, from which, for the purpose of practicality, 42 different definitions of rainfall and / or land use applied via the "Clone Element" facility within GoldSIM.

Data from relevant BOM rainfall stations were manually patched such that there was a continuous daily rainfall record for each sub-catchment. Table 3.1 the list of rainfall stations used in the water quality model.

**Table 3.1: Rainfall Stations in the Water Quality Model**

| BOM ID | Station Name | BOM ID | Station Name |
|---|---|---|---|
| 63071 | PORTLAND (JAMIESON ST) | 68166 | BUXTON (AMAROO) |
| 63132 | LIDSDALE (MADDOX LANE) | 70036 | LAKE BATHURST (SOMERTON) |
| 63224 | LITHGOW (BIRDWOOD ST) | 70077 | GOULBURN (SPRINGFIELD) |
| 63146 | CHEETHAM FLATS (JUNDAS) | 70069 | CROOKWELL (GUNDOWRINGA) |

| BOM ID | Station Name | BOM ID | Station Name |
|---|---|---|---|
| 63049 | LOWTHER PARK | 70055 | GOULBURN (KIPPILAW) |
| 63009 | BLACKHEATH (LAWRENCE ST) | 70263 | GOULBURN TAFE |
| 63270 | LITTLE HARTLEY (ROSCOMMON) | 70269 | MARULAN (JOHNNIEFELDS) |
| 63283 | HAMPTON (BINDO) | 70147 | GOULBURN (HILLWOOD) |
| 63039 | KATOOMBA (MURRI ST) | 70119 | BIG HILL (GLEN DUSK) |
| 63036 | OBERON (JENOLAN CAVES) | 68008 | BUNDANOON (BALLYMENA) |
| 63227 | WENTWORTH FALLS COUNTRY CLUB | 68186 | BERRIMA WEST (MEDWAY (WOMBAT CREEK)) |
| 67029 | WALLACIA POST OFFICE | 68089 | JOADJA (GREENWALK) |
| 68125 | OAKDALE (COOYONG PARK) | 63093 | WOMBEYAN CAVES |
| 63033 | GURNANG STATE FOREST (OBERON (YOUNG ADUL | 70325 | WOLLONDILLY (RIVER VIEW) |
| 68044 | MITTAGONG (ALFRED STREET) | 68062 | HIGH RANGE (WANGANDERRY) |

Evaporation in the model was based on average daily evaporation for each month at BOM Station No. 061089 (Scone SCS). Table 3.2 presents the relevant data.

**Table 3.2: Mean Daily Evaporation (mm/d) (BOM Station Scone SCS (No. 061089))**

| | J | F | M | A | M | J | J | A | S | O | N | D | Ann. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Daily Evap. | 7.1 | 6.1 | 5.0 | 3.5 | 2.2 | 1.6 | 1.8 | 2.7 | 3.9 | 5.0 | 6.1 | 7.1 | 4.3 |

Salt mass flux was determined based on a simple model. For general runoff, it was assumed there were several land use types:

- Natural
- Pasture
- Urban
- Disturbed
- Channel.

For each land use type, an assumed salinity, as TDS (mg/L), was defined. Salt mass flux was then calculated based on runoff multiplied by assumed concentration plus such salt mass inflow from upstream sub-catchment plus groundwater discharge from respective LDPs (both Centennial and other operations). Salt concentration was then calculated by mass flux (kg/d) divided by water flow (ML/d). It is noted that the model approach adopted assumed concentration was 50mg/L when water flow was 0ML/d, so as to avoid a division-by-zero error.

### 3.1.2 Catchment Land Use

For simplicity, land uses were not changed in time during a model simulation. Land uses were different, however, in the certain sub-catchments between the calibration and prediction model to account for their change in use. For example, from an active open cut mining (Disturbed) to rehabilitated (Pasture) or from undeveloped (Natural) to open cut mining (Disturbed).

Groundwater discharge during the prediction simulation of various activities in the catchment was derived from the Western Coalfields Water and Salt Balance prepared by GHD (2014).

The layout of the model at pertinent locations is presented in Figure 3.1. Further detail of model layout is provided in the electronic deliverable, including relevant model files and GIS files.

The adopted parameters for runoff salinity and groundwater discharge through LDPs (1,200µS/cm, or 804mg/L) as well as AWBM surface storage capacities and baseflow indices are presented in Section 3.2.3.

It is noted that mine water make presented in Figure 16 of RPS (2014a) and Figure 18 of RPS (2014b) were used to define discharge to Angus Place LDP001 and Springvale LDP009. It is noted that, given each sub-catchment was implemented in the water quality model that local LDPs, such as Angus Place LDP002, Springvale LDP001 and LDP002 were assumed to be represented by catchment runoff through sediment retention structures without attenuation of flow or salinity.

Further detail on model assumptions is presented in Section 3.3.2.

### 3.1.3 Reservoirs

There are five reservoirs included in the model. These comprise:

- Lake Wallace (Node #074)
- Lake Lyell (Node #174)
- Thompsons Creek Reservoir (Node #272)
- Sawyers Swamp Creek Ash Dam (Node #297)
- Lake Burragorang/Warragamba Dam (Node #280).

Detail as to assumed storage capacities of these reservoirs is presented in Section 2.4.

### 3.1.4 Model Periods

The water quality model comprises two components:

- calibration period (1 January 1979 to 30 June 2014, 12965 days)
- prediction period (1 July 2014 to 31 December 2032, 6759 days).

The adopted timestep for the calibration and prediction simulations was 1 day.

## 3.2 Model Calibration

### 3.2.1 Observation Dataset

The water quality model was calibrated by comparing time-series flow (ML/d) and salinity, converted to TDS (mg/L), and volume (ML) to historical observation. As presented in Section 2.6, there has been some historical monitoring in the Coxs River catchment in the past and all available data is presented in the calibration simulation plots below. This includes recent water quality monitoring by Angus Place Colliery and Springvale Mine. As well, there have been daily flow measurements at several NSW Office of Water gauging sites within the catchment.

Table 3.3 presents the observation dataset including model node identifiers.

### 3.2.2 Calibration Parameters

There are two sets of calibration parameters in the water quality model:

- rainfall-runoff parameters
- rainfall salinity and groundwater discharge salinity.

Table 3.4 presents the calibrated values for these parameters. The results of model calibration are presented below.

### 3.2.3 Calibration Results

The model control file pertaining to the calibration simulation is:

- 021a_CAL-Jun14_10a.gsm

## Table 3.3: Calibration Dataset

| Node | Easting[1] | Northing[1] | Description | Alias_NOW[2] | Alias_Centennial | Alias_Delta[3] | Alias_AWT[4] | Flow | Salinity |
|---|---|---|---|---|---|---|---|---|---|
| RES272 | 221040 | 6296878 | Thompson Creek Reservoir | NA | NA | TC1 | NA | 0 | 1 |
| DIS105 | 226151 | 6305131 | Wangcol Creek above WSLDP006 | 212055 | WCS_WangcolNOW | NA | E015 | 1 | 1 |
| DIS167 | 227998 | 6304334 | Wangcol Creek above Blue Lagoon | NA | WCS_WangcolFarDownstream | NA | E006 | 0 | 1 |
| NAT134 | 229749 | 6309050 | Coxs River Far Upstream | NA | AP_COXS_FAR_UPSTREAM | NA | NA | 0 | 1 |
| PAS007 | 229671 | 6307355 | Coxs River above Kangaroo Creek | NA |  | NA | NA | 0 | 1 |
| NAT011 | 230336 | 6306130 | Kangaroo Creek below APLDP001 | NA | AP_KANGAROO_DOWNSTREAM | NA | NA | 0 | 1 |
| PAS137 | 229483 | 6306289 | Coxs River at confluence with Kangaroo Creek | NA | AP_KANGAROO-COXS_CONFLUENCE | NA | NA | 0 | 1 |
| PAS056 | 228689 | 6305288 | Coxs River below Kangaroo Creek | NA | AP_COXS_DOWNSTREAM | NA | E005 | 0 | 1 |
| PAS166 | 228660 | 6302941 | Sawyers Swamp Creek at Coxs River | NA | WCS_LDP003_DOWNSTREAM | NA | NA | 0 | 1 |
| CHA047 | 228658 | 6300675 | Coxs River above Lake Wallace | 212054 | SV_COXS_UPSTREAM | WX9 | E013 | 1 | 1 |
| RES074 | 228394 | 6297901 | Lake Wallace | NA | NA | COX3 | NA | 0 | 1 |
| PAS032 | 228588 | 6297735 | Coxs River below Lake Wallace but above EALDP004 | 212008 | SV_COXS_DOWNSTREAM | WX13 | E037 | 1 | 1 |
| NAT154 | 228152 | 6292169 | Coxs River above Lake Lyell | 212058 | NA | NA | NA | 1 | 0 |
| NAT035 | 227753 | 6291380 | Coxs River above Lake Lyell | NA | NA | COX5 | NA | 0 | 1 |
| NAT117 | 227015 | 6289786 | Coxs River aboveFarmers Creek | NA | NA | NA | E039 | 0 | 1 |
| PAS070 | 230427 | 6289933 | Farmers Creek | 212042 | NA | COX6 | E054 | 1 | 1 |
| RES174 | 228880 | 6286559 | Lake Lyell | NA | NA | COXS8A | NA | 0 | 1 |
| PAS209 | 230238 | 6285698 | Coxs River below Lake Lyell | 212011 | NA | COX9 | E070 | 1 | 1 |
| PAS221 | 240375 | 6261223 | Coxs River above Little River | 212045 | NA | NA | E081 | 1 | 1 |
| NAT225 | 246019 | 6248741 | Coxs River above Lake Burragorang | NA | NA | NA | E083 | 0 | 1 |

1. Eastings and Northings are in Map Grid of Australia 1994, Zone 56; 2. NOW is NSW Office of Water; 3. Delta is Delta Electricity (Delta Electricity, 2009); 4. AWT is Australian Water Technologies (AWT, 1992).

## Table 3.4: Calibrated AWBM and Water Quality Parameters

| Land Use | C1 (mm) | C2 (mm) | C3 (mm) | CAve[1] (mm) | BFI[2] | Kb[2] | Ks[2] | Concn[3] (mg/L) |
|---|---|---|---|---|---|---|---|---|
| Natural | 10.4 | 106.7 | 213 | 140 | 0.41 | 0.981 | 0 | 50 |
| Pasture | 11.9 | 122 | 244 | 160 | 0 | 1 | 0.5 | 100 |
| Urban | 2.0 | 20.6 | 41.2 | 27 | 0 | 1 | 0 | 250 |
| Disturbed | 4.9 | 50.3 | 100.6 | 66 | 0 | 1 | 0.5 | 400 |
| Channel | 2.0 | 20.6 | 41.2 | 27 | 0 | 1 | 0 | 100 |

1. Assumed pattern of distribution of partial areas is A1 = 0.134, A2 = 0.433, A3 = 0.433 for all land use classes; 2. BFI is Baseflow Index, Kb is daily baseflow recession constant and Ks is daily surface recession constant; 3. Concn is assumed run-off salinity from each land use class.

*Kangaroo Creek and Coxs River above Wangcol Creek / Blue Lagoon*

Water quality modelling indicates that historical discharge at Angus Place LDP001 accounts for observed increase in salinity in Kangaroo Creek and the Upper Coxs River above Blue Lagoon. The calibration simulation is presented in Figure 3.2 at monitoring station AP_KANGAROO_DOWNSTREAM (#011).

Modelling assumes water quality upstream of point of discharge of Angus Place LDP001 to Kangaroo Creek (#010 and above) is 50mg/L TDS. Modelled water quality at monitoring station AP_COXS_FAR_UPSTREAM (#134) is also 50mg/L TDS.

Review of simulated daily flows in Kangaroo Creek at point of discharge of Angus Place LDP001 (#011) during historical discharge indicates that River Flow Objective – Maintain Natural Flow Variability has been met in the past.

From Figure 3.2, there is reasonable fit between modelled and observed salinity in Kangaroo Creek.

Monitoring location AP_COXS_DOWNSTREAM (#056) corresponds with historical monitoring in the AWT (1992) study at their site, E005. The calibration simulation at Node #056 is presented in Figure 3.2.

From Figure 3.2, the assumed historical discharge from Angus Place LDP001 is conservative since the water quality model overpredicts salt concentration in the early 1980s, however, fit to recent data is reasonable.

Review of simulated daily flow in Coxs River at monitoring location AP_COXS_DOWNSTREAM indicates River Flow Objective – Natural Flow Variability has been met in the past.

*Sawyers Swamp Creek*

Sawyers Swamp Creek is diverted around the Sawyers Swamp Creek Ash Dam and is transmitted from #014, inclusive of point of discharge from Springvale LDP009, to #061, #098, #275, #09 and #166 before entering the Coxs River.

Water quality modelling implies increased salinity observed in Sawyers Swamp Creek above Coxs River is associated with mine water discharge at Springvale LDP009, however, the Sawyers Swamp Creek catchment is in a highly disturbed state and there are multiple potential sources of salinity and other contaminants both presently and in the past.

Monitoring location WCS_LDP003_DOWNSTREAM (#166) is located on Sawyers Swamp Creek immediately above the Coxs River. Figure 3.3 presents the calibration simulation at that location.

From the above, the calibration model overpredicts the observed salinity at WCS_LDP003_DOWNSTREAM. It is noted that discharge at Springvale LDP009 commenced in August 2012 and prior to this was associated with Energy Australia LDP020 from June 2006. The location of LDP020 changed in the past, however, was still within sub-catchment #014.

*Wangcol Creek*

Industrial activity within Wangcol Creek comprises Mt Piper Power Station (assumed to have commenced on 1 January 1993), Western Coal Services site (assumed to be active since commencement of calibration simulation in 1979) and Pine Dale Coal Mine (also assumed to be active since 1979).

Given that there are no licenced surface water discharge of Cooling Tower blowdown at Mt Piper Power Station, it was assumed there was a seepage to Wangcol Creek through the Ash Placement Facility at a rate of 5% of modelled water demand, at 400mg/L, from 1 January 1993 to 30 December 2006 and at 750mg/L from 1 January 2007, associated with assumed commencement of brine conditioning of ash (RO Plant Brine Stream).

As noted in Section 2.3, there was monthly water use data available for Mt Piper Power Station for the period July 2005 to June 2009. The estimated daily demand at Mt Piper Power Station is 38.9ML/d. To attempt to account for monthly variation in water demand, a month-to-month distribution of the estimated daily demand was calibrated against observation period between July 2005 and June 2009 and is presented below.

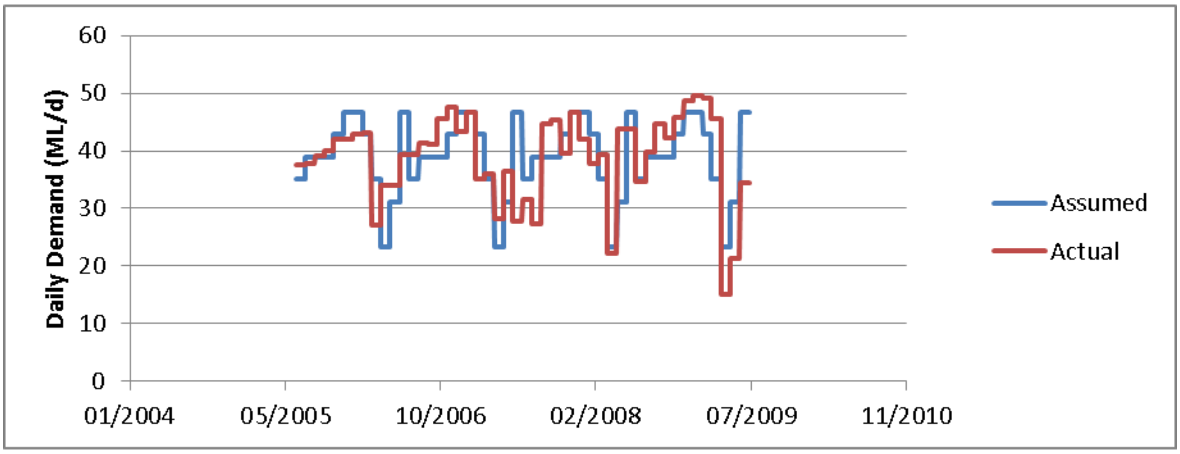

Figure: Calibrated Distribution of Daily Demand at Mt Piper Power Station (ML/d).

Table 3.5 presents the calibrated multiplication factors for Mt Piper Power Station and Wallerawang Power Station. Details of Wallerawang Power Station are presented below.

**Table 3.5: Assumed Monthly Distribution of Water Demand at Mt Piper Power Station and Wallerawang Power Station**

| Month | MPS Daily Demand (ML/d) | Multiplication Factor[1] | WPS Daily Demand (ML/d) | Multiplication Factor[2] |
|---|---|---|---|---|
| January | 46.7 | 1.20 | 44.1 | 1.20 |
| February | 42.8 | 1.10 | 36.8 | 1.00 |
| March | 35.0 | 0.90 | 25.7 | 0.70 |
| April | 23.4 | 0.60 | 29.4 | 0.80 |
| May | 31.2 | 0.80 | 36.8 | 1.00 |
| June | 46.7 | 1.20 | 40.5 | 1.10 |
| July | 35.0 | 0.90 | 44.1 | 1.20 |
| August | 38.9 | 1.00 | 47.8 | 1.30 |
| September | 38.9 | 1.00 | 40.5 | 1.10 |
| October | 38.9 | 1.00 | 33.1 | 0.90 |
| November | 42.8 | 1.10 | 25.7 | 0.70 |
| December | 46.7 | 1.20 | 36.8 | 1.00 |

1. Assumed daily demand at Mt Piper Power Station is 38.9ML/d; 2. Assumed daily demand at Wallerawang Power Station was 36.8ML/d.

It is noted that the distribution presented in Table 3.5 was used in the prediction simulation.

Figure 3.4 presents the calibration simulation at the location of the NSW Office of Water gauging station, 212055 (#105). This location was assumed to correspond with AWT (1992) monitoring site E015 and is the location of current water quality monitoring at Centennial Western Coal Services, WCS_WangcolNOW.

From Figure 3.4, there is reasonable fit between observed salinity and modelled. The staged increase in modelled salinity in January 1993 and January 2007 is due to assumed seepage from the Ash Placement facility.

Time-series water quality at monitoring location WCS_WangcolFarDownstream (#167) is also presented in Figure 3.4. This location corresponds with AWT (1992) location E006.

From Figure 3.4, the water quality model underpredicts recent observation at this location. It is noted that there is no assumed groundwater discharge from the Western Coal Services site and the recent inflow from 2011 may reflect changes in the catchment due to expansion of the Ash Placement Area at Mt Piper Power Station insofar dislocation of water previously stored within Huon Gully / Dam.

*Lake Wallace*

Daily demand at Wallerawang Power Station was based on data reported in the period 2005 to 2009 by Delta Electricity / Energy Australia (2006, 2007, 2008, 2009), daily consumption data from January 2006 as well as daily SDWTS consumption. From the available data between July 2005 and June 2009, average daily demand was 36.8ML/d. As for the Mt Piper Power Station, the monthly distribution of daily demand was calibrated based on available data and is presented below. Table 3.5 presents the adopted multiplication factors.

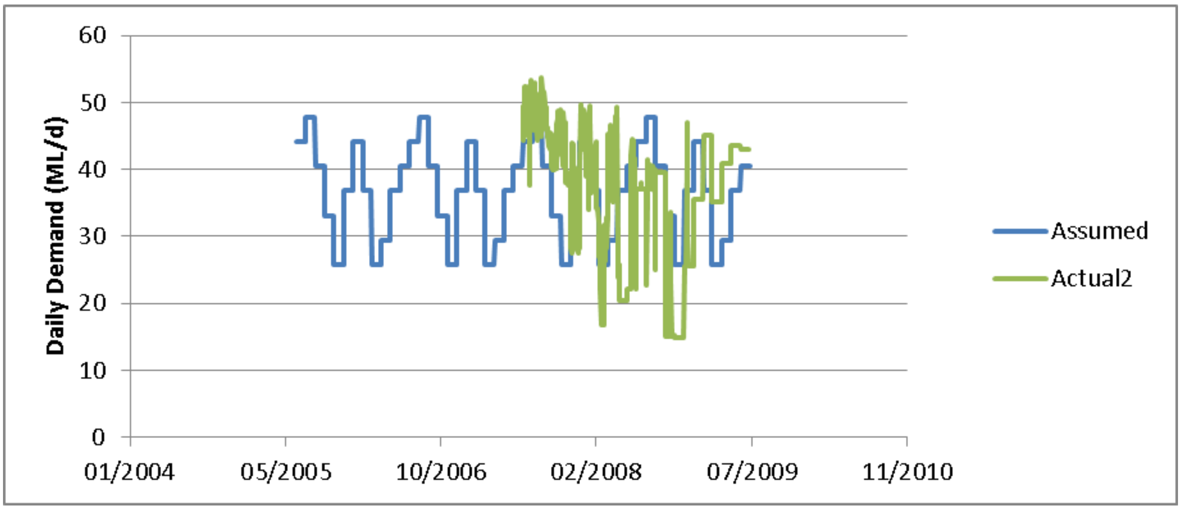

Figure: Calibrated Distribution of Daily Demand at Wallerawang Power Station (ML/d).

There is flow gauging and salinity monitoring in the Coxs River immediately upstream of Lake Wallace by the NSW Office of Water (No. 212054). This location (#047) also corresponds to historical monitoring reviewed in the AWT study, water quality monitoring by Energy Australia between 2000 and 2009 as well as recent monitoring by Springvale, SV_COXS_UPSTREAM. It is noted that this location is upstream of the confluence with Springvale Creek. Springvale Creek receives surface water discharge from Springvale Pit Top. Figure 3.5 presents results of calibration simulation at this model node.

From Figure 3.5, there is a good fit between observed salinity and flow and model simulation, in particular in the period after 1993. It is suggested in the period 1979 to 1993, the conservative assumption about mine water discharge at Angus Place may account for overprediction of salinity.

Calibration simulation results in Lake Wallace is also presented in Figure 3.5 (#074). From Figure 3.5m there is reasonable agreement between observed and modelled salinity. It is noted that the model assumes instantaneous and complete mixing within reservoirs. Also of note in Figure 3.5, the reservoir volume fluctuates between full at 4,221ML and 3,106ML. The trigger value for the Lyell to Wallace transfer to occur is 3,106ML (pump-off is 3,521ML). The transfer capacity of the Energy Australia Coxs River Water Supply System is 95ML/d.

*Lake Lyell*

There are several observation locations between Lake Wallace and Lake Lyell. These include:

- Coxs River immediately below Lake Wallace (#032, flow and quality)
- Coxs River between Lake Wallace and Lake Lyell (#154, flow; #035, quality; #117, quality)
- Lake Lyell (#174, quality).

Figure 3.6 presents the modelled and historical concentration and flow at these locations.

From Figure 3.6, for #032, there is reasonable fit between modelled flow and observation at NSW Office of Water Gauge 212008 and salinity, although peaks in recent water quality observations from 2010 are somewhat underestimated.

Observation at #154 is flow only and is generally consistent with historical record at NSW Office of Water Gauge 212058. Small magnitude peak flows are somewhat overestimated but larger peaks are underestimated.

The observation at #035 is quality and the water quality model underpredicts observed salinity. During available monitoring period between 2000 and 2009, salinity at #035 ranged between 200mg/L and 1,200mg/L. Calibration simulation during that period is 200 to 700mg/L, by comparison.

At #117, the calibration model underpredicts observed salinity, however, as noted above, the assumption of continuous discharge at Angus Place from 1979 is probably too conservative.

From Figure 3.6, the modelled salinity in Lake Lyell (#174) during the calibration simulation is reasonably matched with historical observation. Modelled storage volume (ML) is somewhat underpredicted, however, this is due to assumptions necessary for daily demand at Wallerawang Power Station and Mt Piper Power Station from 1993 and other input data. The results, however, are suitable for the purpose of cumulative impact assessment.

*Thompsons Creek Reservoir*

Figure 3.7 presents the calibration simulation of Thompsons Creek Reservoir.

From Figure 3.7, the modelled salinity in Thompsons Creek Reservoir (#272) is reasonably matched, although the model is overpredicting salinity, the increasing trend is captured. As for Lake Lyell, modelled storage volume (ML) is somewhat underpredicted.

*Lake Burragorang*

There are three observation locations in the water quality model between Lake Lyell and Lake Burragorang as well as Lake Burragorang itself:

- Coxs River below Lake Lyell (#209)
- Coxs River above Little River (#221)
- Coxs River above Lake Burragorang (#225)
- Lake Burragorang (#280) – whilst no observation data is available, it is useful to present the modelled historical volume and salinity.

Figure 3.8 presents the calibration simulation results at these locations.

Lake Burragorang was represented in the model as a reservoir element, with an assumed full capacity of 2,031,000ML and a minimum storage of 4,000ML. There are environmental release requirements of 22ML/d between April and October and 30ML/d between November and March. Daily consumptive demand was assumed to be 1,080ML based on SCA weekly storage reports.

From Figure 3.8, there is reasonable fit for both flow and concentration at #209. For #221, flow is reasonably matched and fit of modelled salinity to water quality data from 1980 – 1992 is also reasonable. Model node #225 corresponds with water quality observation point E083 and Figure 3.8 indicates reasonable agreement between model and observation. The large peak in observed salinity in 1988 is not replicated in the model and could potentially be low flow conditions or may be a unit transcription error. i.e. 10.5mS/m rather than 105mS/m.

The calibration simulation of water volume (ML) and salinity (mg/L) in Lake Burragorang (#280) is also presented in Figure 3.8. From Figure 3.8, storage volume in fluctuates between full and approximately 1,000,000ML, corresponding with drought periods. Modelled salinity of Lake Burragorang ranges between 74mg/L and 96mg/L, with highest salinity corresponding with drought period in the model.

## 3.3 Model Prediction

### 3.3.1 Model Setup

There are several industrial projects in the Coxs River catchment of relevance. These include:

- Centennial Neubecks Open Cut
- Energy Australia Pine Dale Stage 2
- Closure of Wallerawang Power Station
- Extension of Angus Place Colliery and Springvale Mine.

The prediction model was based on the calibration simulation and updated to account for:

- change in land use within the catchment
- updated rainfall dataset
- predicted groundwater discharge from the Western Coalfields Water and Salt Balance.

The prediction period is 19 years, being 1 July 2014 through to 31 December 2032. The historical rainfall dataset from BOM Station No. 63224, 63132 and 63071 were reviewed and 19 year total of annual rainfall depths determined from all available data and ranked. These BOM stations encompass the local catchments above Lake Wallace.

The 50th percentile median 19 year rainfall total corresponded with the period between 1987 and 2005. As will be presented below, for uncertainty analysis simulations, the 10th percentile lowest 19 year rainfall total was 1993 to 2011 and the 90th percentile highest 19 year rainfall total was 1981 to 1999.

### 3.3.2 Prediction Scenarios

There are two Water Management Strategies proposed with respect to extension of Angus Place Colliery and Springvale Mine. These consist:

- *Water Strategy WS1* - Angus Place discharging all mine water make at Angus Place via Angus Place LDP001 (up to 30.8ML/d) and Springvale discharging all mine water make at Springvale via Springvale LDP009 (up to 18.8ML/d)
- *Water Strategy WS2a* - Angus Place discharging to Springvale LDP009 (up to 30.0ML/d) via the existing SDWTS pipeline, to the extent available, with excess discharged through Angus Place LDP001 (up to 15.5ML/d)
- *Water Strategy WS2b* – Angus Place discharging to Springvale LDP009 (up to 43.4ML/d), with upgrade of the SDWTS pipeline to 50ML/d when combined mine water make exceeds 30ML/d, with discharge through Angus Place LDP001 at 2.0ML/d.

It is noted that mine water make presented in Figure 16 of RPS (2014a) and Figure 18 of RPS (2014b) were used to define discharge to Angus Place LDP001 and Springvale LDP009. This was a simplification of water management at Angus Place and Springvale given there is no account for the impact of underground storage due to detailed site water balances not being available to RPS. This, however, was a conservative assumption. e.g. discharge at Angus Place LDP001 of up to 15.5ML/d from mine water make (its peak in 2023), in WS2a, is compared to 6.5ML/d in Table 5.2 of the Surface Water Impact Assessments (RPS, 2014ab). A minimum discharge at 2ML/d from

Angus Place LDP001 was also assumed in WS2a and WS2b. Following upgrade of this model to incorporate detailed site water balances, modelled discharges at LDPs will be updated. Inputs presented in this assessment are conservative, however.

It is also noted that for the purpose of modelling the null case consists of both Angus Place Colliery and Springvale Mine ceasing discharge at the end of the calibration period on 30 June 2014.

### 3.3.3 Prediction Results

The model control files pertaining to the prediction simulations are:

- 021a_PRD-WS1_07a.gsm
- 021a_PRD-WS1_07a_NUL.gsm
- 021a_PRD-WS2a_03a.gsm
- 021a_PRD-WS2b_03a.gsm.

*Kangaroo Creek and Coxs River above Wangcol Creek/Blue Lagoon*

Prediction simulation of Kangaroo Creek at #011 for WS1, WS2a and WS2b is presented in Figure 3.9.

During prediction simulation of WS1 and WS2a, there is increased discharge (on a continuous basis); however, variability of flow is still evident but mine water discharge does dominate flows in Kangaroo Creek. During prediction simulation of WS2b, discharge at Angus Place LDP001 remains at 2ML/d. Under this condition, flow variability at point of discharge to Kangaroo Creek is consistent with historical and the River Flow Objective is satisfactorily met.

Flow statistics of predicted daily flow at this location are presented in Table 3.6, including for the prediction null case. As indicated above, the prediction null case comprises both Angus Place Colliery and Springvale Mine ceasing discharge on 30 June 2014.

**Table 3.6: Predicted Daily Flow Statistics (ML/d) at #011 (Kangaroo Creek, downstream of point of discharge from Angus Place LDP001)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 0.1 | 0.0 | 5.4 | 2.0 | 2.0 |
| 5% | 2.2 | 0.1 | 14.5 | 2.1 | 2.1 |
| 10% | 2.4 | 0.1 | 14.9 | 2.2 | 2.1 |
| 20% | 2.9 | 0.2 | 17.1 | 2.3 | 2.2 |
| 50% | 4.1 | 0.5 | 26.1 | 2.9 | 2.5 |
| 80% | 5.3 | 1.2 | 28.8 | 12.1 | 0.8 |
| 90% | 6.7 | 2.9 | 29.4 | 15.1 | 4.9 |
| 95% | 9.6 | 6.4 | 30.9 | 15.7 | 8.4 |
| Maximum | 853.8 | 458.4 | 473.5 | 460.4 | 460.4 |

Summary statistics for predicted daily salinity in Kangaroo Creek (#011) is presented in Table 3.7.

### Table 3.7: Predicted Daily Salinity (mg/L) at #011 (Kangaroo Creek, downstream of point of discharge from Angus Place LDP001)

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 50 | 50 | 75 | 55 | 55 |
| 5% | 277 | 50 | 614 | 266 | 232 |
| 10% | 429 | 50 | 703 | 388 | 356 |
| 20% | 573 | 50 | 760 | 548 | 524 |
| 50% | 704 | 50 | 789 | 698 | 664 |
| 80% | 762 | 51 | 798 | 776 | 733 |
| 90% | 780 | 52 | 800 | 790 | 759 |
| 95% | 790 | 54 | 802 | 797 | 775 |
| Maximum | 804 | 68 | 804 | 804 | 804 |

From the above, predicted salinity in Kangaroo Creek is 804mg/L at maximum at #011. This is consistent with assumed salinity of mine water make at Angus Place. Salinity ranges between 100mg/L and 804mg/L at #011, with median being 789mg/L during WS1.

Review of predicted salinity against historical observation indicates the proposed condition is consistent with historical impact of mine water discharge. As noted above, assumed water quality of Kangaroo Creek, upstream of point of discharge is 50mg/L.

Prediction simulation of Coxs River above Wangcol Creek at #056 is presented in Figure 3.9.

A statistical summary of predicted daily flows is presented in Table 3.8.

### Table 3.8: Predicted Daily Flow Statistics (ML/d) at #056 (Coxs River above Wangcol Creek/Blue Lagoon)

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 0.3 | 0.0 | 6.9 | 2.0 | 2.0 |
| 5% | 2.5 | 0.2 | 15.3 | 2.4 | 2.2 |
| 10% | 3.0 | 0.4 | 16.2 | 2.6 | 2.4 |
| 20% | 3.8 | 0.6 | 19.8 | 3.0 | 2.6 |
| 50% | 5.1 | 1.4 | 27.4 | 5.1 | 3.4 |
| 80% | 8.0 | 4.4 | 30.1 | 15.1 | 6.4 |
| 90% | 14.4 | 11.4 | 34.8 | 16.9 | 13.4 |
| 95% | 26.6 | 22.9 | 44.8 | 26.9 | 24.9 |
| Maximum | 3076.6 | 1613.7 | 1628.8 | 1615.7 | 1615.7 |

During prediction simulation, there is increased contribution from Kangaroo Creek to this location in WS1 and WS2a. During prediction simulation of WS2b, the impact of mine water discharge to Kangaroo Creek on flow variability at this location is small.

A statistical summary of predicted daily salinity is presented in Table 3.9.

**Table 3.9: Predicted Daily Salinity (mg/L) at #056 (Coxs River above Wangcol Creek/Blue Lagoon)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 50 | 50 | 63 | 57 | 57 |
| 5% | 136 | 50 | 402 | 127 | 118 |
| 10% | 211 | 50 | 525 | 183 | 168 |
| 20% | 339 | 50 | 666 | 317 | 289 |
| 50% | 556 | 50 | 761 | 538 | 498 |
| 80% | 684 | 55 | 786 | 738 | 626 |
| 90% | 728 | 60 | 792 | 767 | 683 |
| 95% | 759 | 64 | 798 | 780 | 732 |
| Maximum | 804 | 89 | 804 | 804 | 804 |

Predicted salinity in the Coxs River ranges between 100mg/L and 804mg/L, with median being 761mg/L during WS1.

Review of predicted salinity against historical observation indicates proposed condition is consistent with historical impact of discharge at Angus Place. As indicated above, salinity range of natural condition is between 50mg/L (assumed minimum) and 89mg/L, with median of 50mg/L.

*Sawyers Swamp Creek*

Prediction simulation in Sawyers Swamp Creek at #014 is presented in Figure 3.10 for each water management strategy. During the prediction simulation, under scenarios WS1, WS2a and WS2b, there is discharge to Springvale LDP009. Summary statistics of predicted daily flow at #014 is presented in Table 3.10.

**Table 3.10: Predicted Daily Flow Statistics (ML/d) at #014 (Sawyers Swamp Creek downstream of point of discharge of Springvale LDP009)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 0.0 | 0.0 | 0.0 | 3.0 | 3.0 |
| 5% | 0.0 | 0.0 | 0.0 | 23.3 | 23.3 |
| 10% | 0.0 | 0.0 | 0.1 | 24.4 | 24.4 |
| 20% | 0.1 | 0.1 | 0.1 | 25.1 | 25.1 |
| 50% | 0.2 | 0.2 | 14.4 | 28.0 | 28.0 |
| 80% | 1.0 | 0.4 | 17.9 | 30.1 | 38.1 |
| 90% | 4.1 | 1.1 | 18.3 | 30.3 | 42.7 |
| 95% | 16.1 | 2.3 | 18.7 | 30.8 | 43.2 |
| Maximum | 314.7 | 169.9 | 185.7 | 198.9 | 198.9 |

Summary statistics of predicted daily salinity is presented in Table 3.11.

**Table 3.11: Predicted Daily Salinity Statistics (mg/L) at #014 (Sawyers Swamp Creek downstream of point of discharge of Springvale LDP009)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 50 | 50 | 50 | 160 | 160 |
| 5% | 50 | 50 | 50 | 743 | 747 |
| 10% | 50 | 50 | 50 | 774 | 775 |
| 20% | 50 | 50 | 50 | 792 | 792 |
| 50% | 50 | 50 | 761 | 799 | 800 |
| 80% | 50 | 50 | 798 | 802 | 802 |
| 90% | 634 | 50 | 801 | 803 | 803 |
| 95% | 790 | 50 | 802 | 803 | 803 |
| Maximum | 819 | 50 | 804 | 804 | 804 |

Prediction simulation at Sawyers Swamp Creek at confluence with Coxs River (#166) is presented in Figure 3.10. Summary statistics of predicted daily flows is presented in Table 3.12.

**Table 3.12: Predicted Daily Flow Statistics (ML/d) at #166 (Sawyers Swamp Creek above Coxs River)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 0.0 | 0.0 | 0.0 | 3.0 | 3.0 |
| 5% | 0.0 | 0.0 | 0.1 | 23.4 | 23.4 |
| 10% | 0.0 | 0.1 | 0.1 | 24.4 | 24.4 |
| 20% | 0.1 | 0.1 | 0.2 | 25.2 | 25.2 |
| 50% | 0.2 | 0.2 | 14.5 | 28.2 | 28.2 |
| 80% | 1.2 | 0.6 | 18.0 | 30.2 | 38.3 |
| 90% | 5.2 | 1.5 | 18.4 | 30.4 | 42.8 |
| 95% | 16.5 | 3.3 | 18.9 | 31.5 | 43.3 |
| Maximum | 422.4 | 223.2 | 239.0 | 252.2 | 252.2 |

Summary statistics of predicted daily salinity is presented in Table 3.13.

**Table 3.13: Predicted Daily Salinity Statistics (mg/L) at #166 (Sawyers Swamp Creek above Coxs River)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 50 | 50 | 50 | 154 | 154 |
| 5% | 50 | 50 | 50 | 724 | 729 |
| 10% | 50 | 50 | 50 | 766 | 767 |
| 20% | 50 | 50 | 51 | 788 | 789 |
| 50% | 53 | 51 | 751 | 799 | 799 |
| 80% | 90 | 77 | 798 | 802 | 802 |
| 90% | 605 | 90 | 800 | 803 | 803 |
| 95% | 788 | 103 | 802 | 803 | 803 |
| Maximum | 818 | 379 | 804 | 804 | 804 |

From the above, predicted salinity at #014 and #166 is 804mg/L at maximum, consistent with the assumed salinity of mine water make at Springvale and Angus Place. The catchment upstream of point of discharge, Springvale LDP009, is relatively small; therefore the predicted median salinity is similar to the assumed salinity of mine water make. As indicated, despite the relatively small contributing catchment, there is variability in concentration at #166, albeit of limited range. Predicted median salinity at #166 of 751mg/L is within the range of modelled salinity at monitoring station WCS_LDP003_DOWNSTREAM during the calibration period.

*Lake Wallace*

Prediction simulation of Coxs River immediately above Lake at #047 is presented in Figure 3.11. Predicted daily flow and salinity at this location is summarised in Table 3.14 and 3.15. It is noted that WS1, WS2a and WS2b have identical daily flows at this location.

**Table 3.14: Predicted Daily Flow Statistics (ML/d) at #047 (Coxs River upstream of Lake Wallace)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 2.0 | 4.4 | 13.3 | 13.3 | 13.3 |
| 5% | 3.4 | 6.2 | 33.0 | 33.0 | 33.0 |
| 10% | 4.5 | 6.7 | 35.1 | 35.1 | 35.1 |
| 20% | 6.6 | 7.5 | 36.8 | 36.8 | 36.8 |
| 50% | 41.8 | 10.3 | 47.9 | 47.9 | 47.9 |
| 80% | 105.4 | 30.4 | 60.9 | 60.9 | 60.9 |
| 90% | 112.2 | 51.5 | 81.9 | 81.9 | 81.9 |
| 95% | 131.2 | 95.3 | 126.1 | 126.1 | 126.1 |
| Maximum | 10694.0 | 5576.5 | 5607.4 | 5607.5 | 5607.5 |

**Table 3.15: Predicted Daily Salinity Statistics (mg/L) at #047 (Coxs River upstream of Lake Wallace)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 79 | 107 | 111 | 111 | 111 |
| 5% | 156 | 191 | 358 | 358 | 358 |
| 10% | 195 | 254 | 484 | 484 | 484 |
| 20% | 284 | 397 | 639 | 639 | 639 |
| 50% | 402 | 599 | 755 | 755 | 755 |
| 80% | 514 | 681 | 780 | 780 | 780 |
| 90% | 599 | 713 | 787 | 787 | 787 |
| 95% | 665 | 731 | 791 | 791 | 791 |
| Maximum | 874 | 771 | 797 | 797 | 797 |

From the above, the predicted salinity at this location is comparable to historical salinity although median salinity at 755mg/L is higher than the median salinity of 599mg/L in the null case.

The modelled salinity in Lake Wallace is presented in Figure 3.11. When operational, Wallerawang Power Station, discharged some Cooling Tower blowdown water to the Coxs River above Lake Wallace (Energy Australia, LDP001 and LDP021), however, the majority was discharged below Lake Wallace (Energy Australia, LDP004). ‘Bleed-off’ from Sawyers Swamp Creek Ash Dam (SSCAD) is discharged to Lake Wallace (Energy Australia, LDP003) and whilst included in the water quality model, there was insufficient data of wet ash deposition (prior to 2002) and historical water level response in the dam to improve this component. During the prediction simulation, there was no ‘bleed-off’ from the SSCAD since evaporation from the surface of SSCAD exceeds direct rainfall on the dam surface and runon from the local catchment. As such, the cumulative impact assessment is conservative because there is no contribution from SSCAD via Energy Australia LDP003.

Summary statistics of prediction simulations are presented in Table 3.16 with respect to quality.

**Table 3.16: Predicted Daily Salinity Statistics (mg/L) at #074 (Lake Wallace)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 100 | 91 | 79 | 79 | 79 |
| 5% | 164 | 207 | 369 | 369 | 369 |
| 10% | 197 | 235 | 436 | 436 | 436 |
| 20% | 226 | 265 | 499 | 499 | 499 |
| 50% | 309 | 321 | 604 | 604 | 604 |
| 80% | 408 | 393 | 673 | 673 | 673 |
| 90% | 470 | 433 | 704 | 704 | 704 |
| 95% | 516 | 470 | 720 | 720 | 720 |
| Maximum | 725 | 552 | 747 | 747 | 747 |

From the above, the predicted salinity in Lake Wallace is up to 747mg/L under the proposed water management strategy. Comparison of predicted salinity against historical observation indicates predicted salinity is within the range experienced in the past and variability in salinity is also comparable. Median salinity, however, is higher at 604mg/L under WS1, WS2a and WS2b conditions compared to the calibration period at 309mg/L and prediction null case of 321mg/L.

*Lake Lyell and above Lake Lyell*

There are two monitoring locations between Lake Wallace and Lake Lyell that are of interest. The first station, #154, corresponds with NSW Office of Water Flow Gauge No. 212058. The second station, #035, corresponds with Energy Australia water quality monitoring location, COX5.

Prediction simulations (flow at #154 and salinity at #035) are presented in Figure 3.12 and summary statistics are presented in Table 3.17 (flow at #154) and Table 3.18 (salinity at #035).

**Table 3.17: Predicted Daily Flow Statistics (ML/d) at #154 (Coxs River above Lake Lyell, at location of NSW Office of Water Gauge 212058)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 2.6 | 0.1 | 6.7 | 6.7 | 6.7 |
| 5% | 10.0 | 2.2 | 29.9 | 29.9 | 29.9 |
| 10% | 10.6 | 3.3 | 32.4 | 32.4 | 32.4 |
| 20% | 11.9 | 5.2 | 36.6 | 36.6 | 36.6 |
| 50% | 37.3 | 12.7 | 48.7 | 48.7 | 48.7 |
| 80% | 90.2 | 44.5 | 75.9 | 75.9 | 75.9 |
| 90% | 116.5 | 84.8 | 118.0 | 118.0 | 118.0 |
| 95% | 156.1 | 161.2 | 192.1 | 191.9 | 191.9 |
| Maximum | 16029.0 | 10223.0 | 10254.0 | 10254.0 | 10254.0 |

From predicted flow chart in Figure 3.12 and tabulated statistics in Table 3.17, WS1 (WS2a and WS2b yield identical results) the proposed water management strategies lead to discernible minimum flow in the Coxs River, however, the variability in magnitude of flow is significant.

**Table 3.18: Predicted Daily Salinity Statistics (mg/L) at #035 (Coxs River above Lake Lyell, at location of Energy Australia monitoring location, COX5)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 63 | 50 | 67 | 67 | 67 |
| 5% | 164 | 100 | 263 | 263 | 263 |
| 10% | 229 | 125 | 337 | 337 | 337 |
| 20% | 337 | 159 | 418 | 418 | 418 |
| 50% | 472 | 231 | 552 | 552 | 552 |
| 80% | 658 | 315 | 643 | 643 | 643 |
| 90% | 741 | 366 | 681 | 681 | 681 |
| 95% | 786 | 406 | 705 | 705 | 705 |
| Maximum | 1893 | 540 | 740 | 740 | 740 |

From predicted salinity chart in Figure 3.12 at #035, expected maximum salinity and variability in salinity is consistent with historical observation, however, the median salinity in prediction simulation at 552mg/L is higher than null case at 231mg/L.

The predicted volume (ML) and salinity (mg/L) in Lake Lyell (#174) is presented in Figure 3.12. Summary statistics of predicted salinity in Lake Lyell is presented in Table 3.19.

**Table 3.19: Predicted Daily Salinity Statistics (mg/L) at #174 (Lake Lyell).**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 110 | 127 | 145 | 145 | 145 |
| 5% | 165 | 152 | 246 | 246 | 246 |
| 10% | 185 | 170 | 271 | 271 | 271 |
| 20% | 235 | 186 | 303 | 303 | 303 |
| 50% | 355 | 223 | 422 | 422 | 422 |
| 80% | 437 | 251 | 500 | 500 | 500 |
| 90% | 499 | 262 | 522 | 522 | 522 |
| 95% | 559 | 270 | 539 | 539 | 539 |
| Maximum | 830 | 462 | 566 | 566 | 566 |

From the above, the prediction simulation indicates salinity in Lake Lyell is higher due to proposed water management strategy at Angus Place and Springvale, however, concentration is comparable to historical range and variability.

The prediction simulation indicates a positive difference in stored volume in Lake Lyell (#174) due to the proposed water management strategy.

*Thompsons Creek Reservoir*

The predicted volume (ML) and salinity (mg/L) in Thompsons Creek Reservoir is presented in Figure 3.13. Summary statistics of predicted salinity is presented in Table 3.20.

**Table 3.20: Predicted Daily Salinity Statistics (mg/L) at #272 (Thompsons Creek Reservoir)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 110 | 237 | 314 | 314 | 314 |
| 5% | 110 | 243 | 318 | 318 | 318 |
| 10% | 110 | 245 | 343 | 343 | 343 |
| 20% | 110 | 254 | 365 | 365 | 365 |
| 50% | 274 | 276 | 477 | 477 | 477 |
| 80% | 423 | 307 | 536 | 536 | 536 |
| 90% | 491 | 313 | 575 | 575 | 575 |
| 95% | 561 | 344 | 588 | 588 | 588 |
| Maximum | 914 | 471 | 613 | 613 | 613 |

The predicted salinity in Thompsons Creek Reservoir (#272) is higher due to the proposed water management strategy but is only marginally higher than the modelled calibration values.

Similar to the predicted impact in Lake Lyell, there is a minor positive difference to predicted storage volume (ML) in Thompsons Creek Reservoir due to the proposal.

*Lake Burragorang and above Lake Burragorang*

Figure 3.14 presents the modelled flow and predicted salinity at #225 which lies on the Coxs River immediately above Lake Burragorang. Table 3.21 presents summary statistics of flow and Table 3.22 presents summary statistics of salinity at this model node.

From Figure 3.14, the proposed water management strategy has minimal impact on predicted flow. The difference in predicted salinity is more significant.

**Table 3.21: Predicted Daily Flow Statistics (ML/d) at #225 (Coxs River immediately above Lake Burragorang)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 9.0 | 2.7 | 9.0 | 9.0 | 9.0 |
| 5% | 16.5 | 13.9 | 29.0 | 29.0 | 29.0 |
| 10% | 21.1 | 19.6 | 33.2 | 33.2 | 33.2 |
| 20% | 30.0 | 29.4 | 41.3 | 41.3 | 41.3 |
| 50% | 72.5 | 75.7 | 86.9 | 86.9 | 86.9 |
| 80% | 289.9 | 312.1 | 335.0 | 335.0 | 335.0 |
| 90% | 704.9 | 735.1 | 788.6 | 788.6 | 788.6 |
| 95% | 1603.0 | 1701.7 | 1830.4 | 1830.4 | 1830.4 |
| Maximum | 93964.0 | 65977.0 | 68789.0 | 68789.0 | 68789.0 |

**Table 3.22: Predicted Daily Salinity Statistics (mg/L) at #225 (Coxs River immediately above Lake Burragorang)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 51 | 50 | 52 | 52 | 52 |
| 5% | 63 | 63 | 80 | 80 | 80 |
| 10% | 70 | 67 | 90 | 90 | 90 |
| 20% | 80 | 74 | 106 | 106 | 106 |
| 50% | 101 | 90 | 153 | 153 | 153 |
| 80% | 155 | 106 | 252 | 252 | 252 |
| 90% | 209 | 118 | 315 | 315 | 315 |
| 95% | 269 | 129 | 358 | 358 | 358 |
| Maximum | 576 | 217 | 503 | 503 | 503 |

From Table 3.22, the median salinity under the proposed water management strategy is 153mg/L compared to the null case of median of 90mg/L. The predicted median salinity is higher than the calibration period and, in general, the predicted range is at the upper end of historical observation. Predicted salinity at this location, however, is below the default ANZECC 95% trigger value of 234mg/L (350µS/cm).

The modelled volume (ML) and salinity (mg/L) in Lake Burragorang is presented in Figure 3.14. Table 3.23 presents summary statistics of modelled daily salinity.

**Table 3.23: Predicted Daily Salinity Statistics (mg/L) at #280 (Lake Burragorang)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 75 | 73 | 74 | 74 | 74 |
| 5% | 77 | 75 | 77 | 77 | 77 |
| 10% | 79 | 77 | 78 | 78 | 78 |
| 20% | 80 | 81 | 85 | 85 | 85 |
| 50% | 83 | 85 | 97 | 97 | 97 |
| 80% | 86 | 87 | 104 | 104 | 104 |
| 90% | 92 | 94 | 108 | 108 | 108 |
| 95% | 94 | 95 | 109 | 109 | 109 |
| Maximum | 97 | 97 | 112 | 112 | 112 |

From the above, the proposed discharge by the extensions at Angus Place and Springvale to the Coxs River lead to a marginal increase in salinity in Lake Burragorang compared to the null case. In the null case, median salinity is 85mg/L and is 97mg/L under WS1, WS2a and WS2b. There is a small positive impact to volume in Lake Burragorang due to the proposal.

## 3.4 Uncertainty Analysis

There are two uncertainty analysis conditions presented:

- Low Rainfall Condition
- High Rainfall Condition

### 3.4.1 Low Rainfall Condition

### Model Setup

The uncertainty analysis simulation was based on the prediction simulation with rainfall dataset updated. All other parameters in the model were left unchanged. As presented in Section 3.3.1, historical annual rainfall totals at BOM Stations 63224, 63071 and 63132 were reviewed and the 19 year total rainfall depth derived. For the low rainfall condition, the lowest 10th percentile rainfall total coincided with the period 1993 to 2011.

The calibrated AWBM parameters and run-off salinity concentrations presented in Table 3.3 were retained for the uncertainty analysis simulation.

### Uncertainty Results

The model control files pertaining to the uncertainty analysis simulation were:

- 021a_UNC-LowRf_WS1_01a.gsm
- 021a_UNC-LowRf_WS1_01a_NUL.gsm
- 021a_UNC-LowRf_WS2a_01a.gsm
- 021a_UNC-LowRf_WS2b_01a.gsm

Results from uncertainty analysis are presented at selected locations.

*Kangaroo Creek*

Figure 3.15 presents modelled flow and salinity in Kangaroo Creek at #011, downstream of point of discharge from Angus Place LDP001. Table 3.24 presents the summary statistics of daily flows at this location. Table 3.25 presents the summary statistics of daily salinity.

**Table 3.24: Uncertainty Simulation (Low Rainfall) Daily Flow Statistics (ML/d) at #011 (Kangaroo Creek downstream of Angus Place LDP001)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 0.1 | 0.0 | 5.6 | 2.0 | 2.0 |
| 5% | 2.2 | 0.1 | 14.2 | 2.1 | 2.1 |
| 10% | 2.4 | 0.1 | 14.7 | 2.1 | 2.1 |
| 20% | 2.9 | 0.2 | 16.0 | 2.2 | 2.2 |
| 50% | 4.1 | 0.4 | 26.4 | 2.7 | 2.4 |
| 80% | 5.3 | 0.9 | 28.7 | 12.3 | 2.9 |
| 90% | 6.7 | 2.1 | 29.4 | 14.9 | 4.1 |
| 95% | 9.6 | 4.6 | 30.3 | 15.7 | 6.6 |
| Maximum | 853.8 | 206.6 | 221.6 | 208.6 | 208.6 |

**Table 3.25: Uncertainty Simulation (Low Rainfall) Daily Salinity Statistics (mg/L) at #011 (Kangaroo Creek downstream of Angus Place LDP001)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 50 | 50 | 102 | 59 | 59 |
| 5% | 277 | 50 | 667 | 333 | 280 |
| 10% | 429 | 50 | 738 | 478 | 422 |
| 20% | 573 | 50 | 771 | 600 | 567 |
| 50% | 704 | 50 | 791 | 711 | 680 |
| 80% | 762 | 51 | 798 | 778 | 744 |
| 90% | 780 | 52 | 801 | 790 | 768 |
| 95% | 790 | 54 | 802 | 795 | 782 |
| Maximum | 804 | 74 | 804 | 804 | 804 |

From Figure 3.15, simulated salinity during WS1 is higher than the equivalent peak under median rainfall conditions, however, is not significantly outside the range of historical observation. The median simulated salinity is 791mg/L. This is compared to 789mg/L during the prediction, as presented in Table 3.7. The maximum simulated salinity is 804mg/L compared to prediction simulation of 804mg/L.

*Sawyers Swamp Creek*

Figure 3.16 presents the modelled flow and simulated salinity at #14, immediately downstream of point of discharge of Springvale LDP009 under each water management strategy.

Table 3.26 presents summary statistics with respect to daily flow. Table 3.27 presents summary statistics with respect to simulated water quality.

**Table 3.26: Uncertainty Simulation (Low Rainfall) Daily Flow Statistics (ML/d) at #014 (Sawyers Swamp Creek downstream of Springvale LDP009)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 0.0 | 0.0 | 0.0 | 3.1 | 3.1 |
| 5% | 0.0 | 0.0 | 0.0 | 23.8 | 23.8 |
| 10% | 0.0 | 0.0 | 0.1 | 24.4 | 24.4 |
| 20% | 0.1 | 0.1 | 0.1 | 25.2 | 25.2 |
| 50% | 0.2 | 0.1 | 14.2 | 27.5 | 27.5 |
| 80% | 1.0 | 0.3 | 17.8 | 30.1 | 38.1 |
| 90% | 4.1 | 0.8 | 18.3 | 30.3 | 42.6 |
| 95% | 16.1 | 1.7 | 18.7 | 30.7 | 43.0 |
| Maximum | 314.7 | 76.5 | 93.3 | 106.3 | 106.3 |

**Table 3.27: Uncertainty Simulation (Low Rainfall) Daily Salinity Statistics (mg/L) at #014 (Sawyers Swamp Creek downstream of Springvale LDP009)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 50 | 50 | 50 | 261 | 261 |
| 5% | 50 | 50 | 50 | 759 | 761 |
| 10% | 50 | 50 | 50 | 782 | 783 |
| 20% | 50 | 50 | 50 | 794 | 795 |
| 50% | 50 | 50 | 782 | 800 | 800 |
| 80% | 50 | 50 | 799 | 802 | 802 |
| 90% | 634 | 50 | 801 | 803 | 803 |
| 95% | 790 | 50 | 802 | 803 | 803 |
| Maximum | 819 | 50 | 804 | 804 | 804 |

From Figure 3.16, Table 3.26 and Table 3.27 there is no significant difference compared to predicted flow or predicted concentration since catchment area contributing to #014 is small. Median salinity in uncertainty analysis simulation at #014 is 782mg/L compared to 761mg/L during prediction simulation.

*Lake Lyell and Above Lake Lyell*

Figure 3.17 presents the simulated concentration at #035, which lies on the Coxs River upstream of Lake Lyell. Model node #035 corresponds to location of Energy Australia monitoring location COX5.

Table 3.28 presents a statistical summary of simulated salinity at this location.

**Table 3.28: Uncertainty Simulation (Low Rainfall) Daily Salinity Statistics (mg/L) at #035 (Coxs River above Lake Lyell)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 63 | 50 | 105 | 105 | 105 |
| 5% | 164 | 116 | 325 | 325 | 325 |
| 10% | 229 | 135 | 381 | 381 | 381 |
| 20% | 337 | 163 | 454 | 454 | 454 |
| 50% | 472 | 231 | 566 | 566 | 566 |
| 80% | 658 | 389 | 642 | 642 | 642 |
| 90% | 741 | 485 | 677 | 677 | 677 |
| 95% | 786 | 519 | 710 | 710 | 710 |
| Maximum | 1893 | 622 | 762 | 762 | 762 |

From Figure 3.17, simulated salinity is marginally higher than the prediction simulation. From Table 3.28, median salinity is 566mg/L. This is compared to a median salinity of 552mg/L, as presented in Table 3.18.

The simulated volume (ML) and salinity (mg/L) in Lake Lyell is presented in Figure 3.17, with a statistical summary of daily salinity presented in Table 3.29.

**Table 3.29: Uncertainty Simulation (Low Rainfall) Daily Salinity Statistics (mg/L) at #174 (Lake Lyell)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 110 | 175 | 247 | 247 | 247 |
| 5% | 165 | 185 | 317 | 317 | 317 |
| 10% | 185 | 190 | 345 | 345 | 345 |
| 20% | 235 | 202 | 375 | 375 | 375 |
| 50% | 355 | 225 | 457 | 457 | 457 |
| 80% | 437 | 374 | 529 | 529 | 529 |
| 90% | 499 | 407 | 554 | 554 | 554 |
| 95% | 559 | 431 | 565 | 565 | 565 |
| Maximum | 830 | 477 | 616 | 616 | 616 |

From Figure 3.17, simulated peak salinity of 616mg/L is higher than the peak of 566mg/L in the prediction simulation. Median simulated salinity in Table 3.29 is also marginally higher than median prediction simulation presented in Table 3.19.

From Figure 3.17, simulated periods of low storage volume correspond with higher salinity, as would be expected.

*Lake Burragorang and Above Lake Burragorang*

Simulated daily flow and daily salinity upstream of Lake Burragorang at #225 is presented in Figure 3.18.

Table 3.30 presents summary statistics with respect to daily flow and Table 3.31 presents summary statistics with respect to salinity.

### Table 3.30: Uncertainty Simulation (Low Rainfall) Daily Flow Statistics (ML/d) at #225 (Coxs River immediately upstream of Lake Burragorang)

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 9.0 | 2.9 | 9.0 | 9.0 | 9.0 |
| 5% | 16.5 | 15.0 | 26.1 | 26.1 | 26.1 |
| 10% | 21.1 | 20.2 | 31.6 | 31.6 | 31.6 |
| 20% | 30.0 | 28.5 | 40.5 | 40.5 | 40.5 |
| 50% | 72.5 | 66.2 | 78.7 | 78.7 | 78.7 |
| 80% | 289.9 | 229.0 | 251.6 | 251.6 | 251.6 |
| 90% | 704.9 | 591.9 | 642.4 | 642.4 | 642.4 |
| 95% | 1603 | 1,345 | 1,416 | 1,416 | 1,416 |
| Maximum | 93964 | 53,590 | 53,627 | 53,627 | 53,627 |

### Table 3.31: Uncertainty Simulation (Low Rainfall) Daily Salinity Statistics (mg/L) at #225 (Coxs River immediately above Lake Burragorang)

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 51 | 51 | 52 | 52 | 52 |
| 5% | 63 | 66 | 95 | 95 | 95 |
| 10% | 70 | 71 | 104 | 104 | 104 |
| 20% | 80 | 77 | 120 | 120 | 120 |
| 50% | 101 | 93 | 170 | 170 | 170 |
| 80% | 155 | 112 | 262 | 262 | 262 |
| 90% | 209 | 140 | 331 | 331 | 331 |
| 95% | 269 | 183 | 378 | 378 | 378 |
| Maximum | 576 | 363 | 513 | 513 | 513 |

From Table 3.31, median salinity at #225 is 170mg/L and is higher compared to equivalent median in the prediction simulation.  As indicated in Table 3.31, the median salinity in the simulated null case is also slightly higher compared to Table 3.22.  From Figure 3.18, simulated salinity is above the range of historical observation, as presented in Figure 3.8.

Figure 3.18 presents the simulated volume and salinity in Lake Burragorang and Table 3.32 presents summary statistics of daily salinity.

From Figure 3.18, the simulated salinity ranges between 79mg/L and 105mg/L and is 79mg/L and 88mg/L at equivalent times in the null case.

**Table 3.32: Predicted Daily Salinity Statistics (mg/L) at #280 (Lake Burragorang)**

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 75 | 79 | 79 | 79 | 79 |
| 5% | 77 | 79 | 84 | 84 | 84 |
| 10% | 79 | 80 | 88 | 88 | 88 |
| 20% | 80 | 81 | 91 | 91 | 91 |
| 50% | 83 | 85 | 95 | 95 | 95 |
| 80% | 86 | 87 | 100 | 100 | 100 |
| 90% | 92 | 89 | 102 | 102 | 102 |
| 95% | 94 | 90 | 103 | 103 | 103 |
| Maximum | 97 | 92 | 105 | 105 | 105 |

From Table 3.32, median salinity in the simulation is 85mg/L and is 95mg/L in the null case. The median salinity in this uncertainty analysis simulation in Table 3.32 is consistent with the median salinity in the prediction simulation and is also the case with respect to the null case.

The results of uncertainty analysis imply simulated salinity in Lake Burragorang is not particularly sensitive to assumed rainfall condition.

### 3.4.2 High Rainfall Condition

#### Model Setup

The uncertainty analysis simulation was based on the prediction simulation, with rainfall dataset updated. As indicated above for the low rainfall condition simulation, the 19 year rainfall totals from historical annual rainfall record of stations 63224, 63071 and 63132 were reviewed and the 90th percentile total determined. This corresponded with the period 1981 to 1999. The daily record from 1 July 1981 to 31 December 1999 was then transcribed into the model.

#### Uncertainty Results

The model control file pertaining to uncertainty analysis simulations are:

- 021a_UNC-HighRf_WS1_01a.gsm
- 021a_UNC-HighRf_WS1_01a_NUL.gsm
- 021a_UNC-HighRf_WS2a_01a.gsm
- 021a_UNC-HighRf_WS2b_01a.gsm

It is noted that the locations of presentation of simulation results in this uncertainty analysis simulation correspond with the locations for the low rainfall conditions such that they can compared.

*Kangaroo Creek*

Figure 3.19 presents the simulated daily flow and salinity at #011 which lies on Kangaroo Creek downstream of point of discharge from Angus Place LDP001. Table 3.33 presents summary statistics with respect to flow and Table 3.34 presents summary statistics with respect to daily salinity at this location.

### Table 3.33: Uncertainty Simulation (High Rainfall) Daily Flow Statistics (ML/d) at #011 (Kangaroo Creek downstream of Angus Place LDP001)

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 0.1 | 0.0 | 6.0 | 2.0 | 2.0 |
| 5% | 2.2 | 0.1 | 14.2 | 2.1 | 2.1 |
| 10% | 2.4 | 0.1 | 14.8 | 2.1 | 2.1 |
| 20% | 2.9 | 0.2 | 16.1 | 2.2 | 2.2 |
| 50% | 4.1 | 0.5 | 26.5 | 2.7 | 2.5 |
| 80% | 5.3 | 1.5 | 28.9 | 12.8 | 3.5 |
| 90% | 6.7 | 3.6 | 29.5 | 15.8 | 5.6 |
| 95% | 9.6 | 8.0 | 32.3 | 17.5 | 10.0 |
| Maximum | 853.8 | 851.2 | 866.2 | 853.2 | 853.2 |

### Table 3.34: Uncertainty Simulation (High Rainfall) Daily Salinity Statistics (mg/L) at #011 (Kangaroo Creek downstream of Angus Place LDP001)

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 50 | 50 | 65 | 53 | 53 |
| 5% | 277 | 50 | 607 | 286 | 202 |
| 10% | 429 | 50 | 698 | 444 | 318 |
| 20% | 573 | 50 | 754 | 584 | 483 |
| 50% | 704 | 50 | 787 | 697 | 652 |
| 80% | 762 | 51 | 797 | 761 | 728 |
| 90% | 780 | 52 | 800 | 778 | 758 |
| 95% | 790 | 53 | 801 | 787 | 776 |
| Maximum | 804 | 68 | 804 | 804 | 804 |

From Table 3.34, simulated median salinity is 787mg/L compared to median salinity in null case of 50mg/L. As presented in the prediction simulation in Figure 3.9, discharge at Angus Place does dominate daily flows and daily salinity in Kangaroo Creek since contributing catchment of Kangaroo Creek is only of moderate size.

*Sawyers Swamp Creek*

Figure 3.20 presents the results of uncertainty analysis simulation at #014, which lies on Sawyers Swamp Creek, immediately downstream of point of discharge of Springvale LDP009. Table 3.35 presents a statistical summary of daily flows at this model node and Table 3.36 presents a statistical summary of daily salinity at this location.

### Table 3.35: Uncertainty Simulation (High Rainfall) Daily Flow Statistics (ML/d) at #014 (Sawyers Swamp Creek downstream of Springvale LDP009)

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 0.0 | 0.0 | 0.0 | 3.2 | 3.2 |
| 5% | 0.0 | 0.0 | 0.0 | 23.6 | 23.6 |
| 10% | 0.0 | 0.0 | 0.1 | 24.3 | 24.3 |
| 20% | 0.1 | 0.1 | 0.1 | 25.1 | 25.1 |
| 50% | 0.2 | 0.2 | 14.2 | 27.6 | 27.6 |
| 80% | 1.0 | 0.6 | 18.1 | 30.3 | 38.3 |
| 90% | 4.1 | 1.3 | 18.7 | 30.8 | 43.0 |
| 95% | 16.1 | 3.0 | 19.9 | 32.0 | 43.5 |
| Maximum | 314.7 | 314.8 | 331.6 | 344.5 | 344.5 |

### Table 3.36: Uncertainty Simulation (High Rainfall) Daily Salinity Statistics (mg/L) at #014 (Sawyers Swamp Creek downstream of Springvale LDP009)

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 50 | 50 | 50 | 115 | 115 |
| 5% | 50 | 50 | 50 | 732 | 740 |
| 10% | 50 | 50 | 50 | 768 | 772 |
| 20% | 50 | 50 | 50 | 789 | 791 |
| 50% | 50 | 50 | 753 | 799 | 799 |
| 80% | 50 | 50 | 796 | 802 | 802 |
| 90% | 634 | 50 | 799 | 803 | 803 |
| 95% | 790 | 50 | 801 | 803 | 803 |
| Maximum | 819 | 50 | 804 | 804 | 804 |

From Figure 3.20, discharge from Springvale LDP009 does dominate flows in Sawyers Swamp Creek with respect to each water management strategy. Simulated median salinity at #014 is 753mg/L and is 50mg/L in the null case. Assumed salinity of mine water discharge is 804mg/L for comparison. As indicated in Section 3.3.3, due to the small size of Sawyers Swamp Creek catchment upstream of this location, median simulated salinity is close to assumed salinity of mine water make.

*Lake Lyell and Above Lake Lyell*

Figure 3.21 presents simulated salinity at #035. #035 lies on the Coxs River above Lake Lyell and corresponds with Energy Australia monitoring location, COX5. Table 3.37 presents a statistical summary of daily salinity at this location.

**Table 3.37: Uncertainty Simulation (High Rainfall) Daily Salinity Statistics (mg/L) at #035 (Coxs River above Lake Lyell)**

| **Percentile** | **CAL** | **NUL** | **WS1** | **WS2a** | **WS2b** |
|---|---|---|---|---|---|
| Minimum | 63 | 50 | 69 | 69 | 69 |
| 5% | 164 | 88 | 231 | 231 | 231 |
| 10% | 229 | 98 | 303 | 303 | 303 |
| 20% | 337 | 120 | 395 | 395 | 395 |
| 50% | 472 | 216 | 533 | 533 | 533 |
| 80% | 658 | 347 | 622 | 622 | 622 |
| 90% | 741 | 412 | 660 | 660 | 660 |
| 95% | 786 | 448 | 688 | 688 | 688 |
| Maximum | 1893 | 546 | 767 | 767 | 767 |

From Figure 3.21, simulated salinity in this uncertainty analysis is marginally lower compared to prediction simulation presented in Figure 3.11. This is due to higher runoff from the catchment given the higher rainfall condition. From Table 3.37, median salinity is 533mg/L and is 216mg/L in the null case.

The simulated volume and salinity in Lake Lyell is presented in Figure 3.21. A statistical summary of daily salinity is presented in Table 3.38.

**Table 3.38: Uncertainty Simulation (High Rainfall) Daily Salinity Statistics (mg/L) at #174 (Lake Lyell)**

| **Percentile** | **CAL** | **NUL** | **WS1** | **WS2a** | **WS2b** |
|---|---|---|---|---|---|
| Minimum | 110 | 109 | 141 | 141 | 141 |
| 5% | 165 | 129 | 203 | 203 | 203 |
| 10% | 185 | 135 | 237 | 237 | 237 |
| 20% | 235 | 148 | 273 | 273 | 273 |
| 50% | 355 | 218 | 420 | 420 | 420 |
| 80% | 437 | 321 | 470 | 470 | 470 |
| 90% | 499 | 334 | 487 | 487 | 487 |
| 95% | 559 | 372 | 504 | 504 | 504 |
| Maximum | 830 | 469 | 598 | 598 | 598 |

From Figure 3.21, the minimum salinity is 141mg/L and maximum is 598mg/L and is 112mg/L and 469mg/L in the null case at equivalent times. In Table 3.38, median salinity in the uncertainty analysis simulation is 420mg/L and is marginally lower than the prediction simulation at 422mg/L, reflecting greater runoff from the Coxs River catchment.

*Lake Burragorang and Above Lake Burragorang*

Figure 3.22 presents the simulated flow and salinity at #225 which lies on the Coxs River upstream of Lake Burragorang. Table 3.39 presents a statistical summary of flow at this location and Table 3.40 presents a statistical summary of salinity.

Table 3.40 indicates the median salinity is 142mg/L in this uncertainty analysis simulation and is 89mg/L in the null case. By comparison, the median salinity presented in Table 3.22 for prediction simulation is 153mg/L. As noted in Section 3.3.3, simulated range of salinity is at the upper end of historical observation at this location.

### Table 3.39: Uncertainty Simulation (High Rainfall) Daily Flow Statistics (ML/d) at #225 (Coxs River immediately upstream of Lake Burragorang)

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 9.0 | 5.8 | 9.0 | 9.0 | 9.0 |
| 5% | 16.5 | 16.0 | 25.3 | 25.3 | 25.3 |
| 10% | 21.1 | 21.0 | 31.5 | 31.5 | 31.5 |
| 20% | 30.0 | 32.9 | 43.5 | 43.5 | 43.5 |
| 50% | 72.5 | 87.9 | 98.6 | 98.6 | 98.6 |
| 80% | 289.9 | 364.9 | 397.3 | 397.3 | 397.3 |
| 90% | 704.9 | 830.0 | 899.6 | 899.6 | 899.6 |
| 95% | 1603.0 | 1,920.0 | 2,048.5 | 2,048.5 | 2,048.5 |
| Maximum | 93964 | 94,117 | 94,154 | 94,154 | 94,154 |

### Table 3.40: Uncertainty Simulation (High Rainfall) Daily Salinity Statistics (mg/L) at #225 (Coxs River immediately above Lake Burragorang)

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 51 | 51 | 52 | 52 | 52 |
| 5% | 63 | 58 | 77 | 77 | 77 |
| 10% | 70 | 63 | 86 | 86 | 86 |
| 20% | 80 | 70 | 100 | 100 | 100 |
| 50% | 101 | 89 | 142 | 142 | 142 |
| 80% | 155 | 113 | 227 | 227 | 227 |
| 90% | 209 | 139 | 286 | 286 | 286 |
| 95% | 269 | 177 | 329 | 329 | 329 |
| Maximum | 576 | 348 | 460 | 460 | 460 |

Figure 3.22 presents simulated volume and salinity in Lake Burragorang and Table 3.41 presents summary statistics of daily salinity.

### Table 3.41: Uncertainty Simulation (High Rainfall) Daily Salinity Statistics (mg/L) at #280 (Lake Burragorang)

| Percentile | CAL | NUL | WS1 | WS2a | WS2b |
|---|---|---|---|---|---|
| Minimum | 75 | 74 | 78 | 78 | 78 |
| 5% | 77 | 75 | 79 | 79 | 79 |
| 10% | 79 | 76 | 80 | 80 | 80 |
| 20% | 80 | 78 | 81 | 81 | 81 |
| 50% | 83 | 82 | 88 | 88 | 88 |
| 80% | 86 | 91 | 102 | 102 | 102 |
| 90% | 92 | 92 | 104 | 104 | 104 |
| 95% | 94 | 93 | 104 | 104 | 104 |
| Maximum | 97 | 95 | 107 | 107 | 107 |

From Figure 3.22, the higher rainfall condition leads to higher storage levels in Lake Burragorang, as would be expected. Simulated salinity under the proposed water management strategies, has minimum of 78mg/L and maximum of 107mg/L, with minimum and maximum in null case at equivalent times 74mg/L and 95mg/L. Median salinity in Table 3.41 is 88mg/L and is 82mg/L in the null case.

The results of uncertainty analysis indicates simulated salinity in Lake Burragorang is not particularly sensitive to assumed rainfall condition.

# 4. Impact Assessment

## 4.1 Impact to Flow

### 4.1.1 Kangaroo Creek and Coxs River above Wangcol Creek / Blue Lagoon

The daily rainfall / runoff model developed as part of this impact assessment indicates that mine water discharge at Angus Place through Angus Place LDP001 does dominate flows in Kangaroo Creek in WS1 and WS2a, however, is commensurate with historical flows under WS2b (discharge at Angus Place LDP001 at 2ML/d).

In the Coxs River, upstream of Wangcol Creek / Blue Lagoon, continuous discharge under WS1 is substantial compared to the null case, however, peak flows in the null case do exceed average daily flow which implies some variability in flow is maintained. Under WS2a, the impact of mine water discharge at Angus Place is reduced and is not significant under WS2b.

### 4.1.2 Sawyers Swamp Creek

At node #014, which lies on Sawyers Swamp Creek, immediately downstream of point of discharge from Springvale LDP009, predicted flow under WS1, WS2a and WS2b are significant compared to the null case. As indicated in Section 3.2.3, this is due to the small catchment upstream of this location on Sawyers Swamp Creek due to the catchment diversion because of the SSCAD.

At the downstream end of Sawyers Swamp Creek, above the Coxs River, at node #166, runoff from the null case is small compared to the predctions under the proposed water management strategies. In context, however, the Sawyers Swamp Creek catchment is already in a highly disturbed state due to the presence of historical open cut mining at Kerosene Vale, the SSCAD and Dry Ash Emplacement Facility. As indicated in Section 2.5.3, with the construction of the SDWTS in 2006, excess mine water was discharged to Sawyers Swamp Creek when not required at Wallerawang Power Station.

### 4.1.3 Downstream Impacts

At node #047, which lies on the Coxs River above Lake Wallace, whilst there is continuous discharge that leads to predicted median flows exceeding predicted median flows in the null case, peak flows (flood flows) at this location are substantial in comparison.

A similar conclusion is drawn for node #154, which lies on the Coxs River between Lake Wallace and Lake Lyell.

At node #255, which lies on the Coxs River immediately upstream of Lake Burragorang, the impact of the proposed water management strategy is essentially indiscernible compared to the null case.

Table 4.1 presents a summary of the model results from the top of the catchment downstream through to Lake Burragorang. The model results presented in Table 4.1 were obtained from detailed results presented in Section 3.0.

**Table 4.1: Summary of Predicted Daily Flows (ML/d) in the Coxs River catchment.**

| Location | Node | NUL[1] | WS1[1] | WS2a[1] | WS2b[1] |
|---|---|---|---|---|---|
| *Kangaroo Creek and Coxs River above Wangcol Creek/Blue Lagoon* | | | | | |
| Kangaroo Creek downstream of Angus Place LDP001 | #011 | 0.5(0.0-458) | 26.1(5.4-474) | 2.9(2.0-460) | 2.5(2.0-460) |
| Coxs River above Wangcol Creek/Blue Lagoon | #056 | 1.4(0.0-1613) | 27.4(6.9-1629) | 5.1(2.0-1616) | 3.4(2.0-1616) |
| *Sawyers Swamp Creek* | | | | | |
| Sawyers Swamp Creek downstream of Springvale LDP009 | #014 | 0.2(0.0-170) | 14.4(0.0-186) | 28.0(3.0-199) | 28.0(3.0-199) |
| Sawyers Swamp Creek above Coxs River | #166 | 0.2(0.0-223) | 14.5(0.0-239) | 28.2(3.0-252) | 28.2(3.0-252) |

| Location | Node | NUL[1] | WS1[1] | WS2a[1] | WS2b[1] |
|---|---|---|---|---|---|
| *Lake Wallace* | | | | | |
| Coxs River above Lake Wallace | #047 | 10.3(4.4-5,577) | 47.9(13.3-5,607) | as per WS1 | as per WS1 |
| Lake Wallace | #074 | n/a | n/a | as per WS1 | as per WS1 |
| *Lake Lyell and above Lake Lyell* | | | | | |
| Coxs River above Lake Lyell | #154 | 12.7(0.1-10,223) | 48.7(6.7-10,254) | as per WS1 | as per WS1 |
| Lake Lyell | #174 | n/a | n/a | as per WS1 | as per WS1 |
| *Thompsons Creek Reservoir* | | | | | |
| Thompsons Creek Reservoir | #272 | n/a | n/a | as per WS1 | as per WS1 |
| *Lake Burragorang and above Lake Burragorang* | | | | | |
| Coxs River above Lake Burragorang | #225 | 75.7(2.7-65,977) | 86.9(9.0-68,789) | as per WS1 | as per WS1 |
| Lake Burragorang | #280 | n/a | n/a | as per WS1 | as per WS1 |

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

## 4.2 Impact to Quality

### 4.2.1 Kangaroo Creek and Coxs River above Wangcol Creek / Blue Lagoon

Modelling indicates that predicted salinity in Kangaroo Creek is dominated by the assumed salinity of mine water discharge at Angus Place. Predicted salinity of a maximum of 804mg/L in the Coxs River above Wangcol Creek / Blue Lagoon is within the range of historical observation due to discharge at Angus Place in the past. Modelled salinity upstream of point of discharge in Kangaroo Creek is 50mg/L and in the Coxs River above the confluence with Kangaroo Creek, fluctuates between 50 and 75mg/L.

### 4.2.2 Sawyers Swamp Creek

Modelling indicates that the predicted salinity in Sawyers Swamp Creek is also dominated by the assumed salinity of mine water discharge at Springvale Mine via Springvale LDP009.

### 4.2.3 Downstream Impacts

In the Coxs River, at #047, which lies immediately upstream of Lake Wallace, the predicted median salinity is 755mgL; however, as presented in Figure 3.11, there is reasonable modelled day to day variability. For comparison, in the null case, the median salinity is 599mg/L. The predicted salinity in Lake Wallace (#074) is 604mg/L (median) and is 321mg/L (median) in the null case.

Further downstream, in Lake Burragorang, the predicted impact of the proposed water management strategies is an increase in median salinity from 85mg/L to 97mg/L.

Table 4.2 presents a summary of the model results from the top of the catchment downstream through to Lake Burragorang. The model results presented in Table 4.2 were obtained from detailed results presented in Section 3.0.

**Table 4.2: Summary of Predicted Daily Salinity (mg/L) in the Coxs River catchment.**

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

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

SCA has adopted a risk assessment based approach to water quality management. As part of that management framework, SCA have developed a Pollution Source Assessment Tool. The outcomes of that work identified the five most significant pollution sources in the catchment which, in general, relate to faecal contamination and/or nutrients (Phosphorous and Nitrogen). They include the following:

- grazing
- intensive animal production
- on-site wastewater management systems
- sewage collection systems
- urban stormwater.

As outlined in SCA's Annual Water Quality Monitoring Report 2012-2013 (SCA, 2013), water quality management is focussed on:

- Australian Drinking Water Guidelines (health-related)
- Raw Water Supply Agreements (in this case Prospect Water Filtration Plant).

The relevant target water quality parameters are reproduced from SCA (2013) in Table 4-1 and Table 4-2 respectively.

From the above, there is no target for salinity since the ADWG do not have a health-based water quality criteria. There is also no target for salinity for the Prospect Water Filtration Plant with respect to Raw Water Supply Agreement. As identified in the SSTV Assessment, other water quality characteristics meet the ADWG and the Raw Water Supply Agreement specifications. The predicted minor increase in salinity in Lake Burragorang due to the proposal is therefore considered to have a neutral effect with respect to the Neutral or Beneficial Effect test criteria.

## Table 4.3: SCA Target Health-Related Water Quality Characteristics for Lake Burragorang

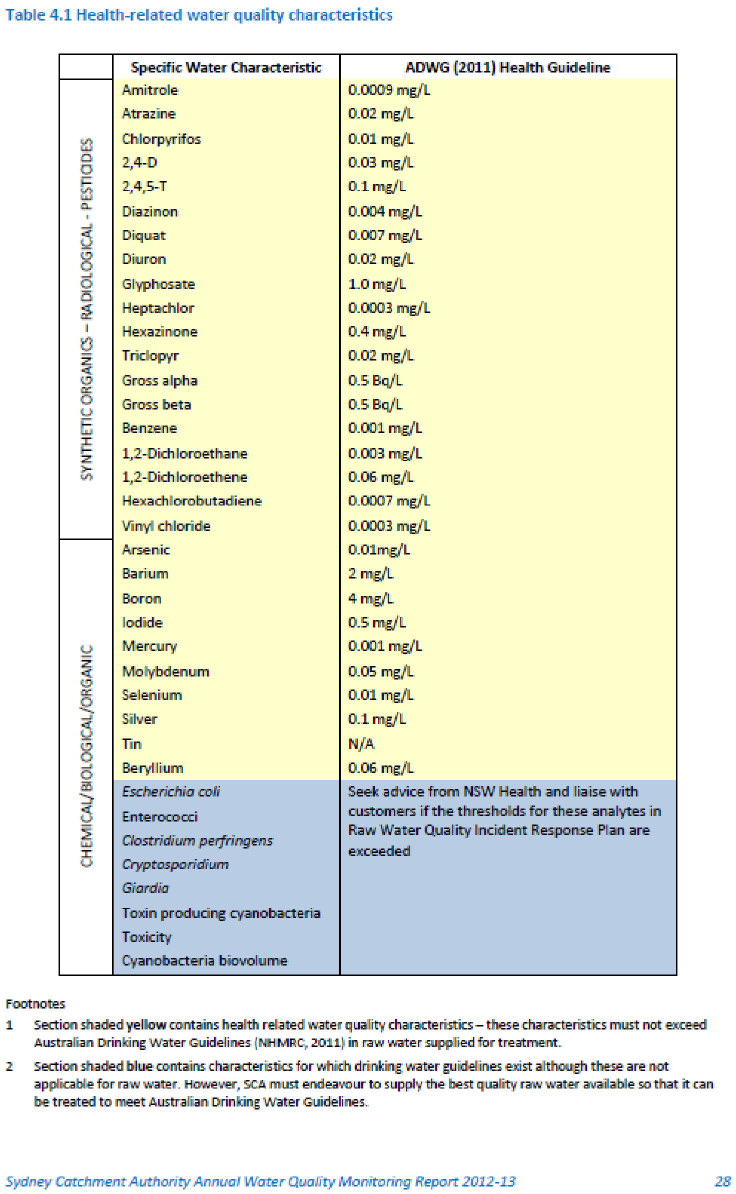

Table 4.1 Health-related water quality characteristics

| | Specific Water Characteristic | ADWG (2011) Health Guideline |
|---|---|---|
| SYNTHETIC ORGANICS – RADIOLOGICAL - PESTICIDES | Amitrole | 0.0009 mg/L |
| | Atrazine | 0.02 mg/L |
| | Chlorpyrifos | 0.01 mg/L |
| | 2,4-D | 0.03 mg/L |
| | 2,4,5-T | 0.1 mg/L |
| | Diazinon | 0.004 mg/L |
| | Diquat | 0.007 mg/L |
| | Diuron | 0.02 mg/L |
| | Glyphosate | 1.0 mg/L |
| | Heptachlor | 0.0003 mg/L |
| | Hexazinone | 0.4 mg/L |
| | Triclopyr | 0.02 mg/L |
| | Gross alpha | 0.5 Bq/L |
| | Gross beta | 0.5 Bq/L |
| | Benzene | 0.001 mg/L |
| | 1,2-Dichloroethane | 0.003 mg/L |
| | 1,2-Dichloroethene | 0.06 mg/L |
| | Hexachlorobutadiene | 0.0007 mg/L |
| | Vinyl chloride | 0.0003 mg/L |
| CHEMICAL/BIOLOGICAL/ORGANIC | Arsenic | 0.01mg/L |
| | Barium | 2 mg/L |
| | Boron | 4 mg/L |
| | Iodide | 0.5 mg/L |
| | Mercury | 0.001 mg/L |
| | Molybdenum | 0.05 mg/L |
| | Selenium | 0.01 mg/L |
| | Silver | 0.1 mg/L |
| | Tin | N/A |
| | Beryllium | 0.06 mg/L |
| | *Escherichia coli* | Seek advice from NSW Health and liaise with customers if the thresholds for these analytes in Raw Water Quality Incident Response Plan are exceeded |
| | Enterococci | |
| | *Clostridium perfringens* | |
| | *Cryptosporidium* | |
| | *Giardia* | |
| | Toxin producing cyanobacteria | |
| | Toxicity | |
| | Cyanobacteria biovolume | |

Footnotes

1 Section shaded **yellow** contains health related water quality characteristics – these characteristics must not exceed Australian Drinking Water Guidelines (NHMRC, 2011) in raw water supplied for treatment.

2 Section shaded **blue** contains characteristics for which drinking water guidelines exist although these are not applicable for raw water. However, SCA must endeavour to supply the best quality raw water available so that it can be treated to meet Australian Drinking Water Guidelines.

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## Table 4.4: SCA Target Raw Water Supply Agreement Water Quality characteristics for Lake Burragorang

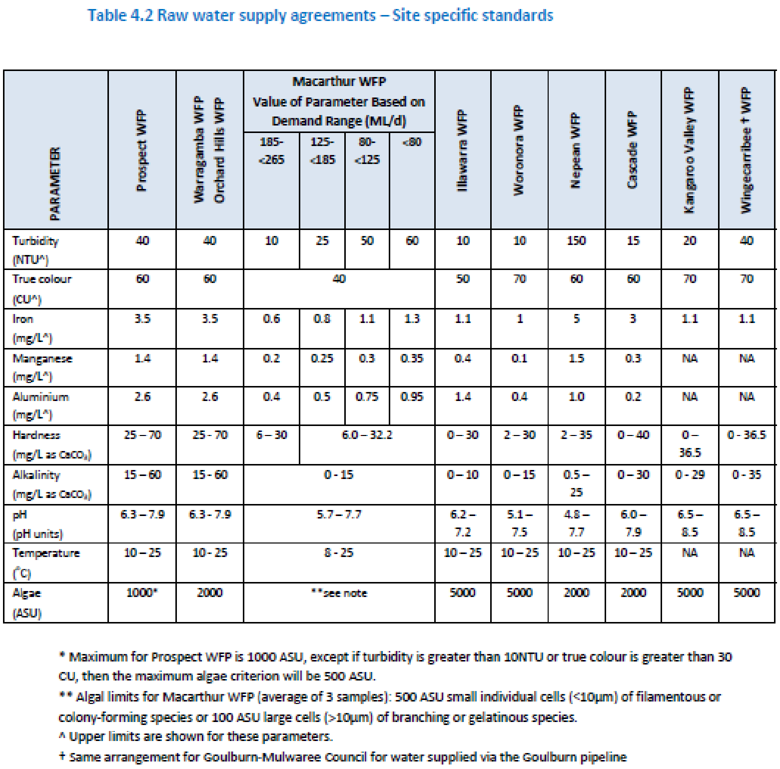

Table 4.2 Raw water supply agreements – Site specific standards

| PARAMETER | Prospect WFP | Warragamba WFP<br>Orchard Hills WFP | Macarthur WFP Value of Parameter Based on Demand Range (ML/d) | | | | Illawarra WFP | Woronora WFP | Nepean WFP | Cascade WFP | Kangaroo Valley WFP | Wingecarribee † WFP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 185-<265 | 125-<185 | 80-<125 | <80 | | | | | | |
| Turbidity (NTU^) | 40 | 40 | 10 | 25 | 50 | 60 | 10 | 10 | 150 | 15 | 20 | 40 |
| True colour (CU^) | 60 | 60 | 40 | | | | 50 | 70 | 60 | 60 | 70 | 70 |
| Iron (mg/L^) | 3.5 | 3.5 | 0.6 | 0.8 | 1.1 | 1.3 | 1.1 | 1 | 5 | 3 | 1.1 | 1.1 |
| Manganese (mg/L^) | 1.4 | 1.4 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 | 0.1 | 1.5 | 0.3 | NA | NA |
| Aluminium (mg/L^) | 2.6 | 2.6 | 0.4 | 0.5 | 0.75 | 0.95 | 1.4 | 0.4 | 1.0 | 0.2 | NA | NA |
| Hardness (mg/L as $CaCO_3$) | 25 – 70 | 25 - 70 | 6 – 30 | 6.0 – 32.2 | | | 0 – 30 | 2 – 30 | 2 – 35 | 0 – 40 | 0 – 36.5 | 0 - 36.5 |
| Alkalinity (mg/L as $CaCO_3$) | 15 – 60 | 15 - 60 | 0 - 15 | | | | 0 – 10 | 0 – 15 | 0.5 – 25 | 0 – 30 | 0 - 29 | 0 - 35 |
| pH (pH units) | 6.3 – 7.9 | 6.3 - 7.9 | 5.7 – 7.7 | | | | 6.2 – 7.2 | 5.1 – 7.5 | 4.8 – 7.7 | 6.0 – 7.9 | 6.5 – 8.5 | 6.5 – 8.5 |
| Temperature (°C) | 10 – 25 | 10 - 25 | 8 - 25 | | | | 10 – 25 | 10 – 25 | 10 – 25 | 10 – 25 | NA | NA |
| Algae (ASU) | 1000* | 2000 | **see note | | | | 5000 | 5000 | 2000 | 2000 | 5000 | 5000 |

* Maximum for Prospect WFP is 1000 ASU, except if turbidity is greater than 10NTU or true colour is greater than 30 CU, then the maximum algae criterion will be 500 ASU.

** Algal limits for Macarthur WFP (average of 3 samples): 500 ASU small individual cells (<10µm) of filamentous or colony-forming species or 100 ASU large cells (>10µm) of branching or gelatinous species.

^ Upper limits are shown for these parameters.

† Same arrangement for Goulburn-Mulwaree Council for water supplied via the Goulburn pipeline

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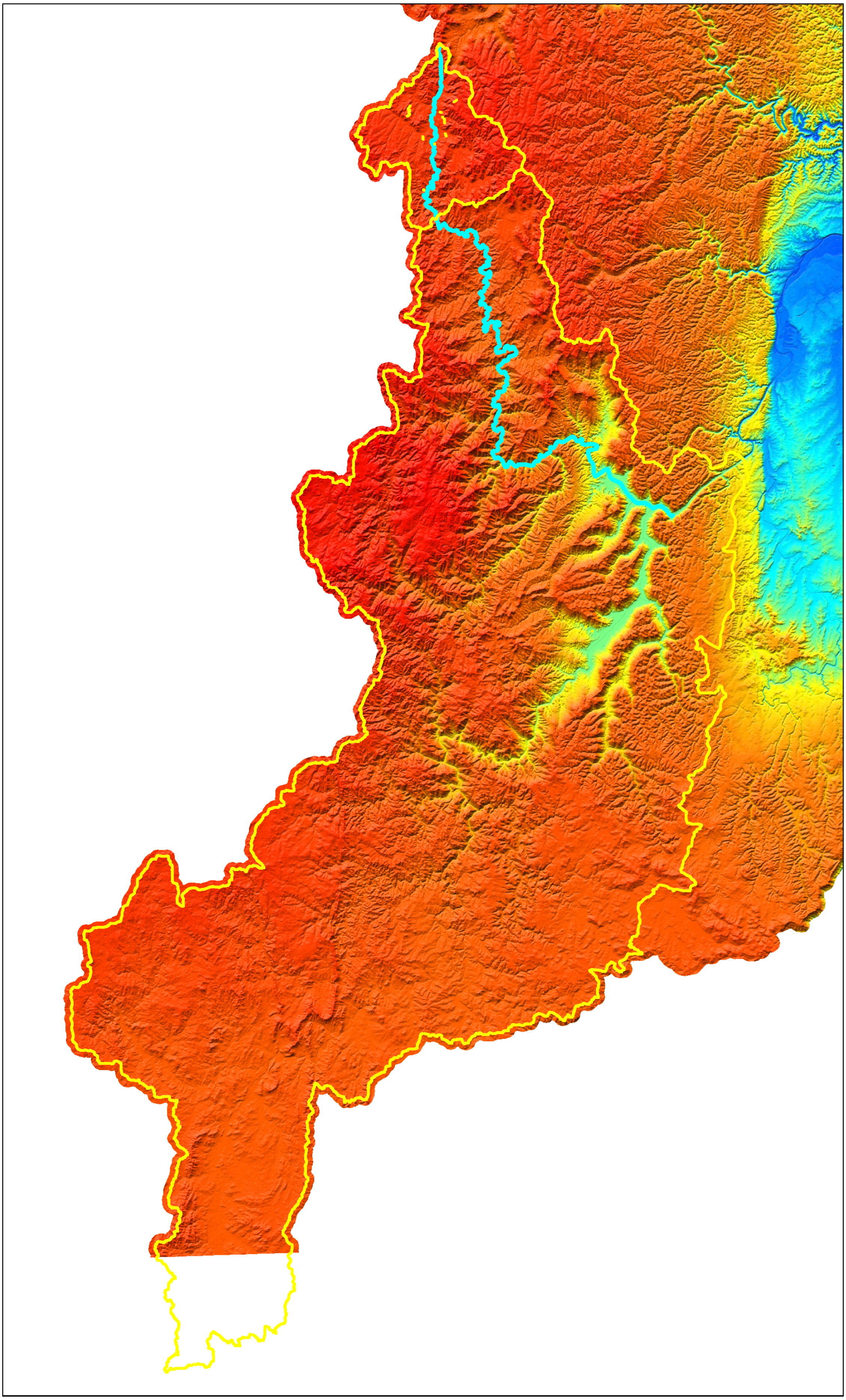
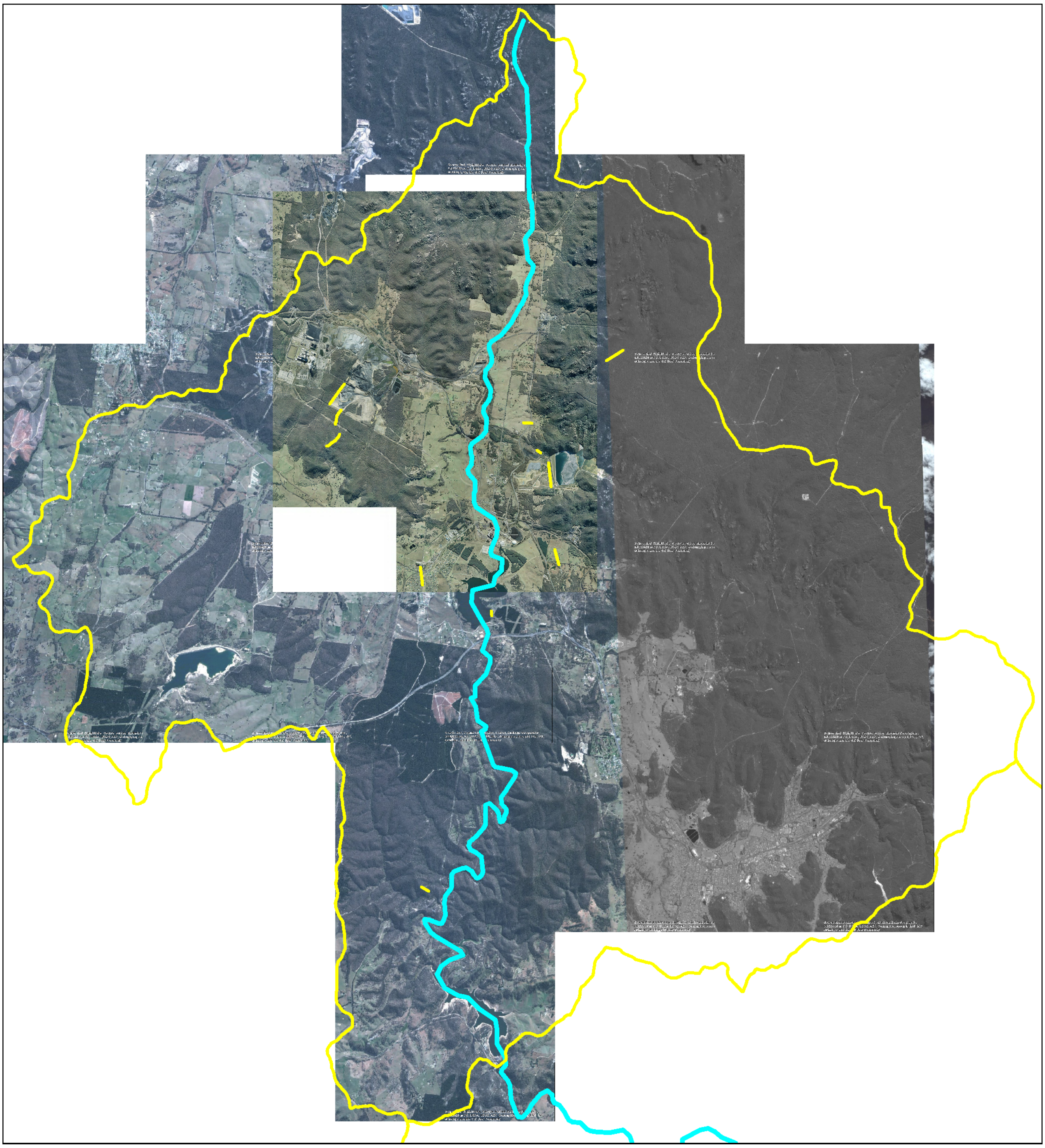
Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources 2012 (NSW). Current version 7 February 2014, accessed 1 September 2014.

# FIGURES



**STUDY AREA** FIGURE 2-1



**STUDY AREA – WYWANDY MANAGEMENT ZONE** FIGURE 2-2

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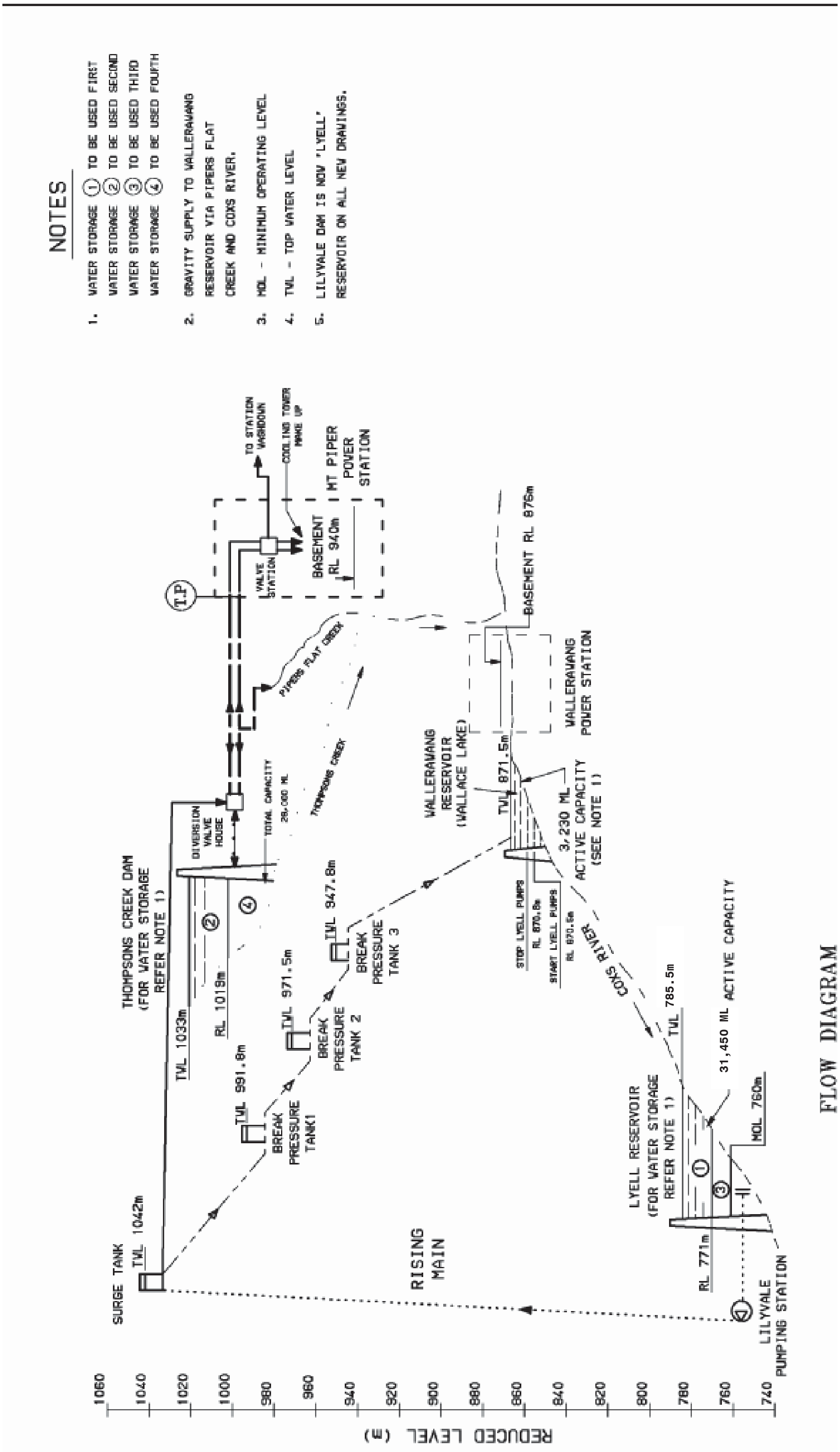
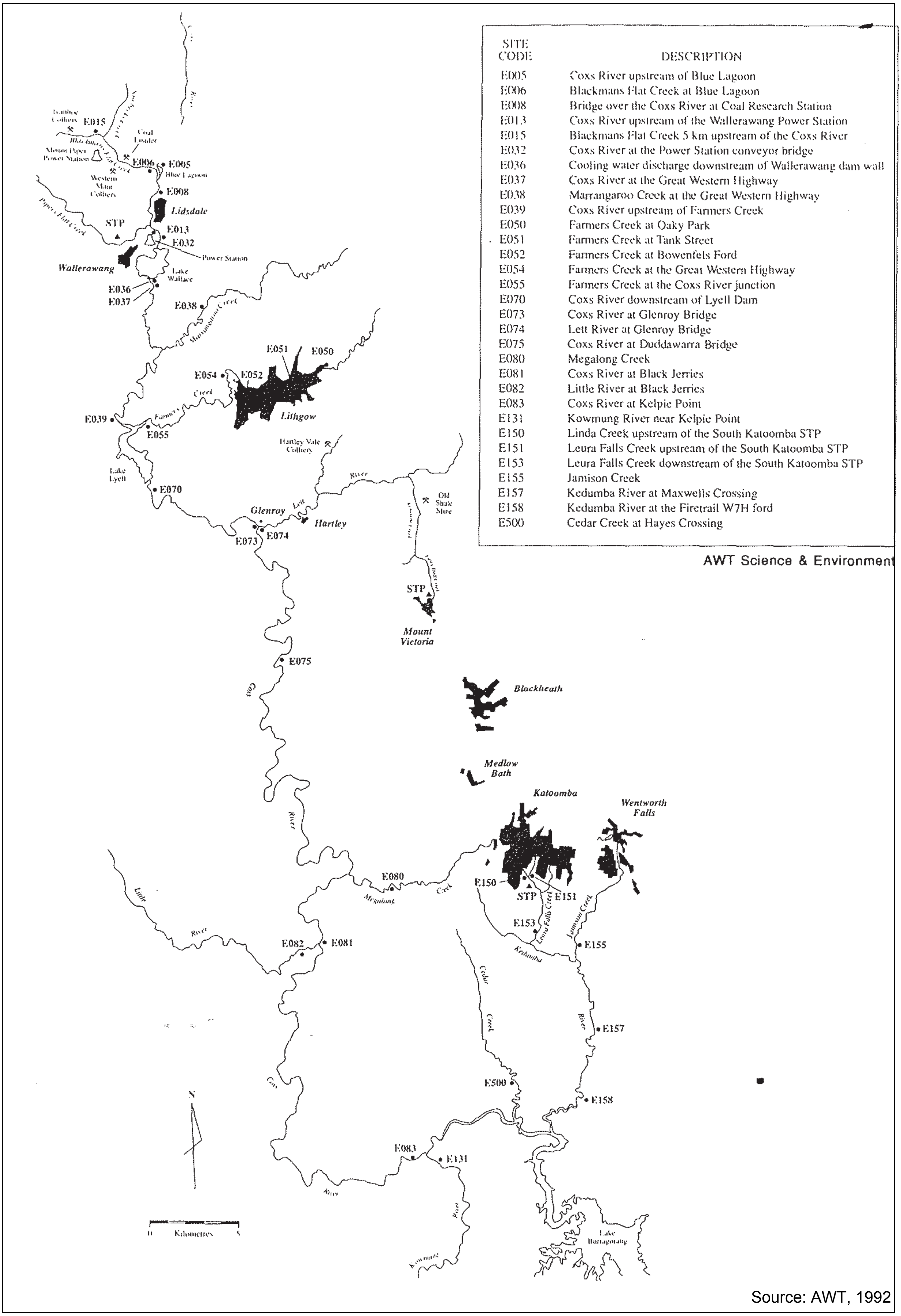


Source: Delta Electricity, 2009

**ENERGY AUSTRALIA COXS RIVER WATER SUPPLY FLOW DIAGRAM** FIGURE 2-3B

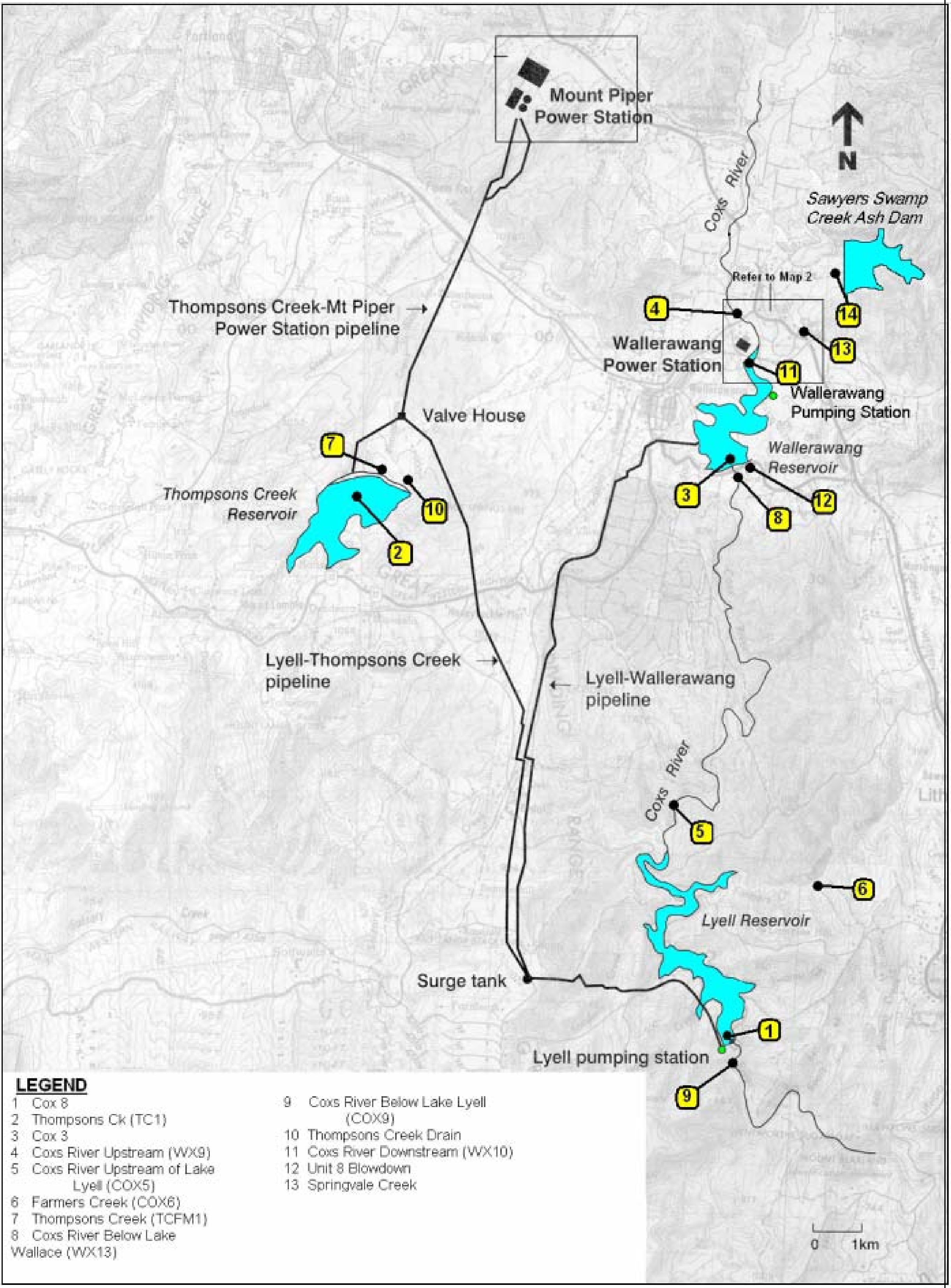


| SITE CODE | DESCRIPTION |
|---|---|
| E005 | Coxs River upstream of Blue Lagoon |
| E006 | Blackmans Flat Creek at Blue Lagoon |
| E008 | Bridge over the Coxs River at Coal Research Station |
| E013 | Coxs River upstream of the Wallerawang Power Station |
| E015 | Blackmans Flat Creek 5 km upstream of the Coxs River |
| E032 | Coxs River at the Power Station conveyor bridge |
| E036 | Cooling water discharge downstream of Wallerawang dam wall |
| E037 | Coxs River at the Great Western Highway |
| E038 | Marrangaroo Creek at the Great Western Highway |
| E039 | Coxs River upstream of Farmers Creek |
| E050 | Farmers Creek at Oaky Park |
| E051 | Farmers Creek at Tank Street |
| E052 | Farmers Creek at Bowenfels Ford |
| E054 | Farmers Creek at the Great Western Highway |
| E055 | Farmers Creek at the Coxs River junction |
| E070 | Coxs River downstream of Lyell Dam |
| E073 | Coxs River at Glenroy Bridge |
| E074 | Lett River at Glenroy Bridge |
| E075 | Coxs River at Duddawarra Bridge |
| E080 | Megalong Creek |
| E081 | Coxs River at Black Jerries |
| E082 | Little River at Black Jerries |
| E083 | Coxs River at Kelpie Point |
| E131 | Kowmung River near Kelpie Point |
| E150 | Linda Creek upstream of the South Katoomba STP |
| E151 | Leura Falls Creek upstream of the South Katoomba STP |
| E153 | Leura Falls Creek downstream of the South Katoomba STP |
| E155 | Jamison Creek |
| E157 | Kedumba River at Maxwells Crossing |
| E158 | Kedumba River at the Firetrail W7H ford |
| E500 | Cedar Creek at Hayes Crossing |

AWT Science & Environment

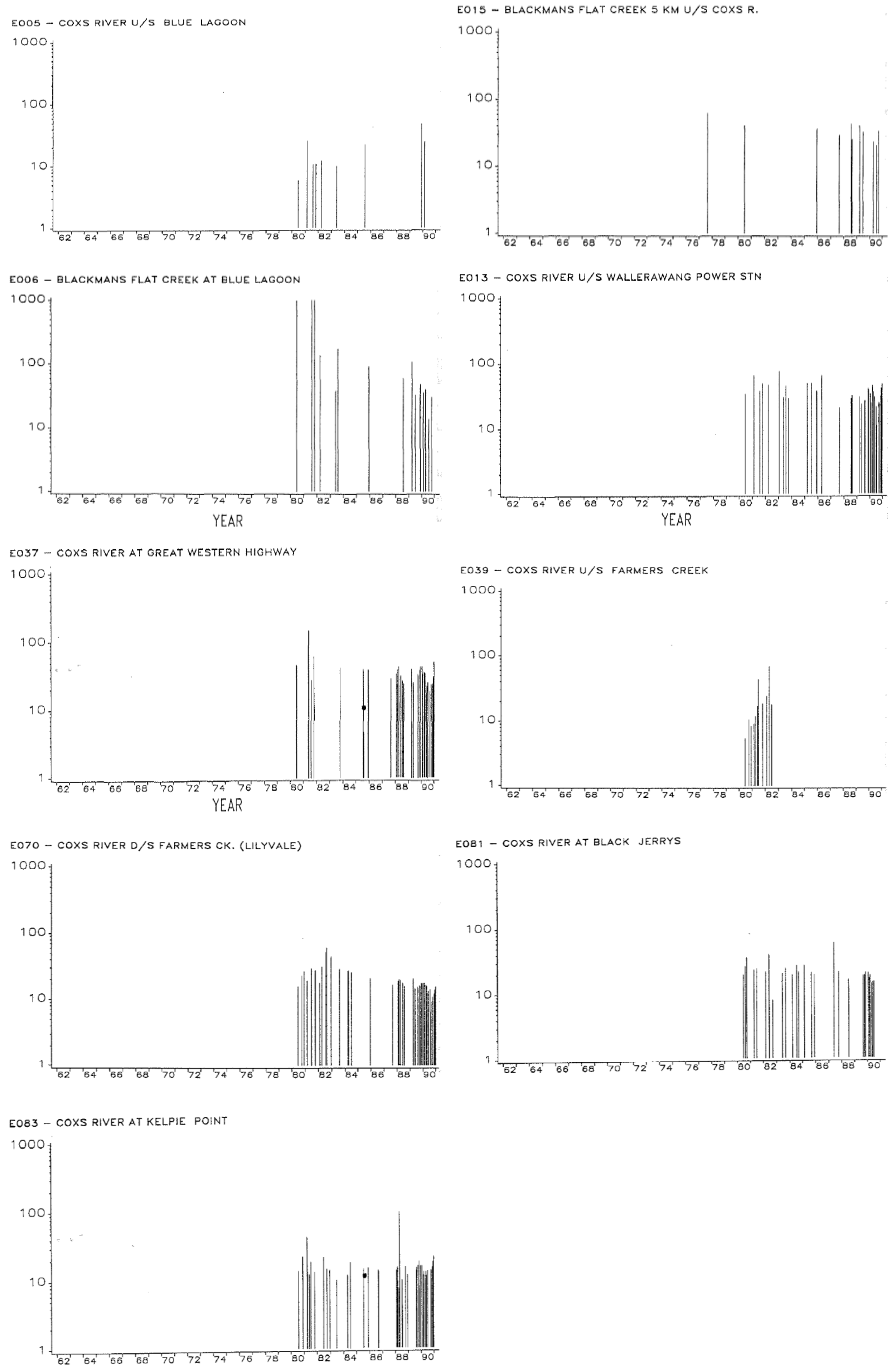
Source: AWT, 1992

**WATER QUALITY MONITORING LOCATIONS – AWT (1992)** FIGURE 2-4



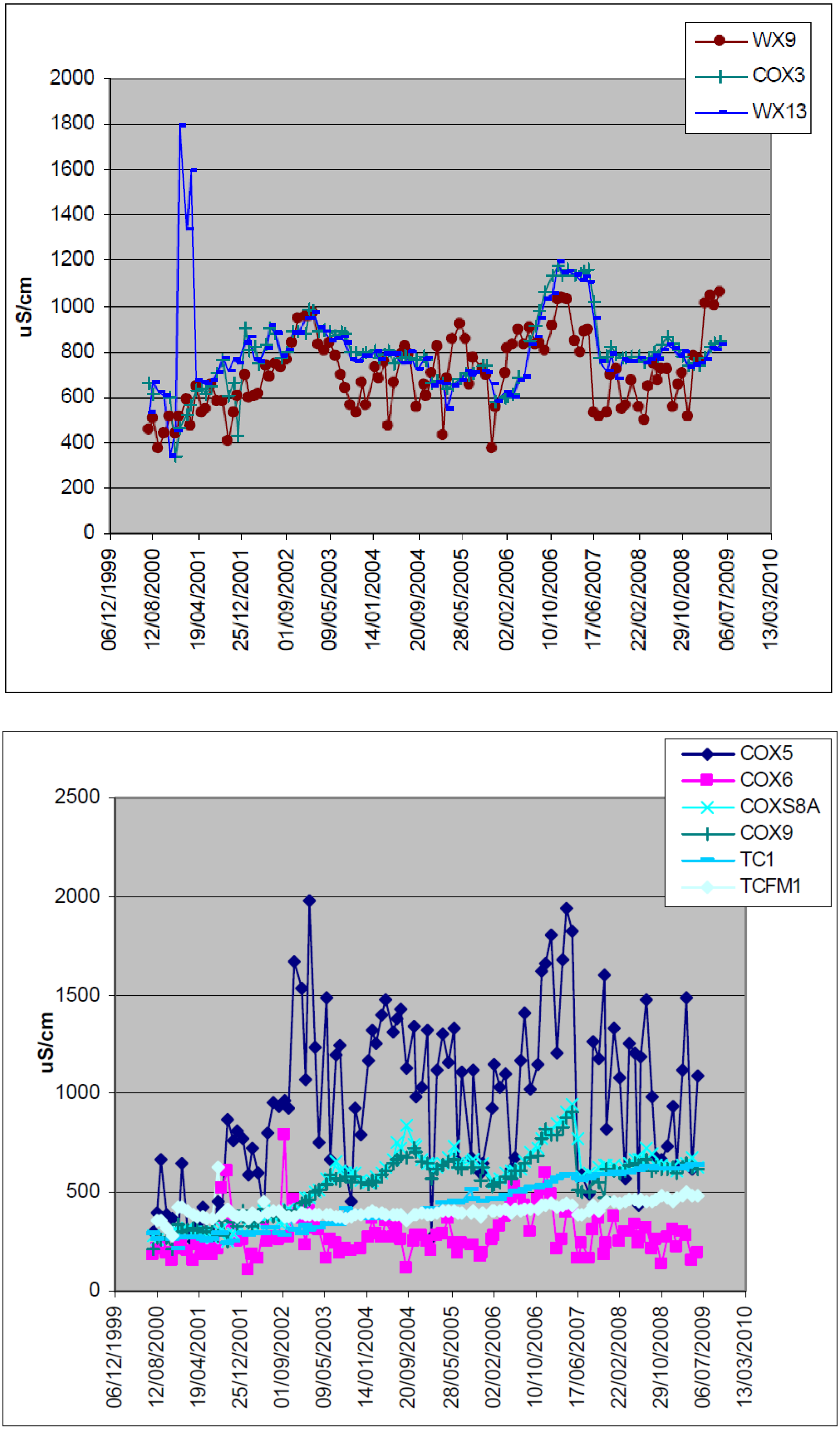
Source: Delta Electricity, 2009

**WATER QUALITY MONITORING LOCATIONS – DELTA ELECTRICITY (2009)** FIGURE 2-5



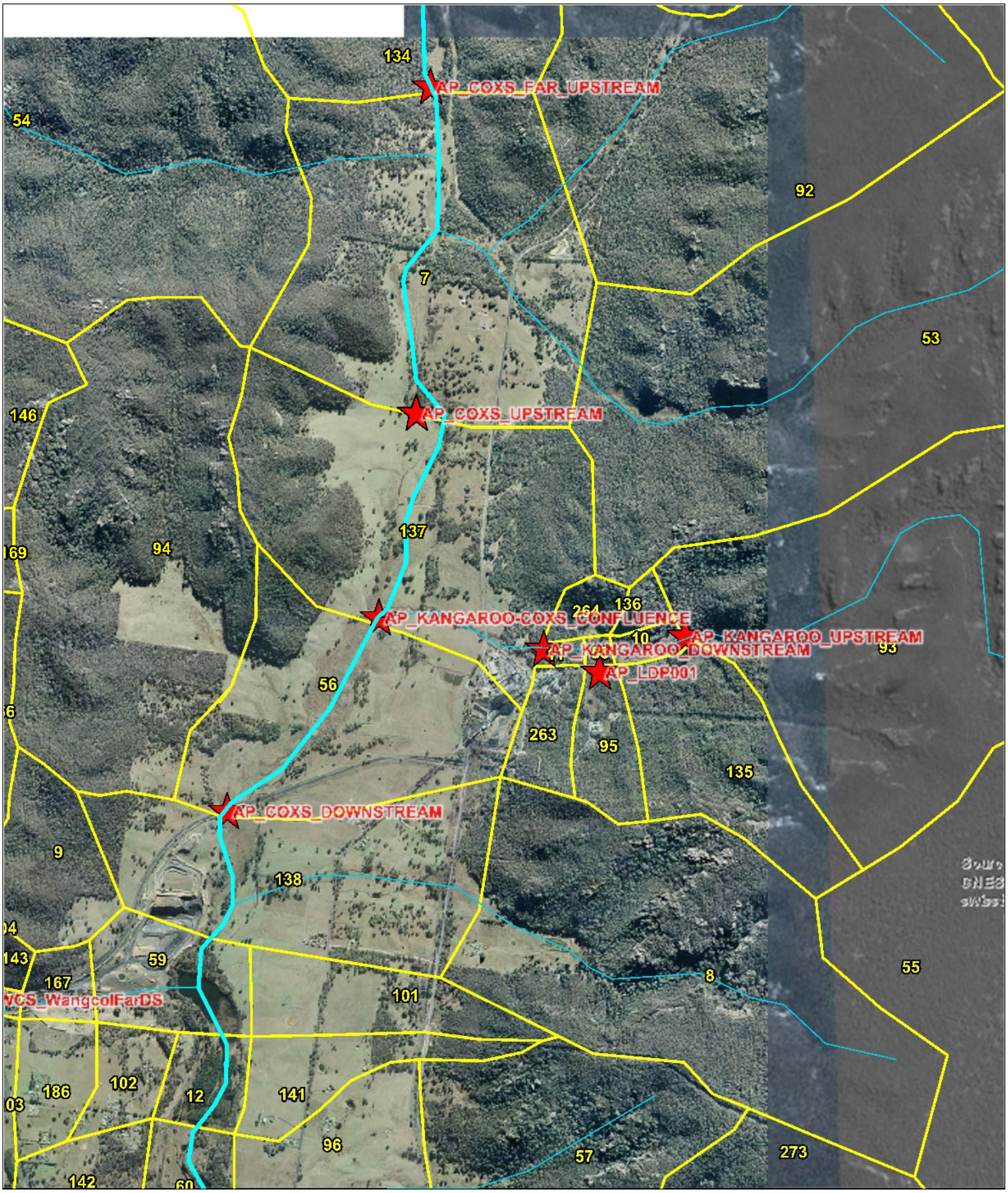
Source: AWT, 1992

**OBSERVED SALINITY IN THE COXS RIVER (AWT, 1992)** FIGURE 2-6



Source: Delta Electricity, 2009

**OBSERVED SALINITY IN THE COXS RIVER (DELTA ELECTRICITY, 2009)** FIGURE 2-7



**LAYOUT OF THE WATER QUALITY MODEL – KANGAROO CREEK** FIGURE 3-1A

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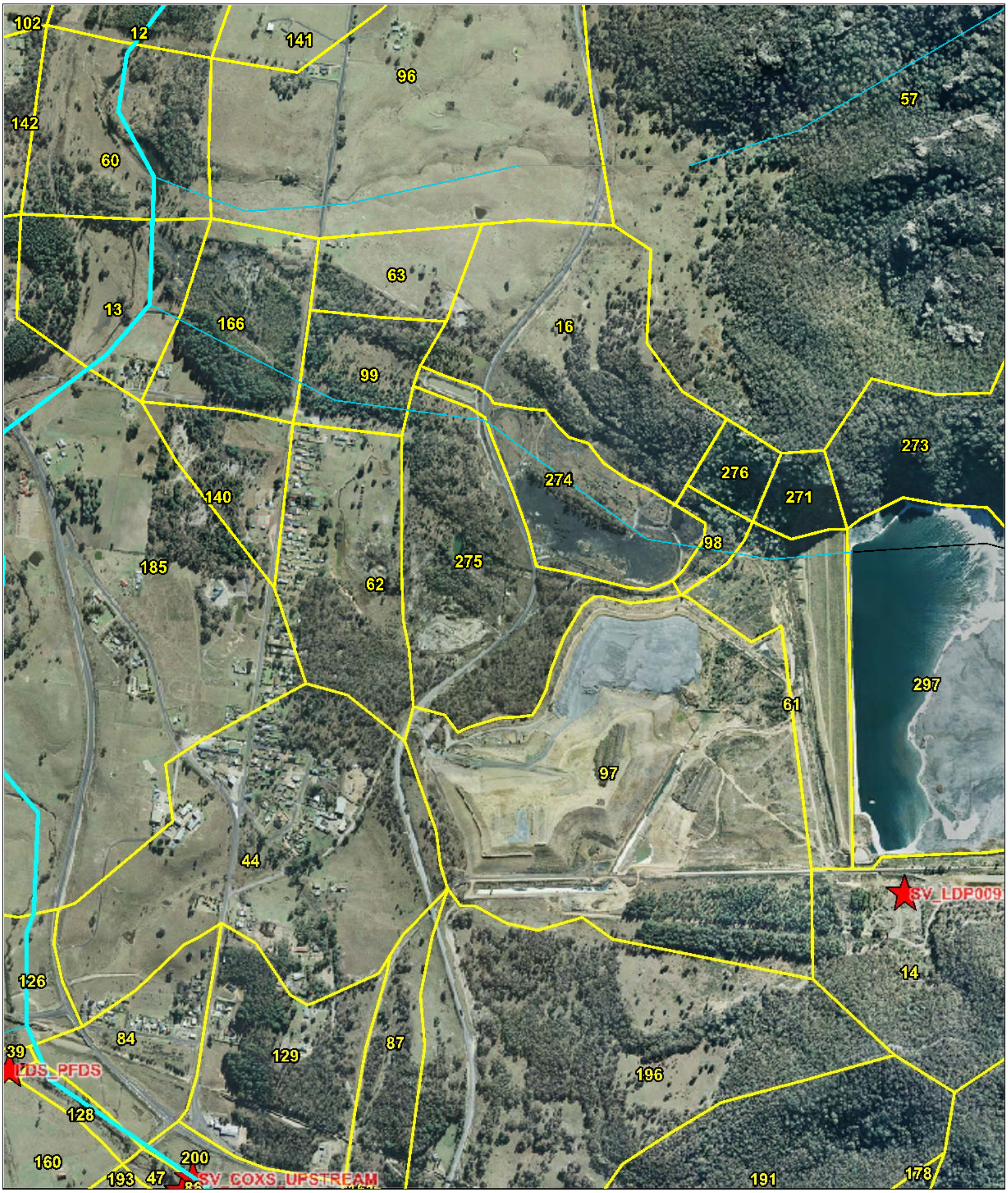

**LAYOUT OF THE WATER QUALITY MODEL – SAWYERS SWAMP CREEK** FIGURE 3-1B

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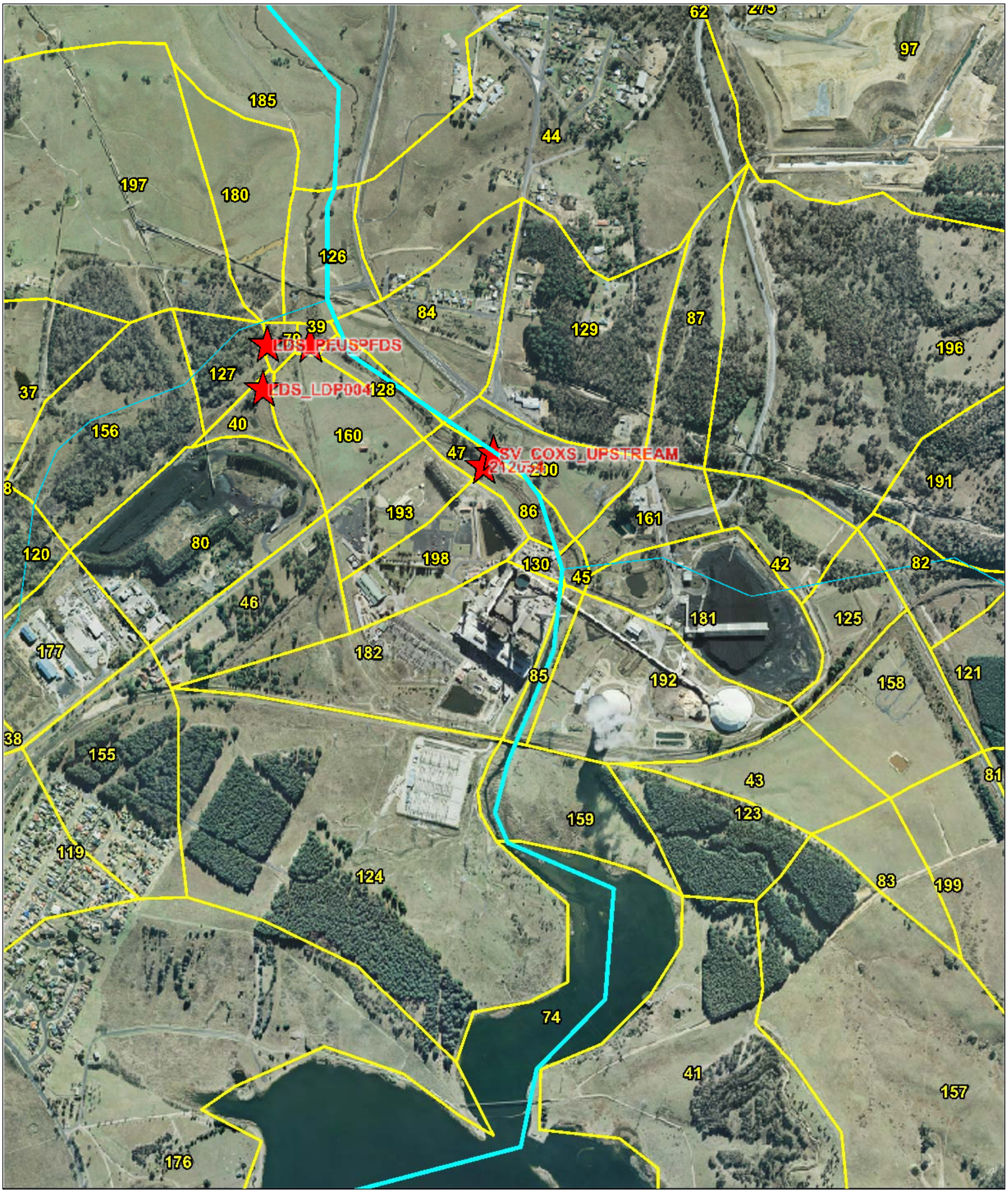
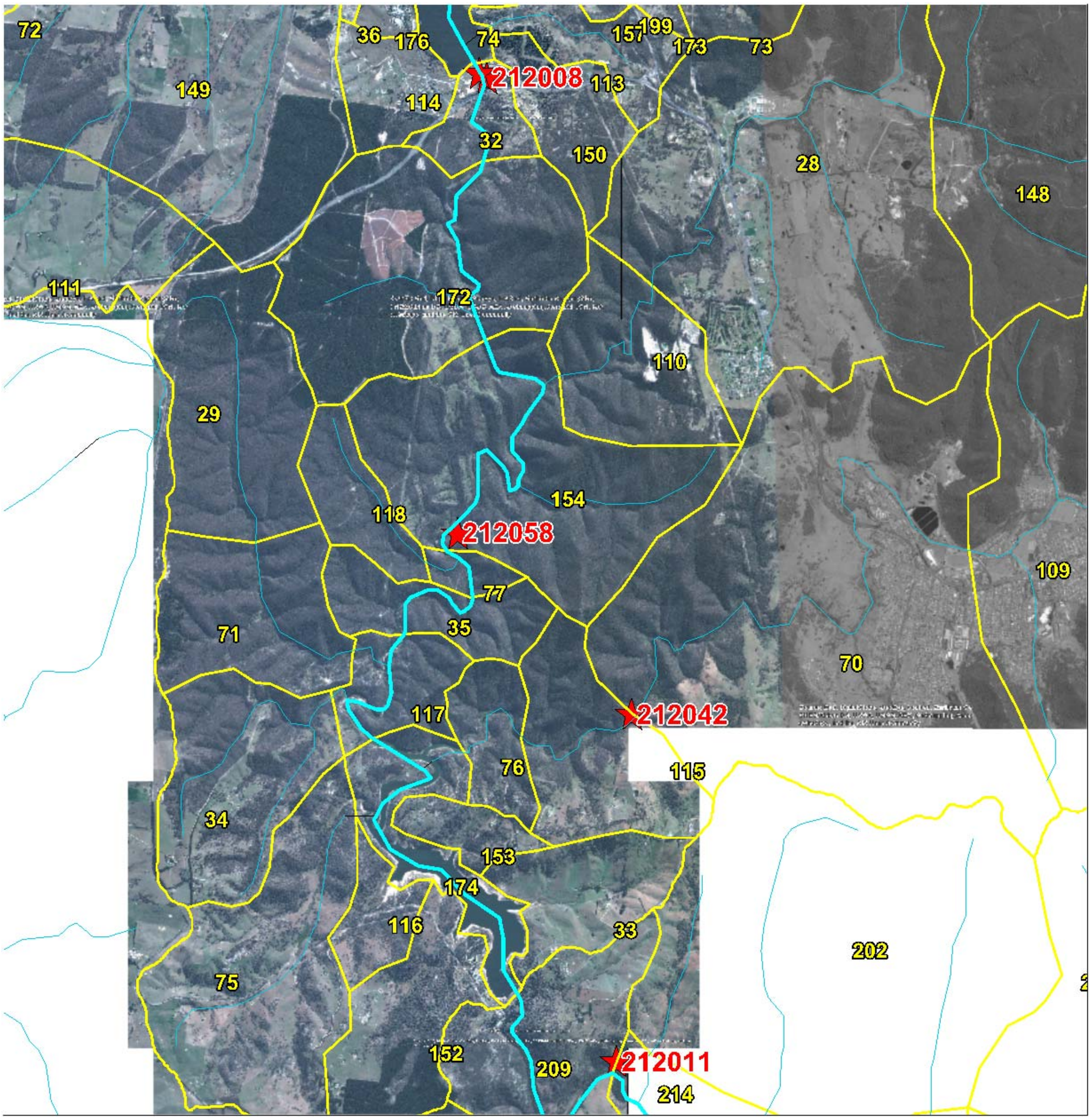


LAYOUT OF THE WATER QUALITY MODEL – LAKE WALLACE FIGURE 3-1C



**LAYOUT OF THE WATER QUALITY MODEL – LAKE LYELL** FIGURE 3-1D

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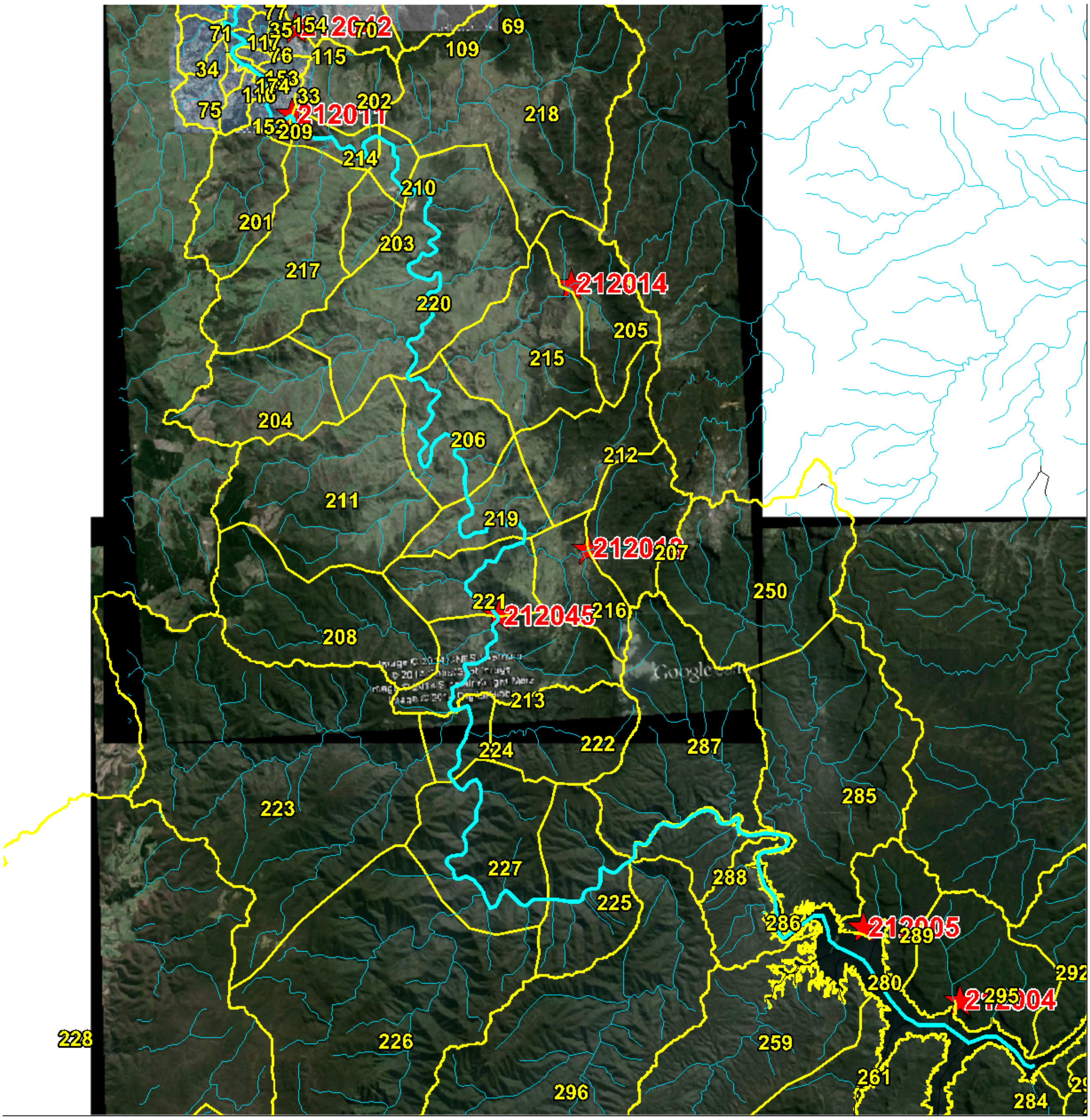

**LAYOUT OF THE WATER QUALITY MODEL – LAKE BURRAGORANG** FIGURE 3-1E

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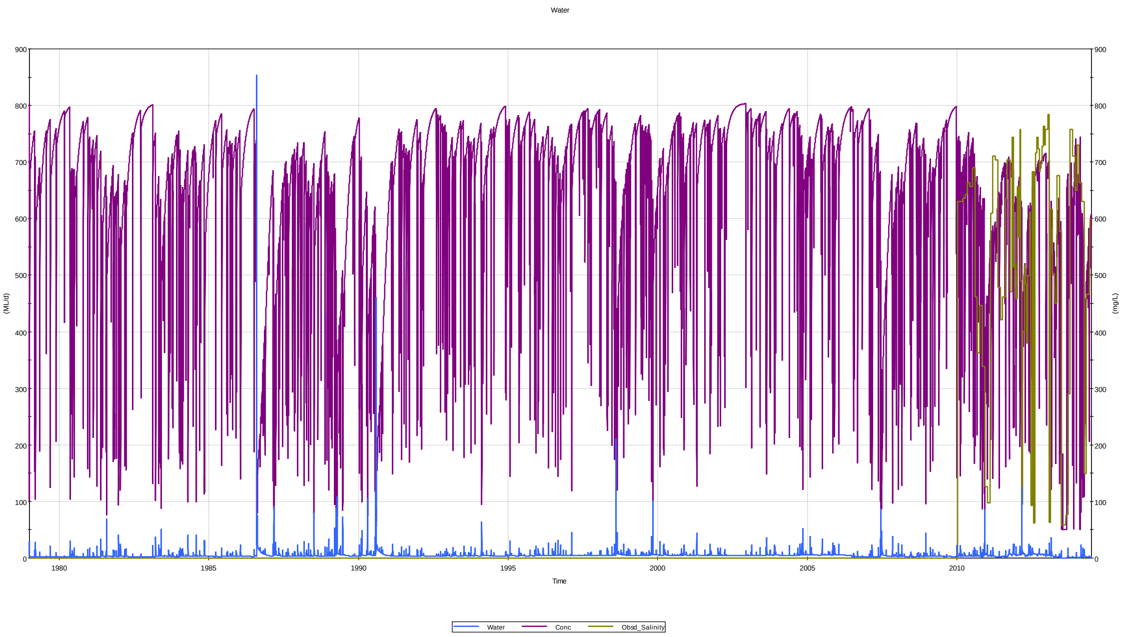
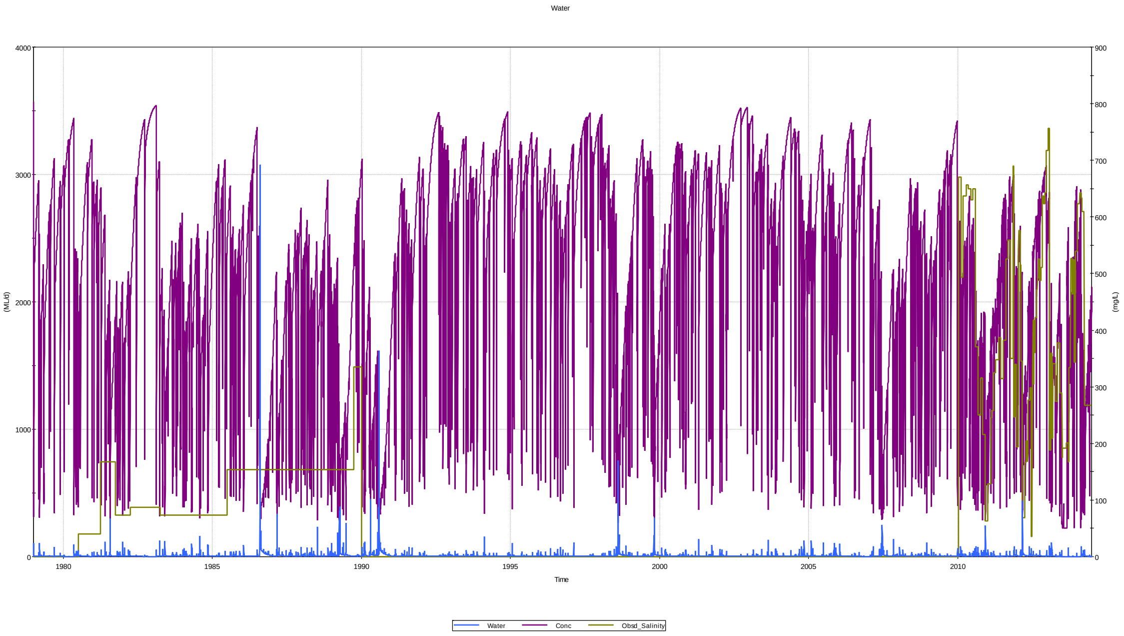


#011: Kangaroo Creek below Angus Place LDP001



#056: Coxs River above Wangcol Creek / Blue Lagoon

LEGEND:

Modelled Flow (ML/d), Volume (ML)
Observed Flow (ML/d), Volume (ML)
Modelled Salinity (mg/L)
Observed Salinity (mg/L)

**CALIBRATION RESULTS – KANGAROO CK & COXS R ABOVE WANGCOL** FIGURE 3.2

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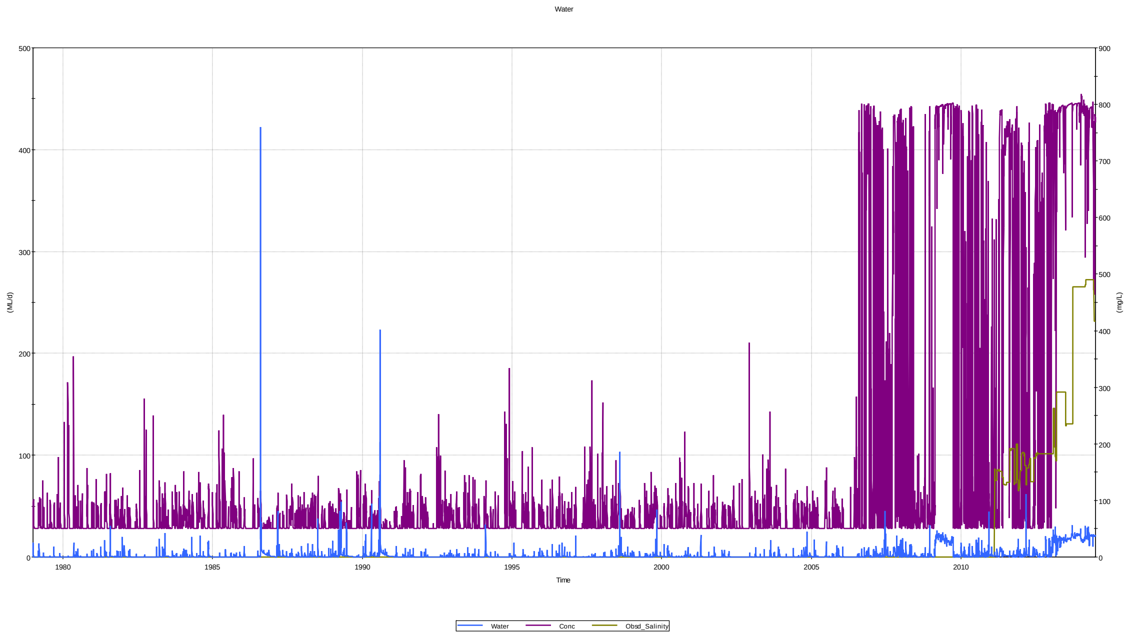


#166: Sawyers Swamp Creek above Coxs River

LEGEND:

Modelled Flow (ML/d), Volume (ML)

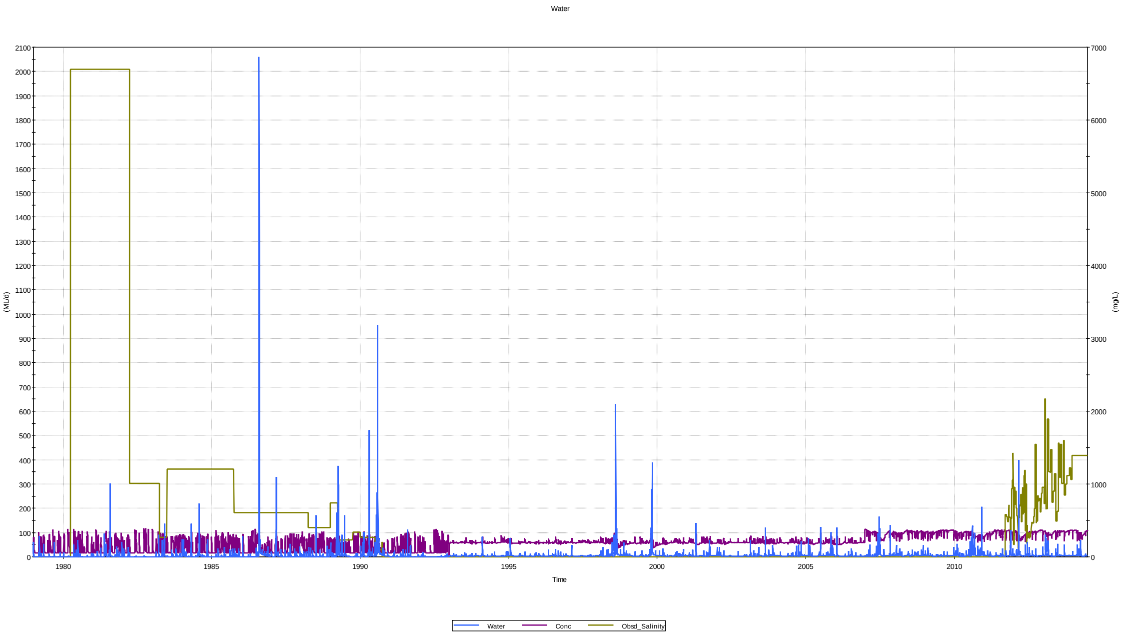
Observed Flow (ML/d), Volume (ML)

Modelled Salinity (mg/L)

Observed Salinity (mg/L)

**MODEL CALIBRATION RESULTS – SAWYERS SWAMP CREEK** FIGURE 3.3

#105: Wangcol Creek above Western Coal Services LDP006



#167: Wangcol Creek above Blue Lagoon

LEGEND:

Modelled Flow (ML/d), Volume (ML)
Observed Flow (ML/d), Volume (ML)
Modelled Salinity (mg/L)
Observed Salinity (mg/L)

**MODEL CALIBRATION RESULTS – WANGCOL CREEK** FIGURE 3.4

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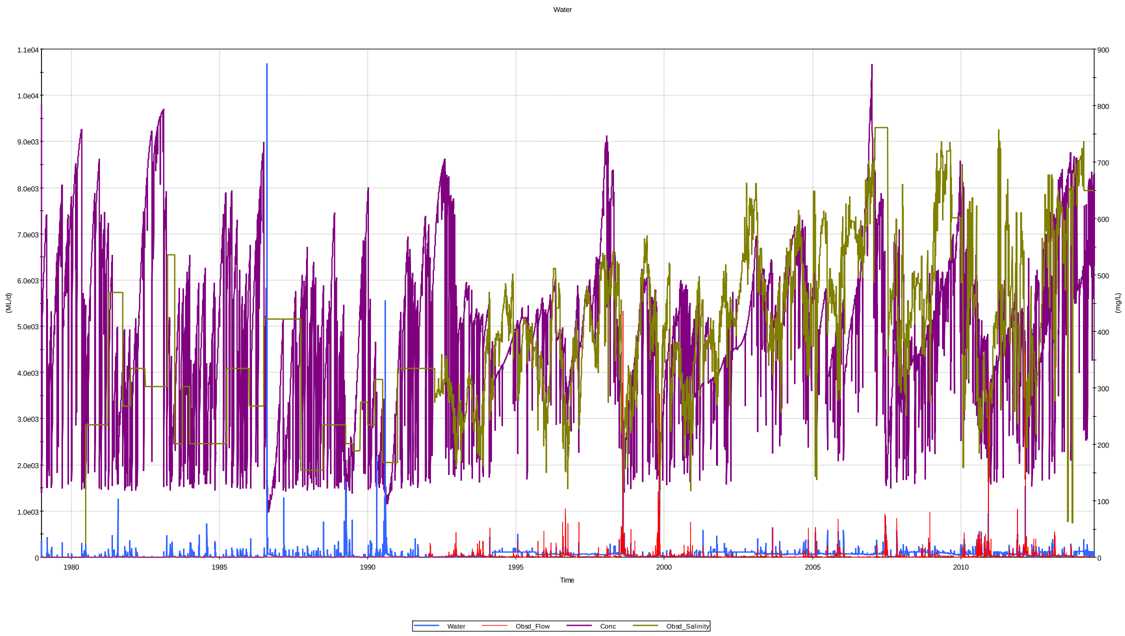
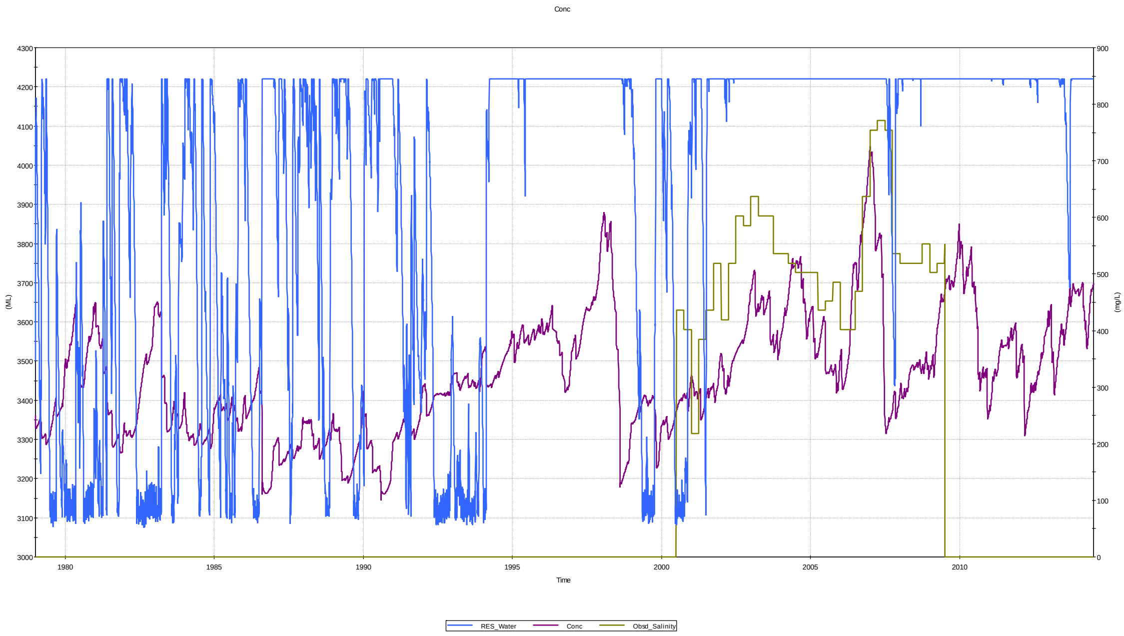


#047: Coxs River above Lake Wallace (location of NSW Office of Water Gauge 212054)



#074: Lake Wallace

LEGEND:

Modelled Flow (ML/d), Volume (ML)
Observed Flow (ML/d), Volume (ML)
Modelled Salinity (mg/L)
Observed Salinity (mg/L)

RPS

**MODEL CALIBRATION RESULTS – LAKE WALLACE** FIGURE 3.5

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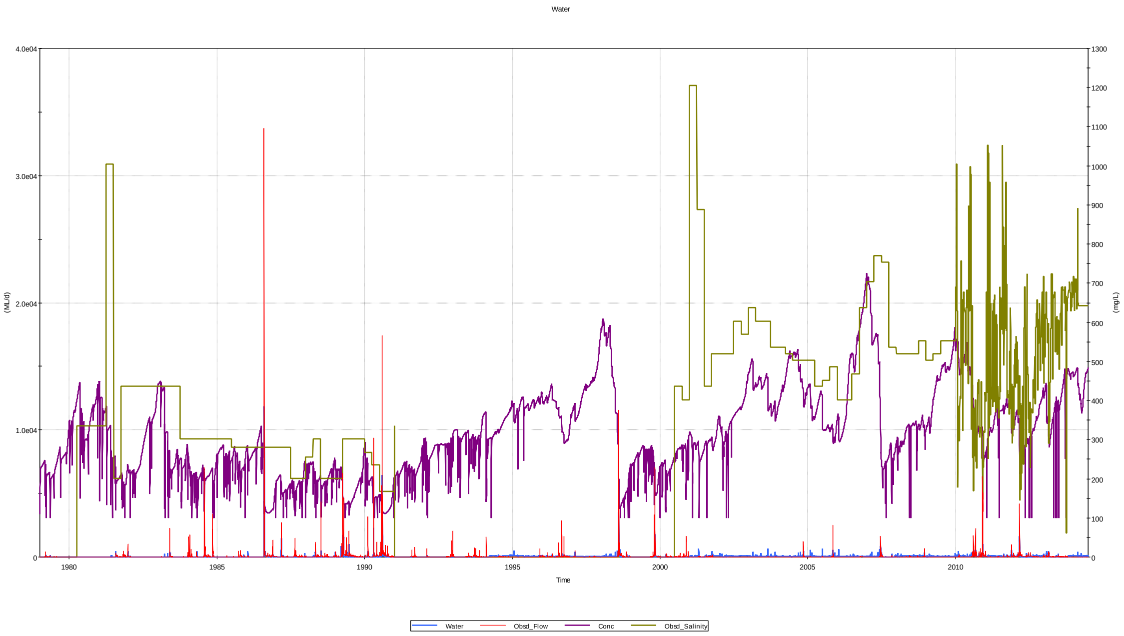
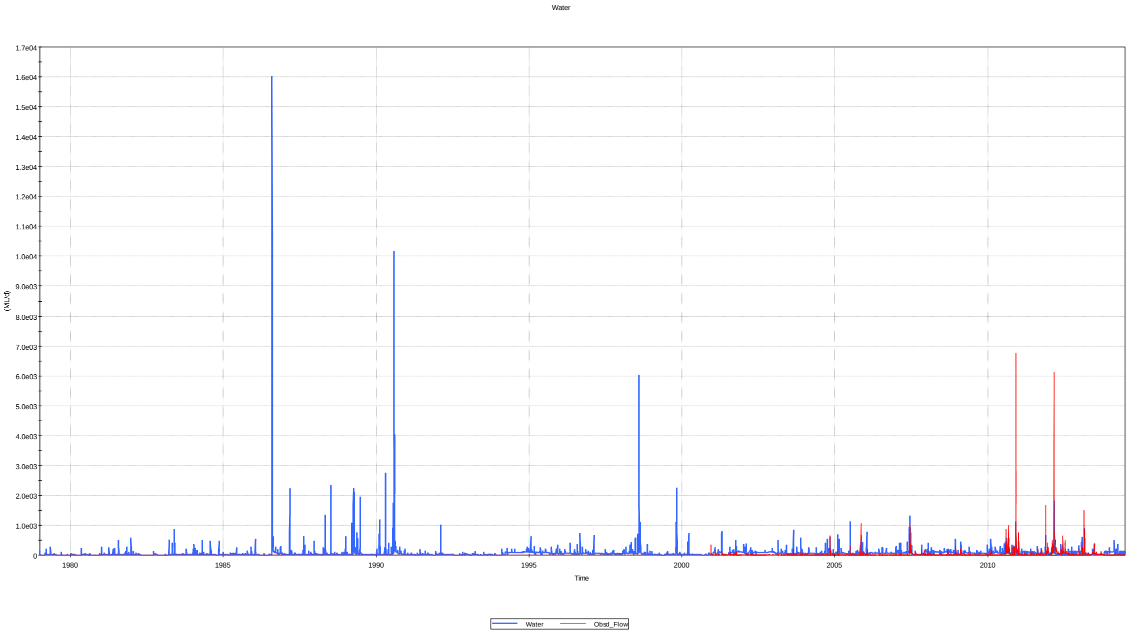


#032: Coxs River below Lake Wallace (location of NSW Office of Water Gauge No. 212008)

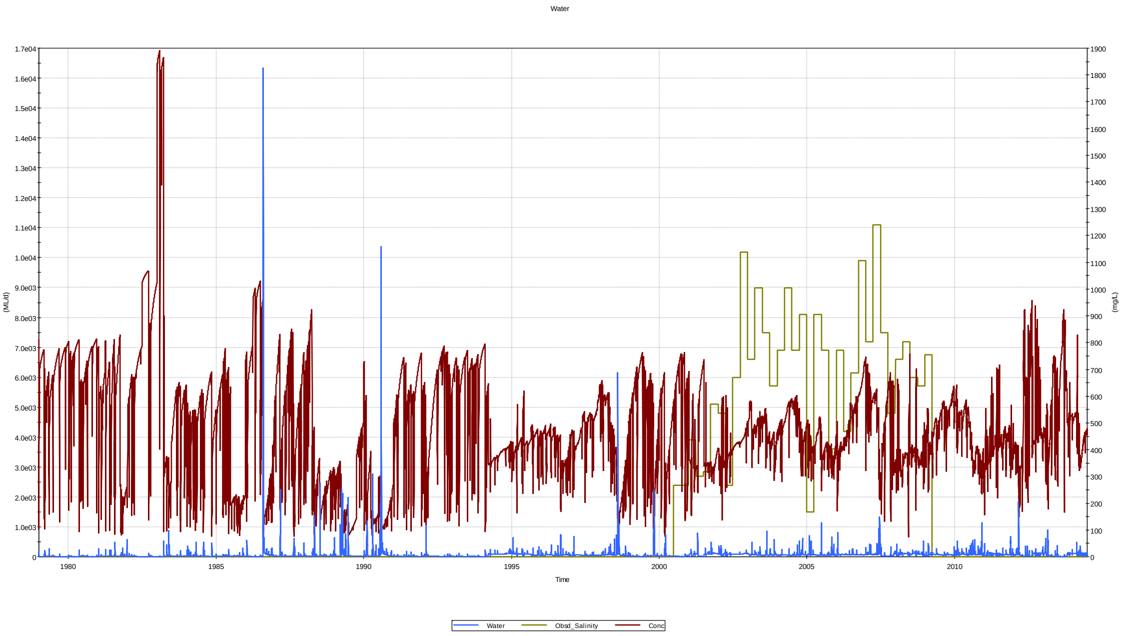


#154: Coxs River above Lake Lyell (location of NSW Office of Water Gauge No. 212058)

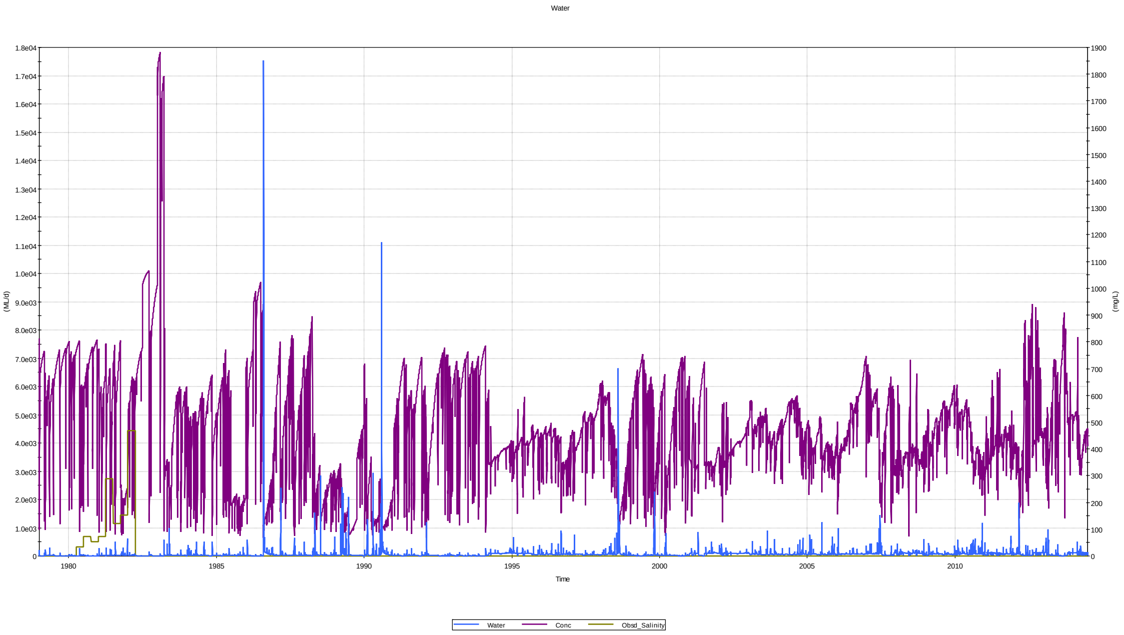
LEGEND:

Modelled Flow (ML/d), Volume (ML)
Observed Flow (ML/d), Volume (ML)
Modelled Salinity (mg/L)
Observed Salinity (mg/L)

**CALIBRATION RESULTS – LAKE LYELL AND ABOVE LAKE LYELL** FIGURE 3.6A



#035: Coxs River below Lake Wallace (location of Energy Australia Monitoring Location, COX5)

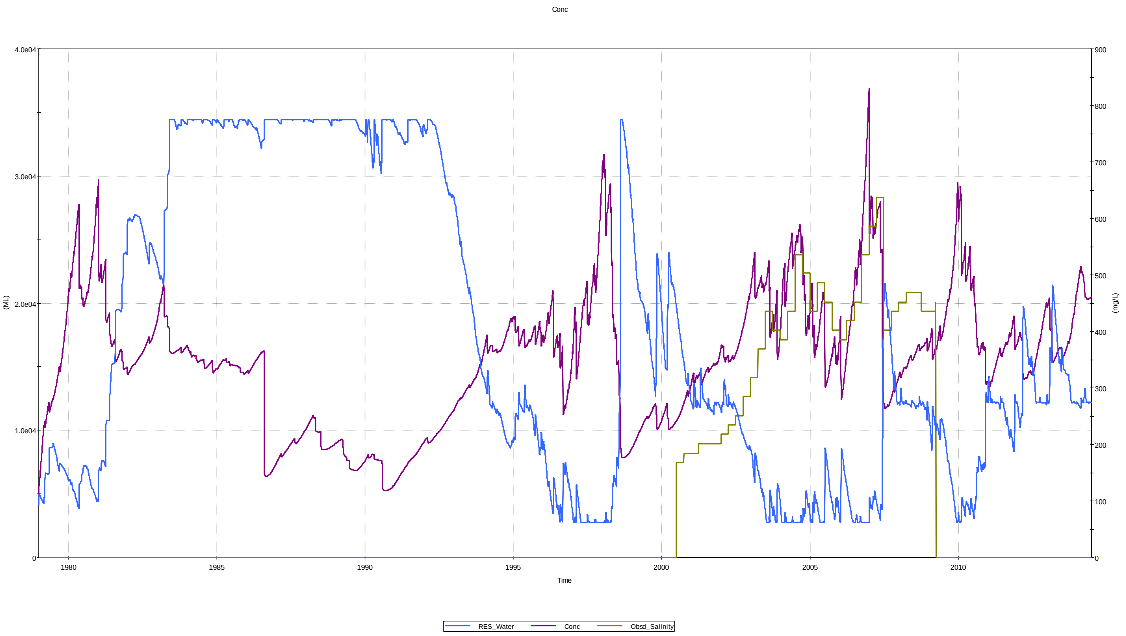


#117: Coxs River above Farmers Creek (location of AWT Monitoring Location, E039)

LEGEND:

— Modelled Flow (ML/d), Volume (ML)
— Observed Flow (ML/d), Volume (ML)
— Modelled Salinity (mg/L)
— Observed Salinity (mg/L)

**CALIBRATION RESULTS – LAKE LYELL AND ABOVE LAKE LYELL** FIGURE 3.6B

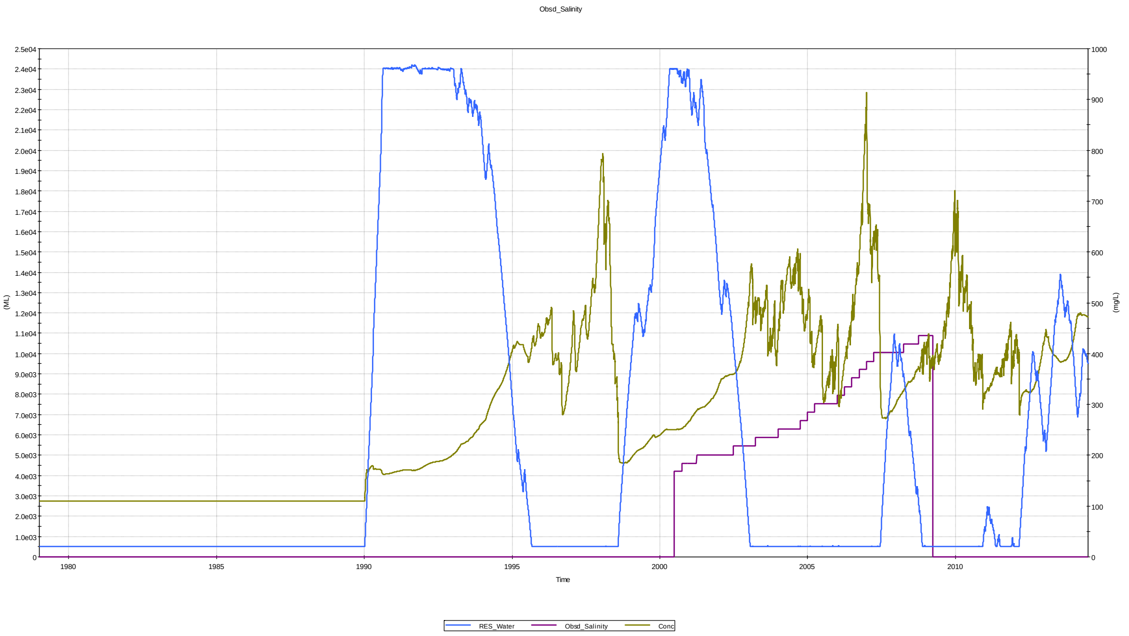


#174: Lake Lyell

LEGEND:

— Modelled Flow (ML/d), Volume (ML)
— Observed Flow (ML/d), Volume (ML)
— Modelled Salinity (mg/L)
— Observed Salinity (mg/L)

**CALIBRATION RESULTS – LAKE LYELL AND ABOVE LAKE LYELL** FIGURE 3.6C

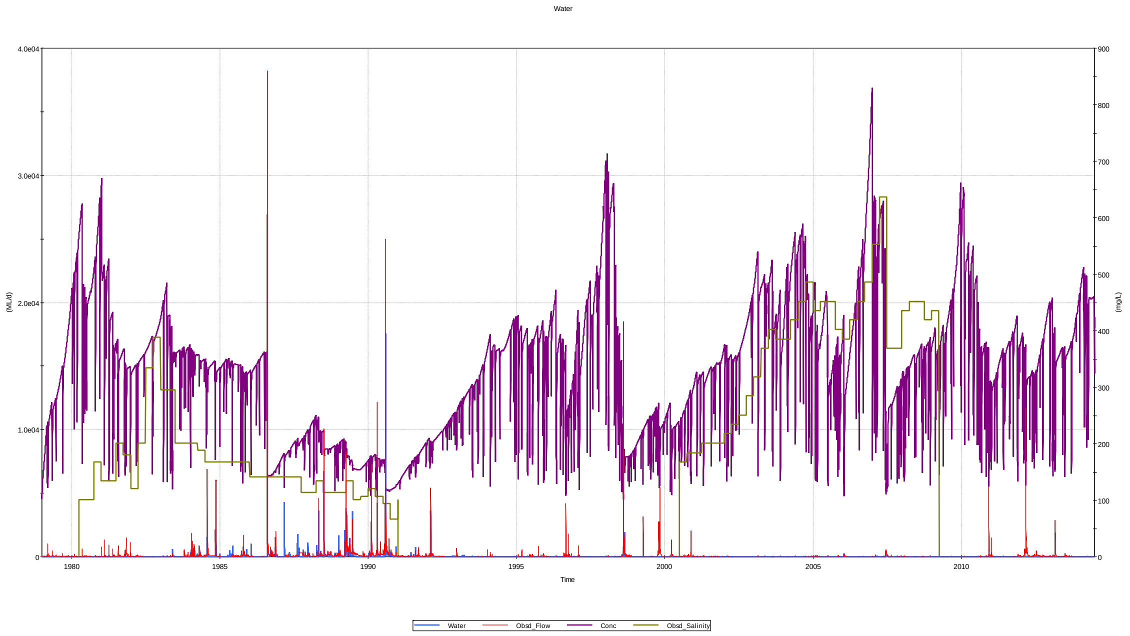


## #272: Thompsons Creek Reservoir

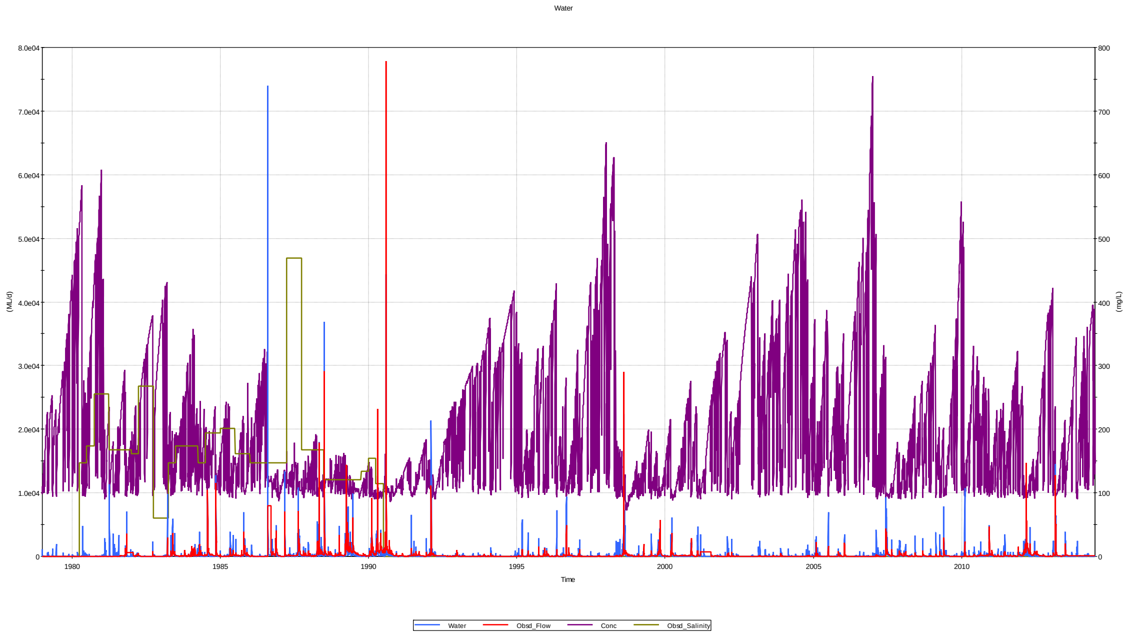
LEGEND:

— Modelled Flow (ML/d), Volume (ML)
— Observed Flow (ML/d), Volume (ML)
— Modelled Salinity (mg/L)
— Observed Salinity (mg/L)

**MODEL CALIBRATION RESULTS – THOMPSONS CREEK RESERVOIR** FIGURE 3.7



#209: Coxs River below Lake Lyell (location of NSW Office of Water Gauge No.212011)



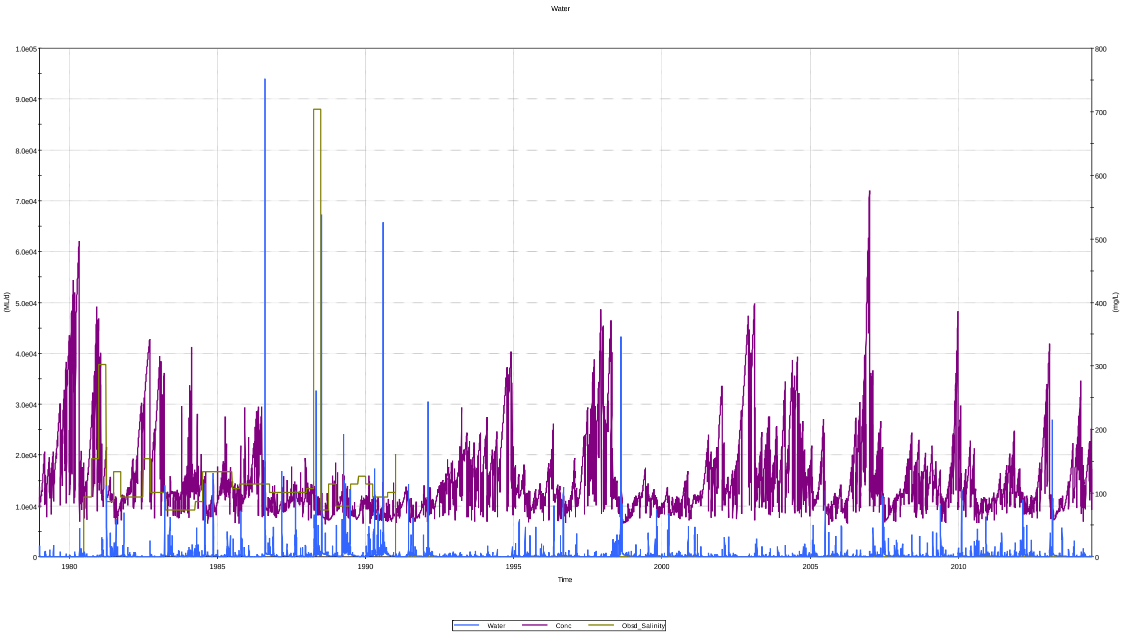
#221: Coxs River above Little River (location of NSW Office of Water Gauge No. 212045)

LEGEND:

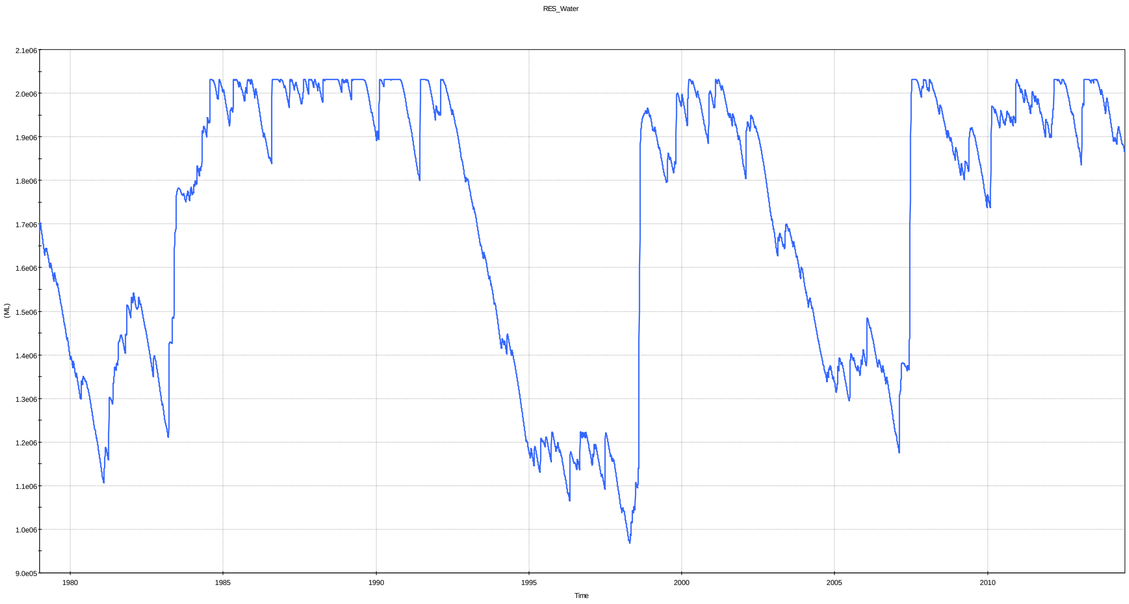
— Modelled Flow (ML/d), Volume (ML)
— Observed Flow (ML/d), Volume (ML)
— Modelled Salinity (mg/L)
— Observed Salinity (mg/L)

RPS

**CALIBRATION RESULTS – LAKE BURRAGORANG AND ABOVE** FIGURE 3.8A



#225: Coxs River immediately above Lake Burragorang (location of AWT monitoring site E083)



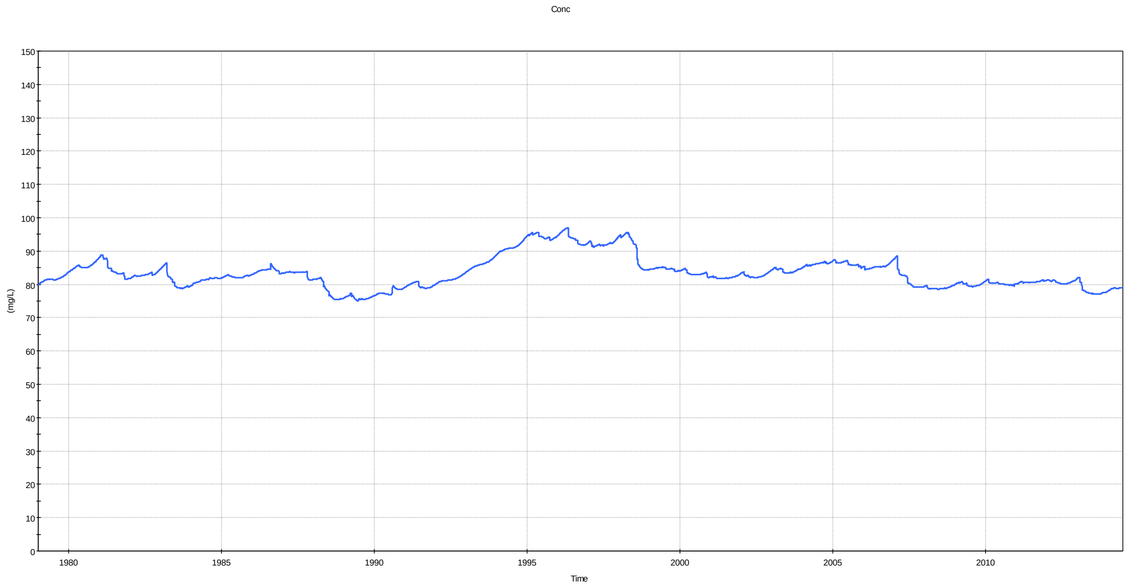
#280: Lake Burragorang (Volume, ML)

LEGEND:

— Modelled Flow (ML/d), Volume (ML)
— Observed Flow (ML/d), Volume (ML)
— Modelled Salinity (mg/L)
— Observed Salinity (mg/L)

RPS

**CALIBRATION RESULTS – LAKE BURRAGORANG AND ABOVE** FIGURE 3.8B



#280: Lake Burragorang (Salinity, mg/L)

LEGEND:

― Modelled Flow (ML/d), Volume (ML)
― Observed Flow (ML/d), Volume (ML)
― Modelled Salinity (mg/L)
― Observed Salinity (mg/L)

**CALIBRATION RESULTS – LAKE BURRAGORANG AND ABOVE** FIGURE 3.8C

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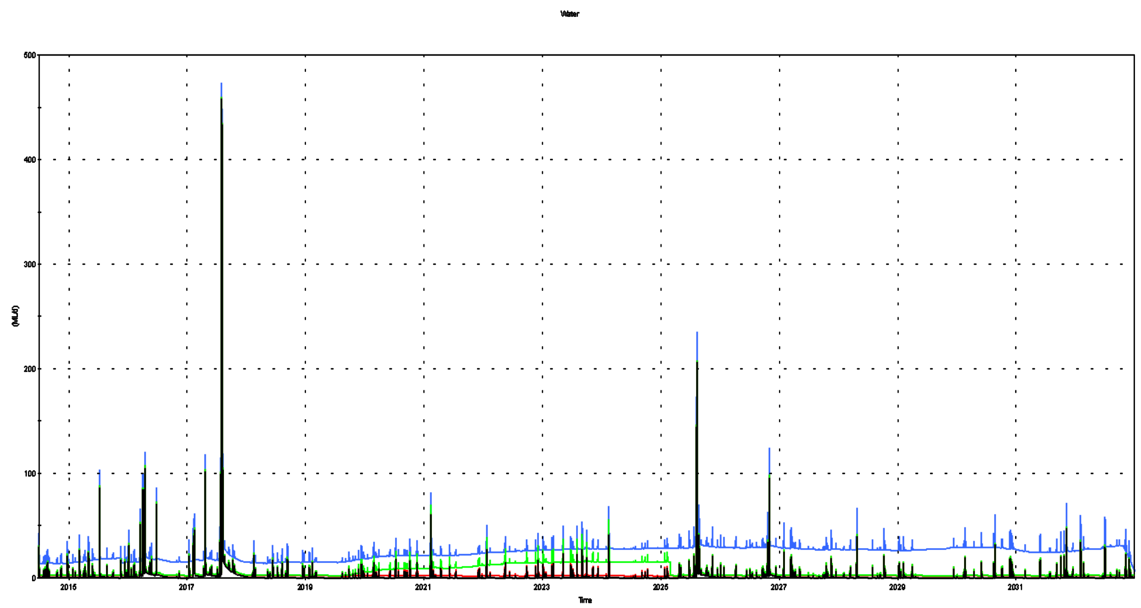
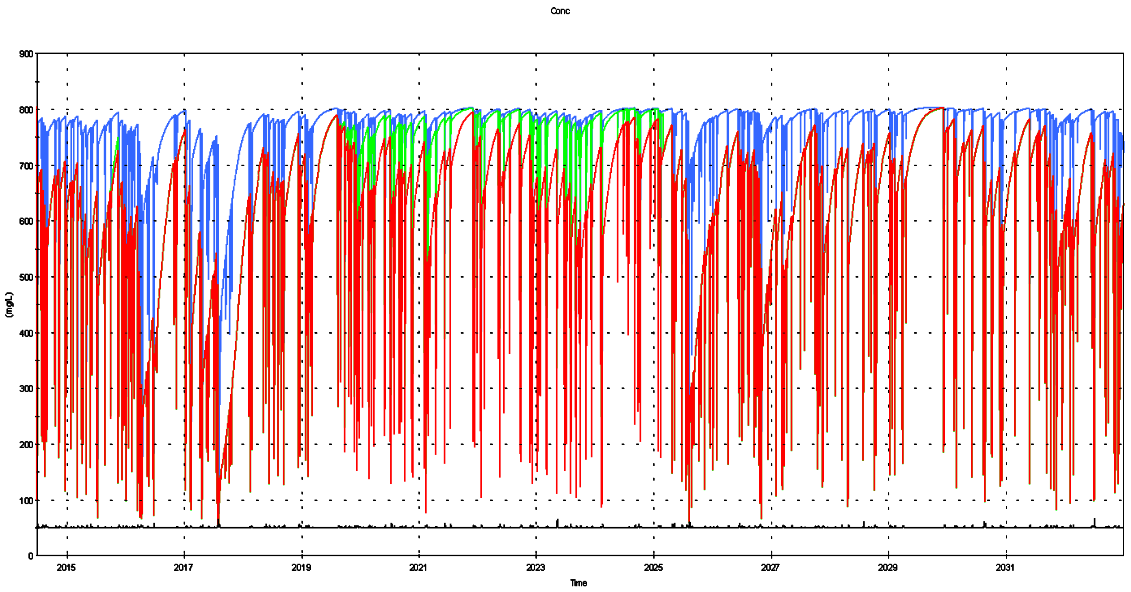


#011: Kangaroo Creek below Angus Place LDP001 (Flow, ML/d)

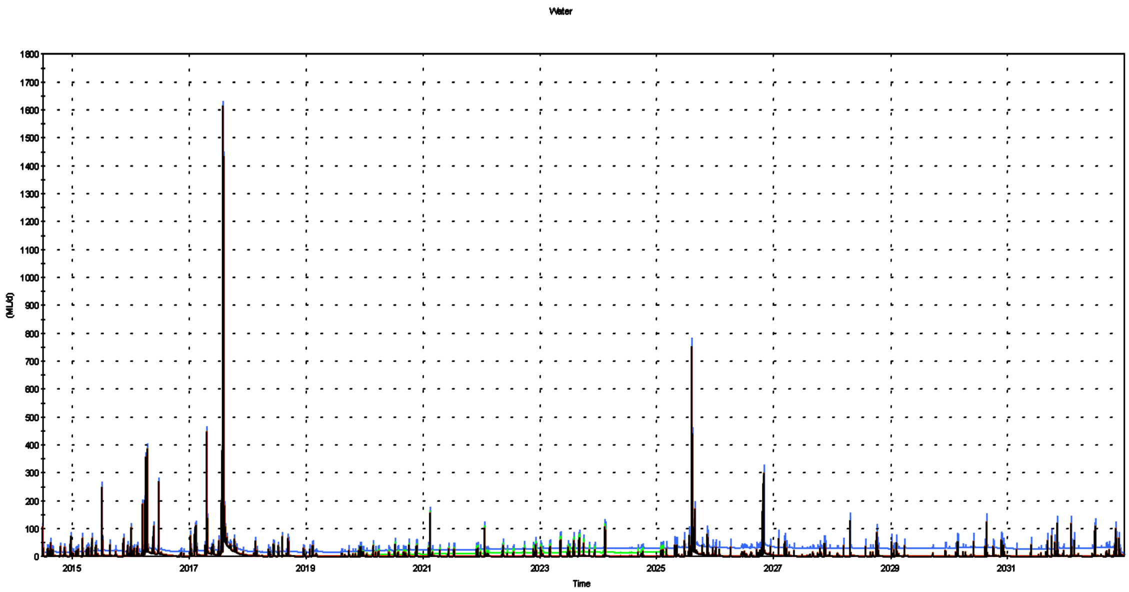


#011: Kangaroo Creek below Angus Place LDP001 (Salinity, mg/L)

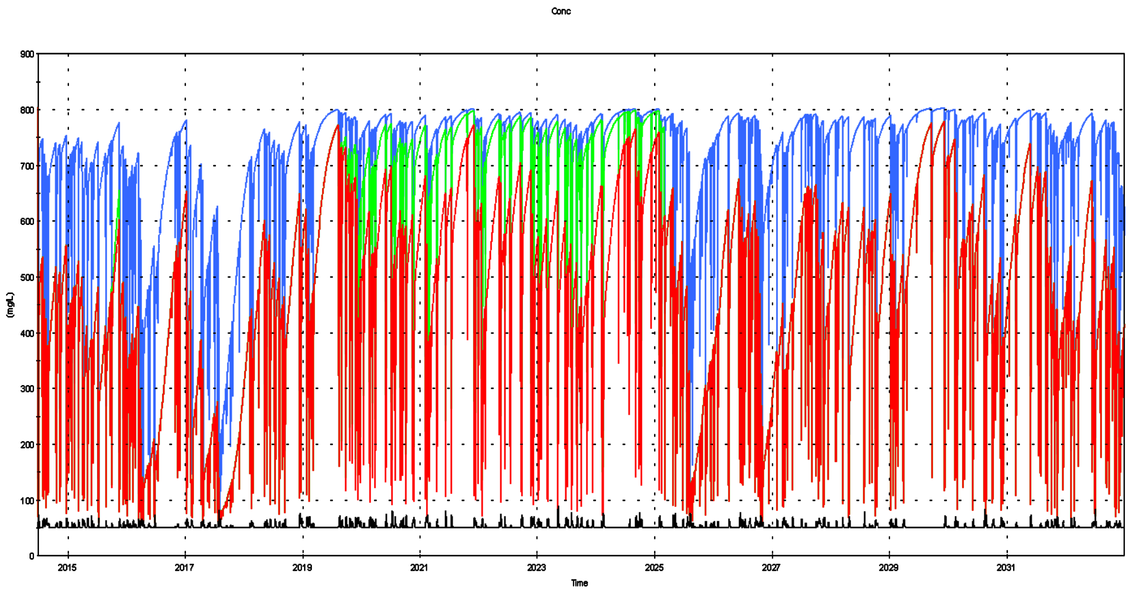
LEGEND:

| | |
|---|---|
| ▬ | WS1 |
| ▬ | WS2 |
| ▬ | WS3 |
| ▬ | Null Case |

**PREDICTION RESULTS – KANGAROO CK & COXS R ABOVE WANGCOL** FIGURE 3.9A



#056: Coxs River above Wangcol Creek/Blue Lagoon (Flow, ML/d)



#056: Coxs River above Wangcol Creek/Blue Lagoon (Salinity, mg/L)

LEGEND:

— WS1
— WS2
— WS3
— Null Case

**PREDICTION RESULTS – KANGAROO CK & COXS R ABOVE WANGCOL** FIGURE 3.9B

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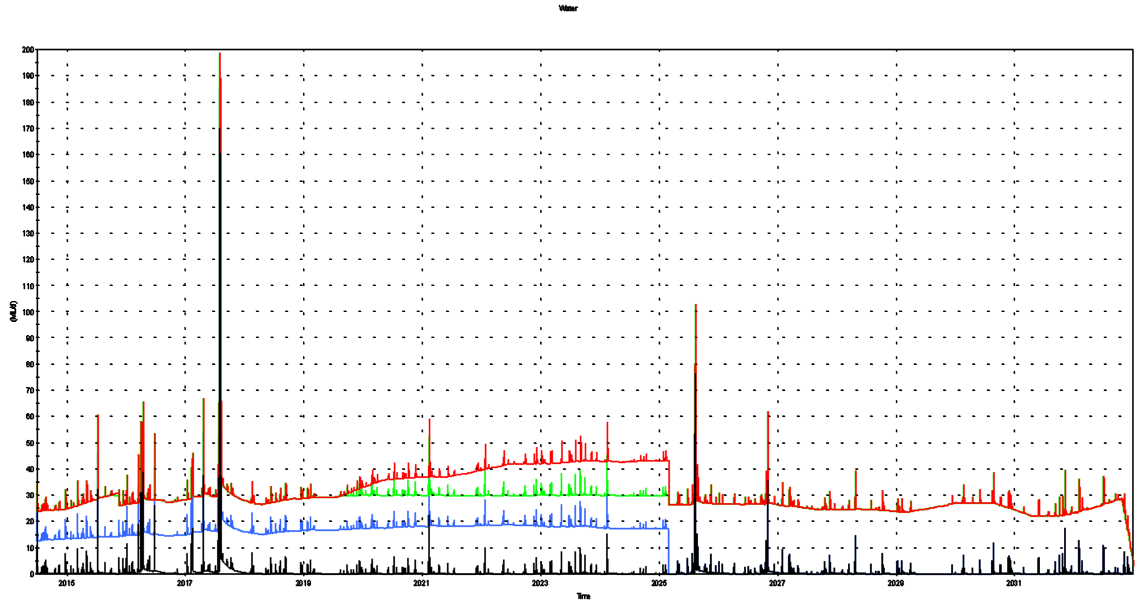
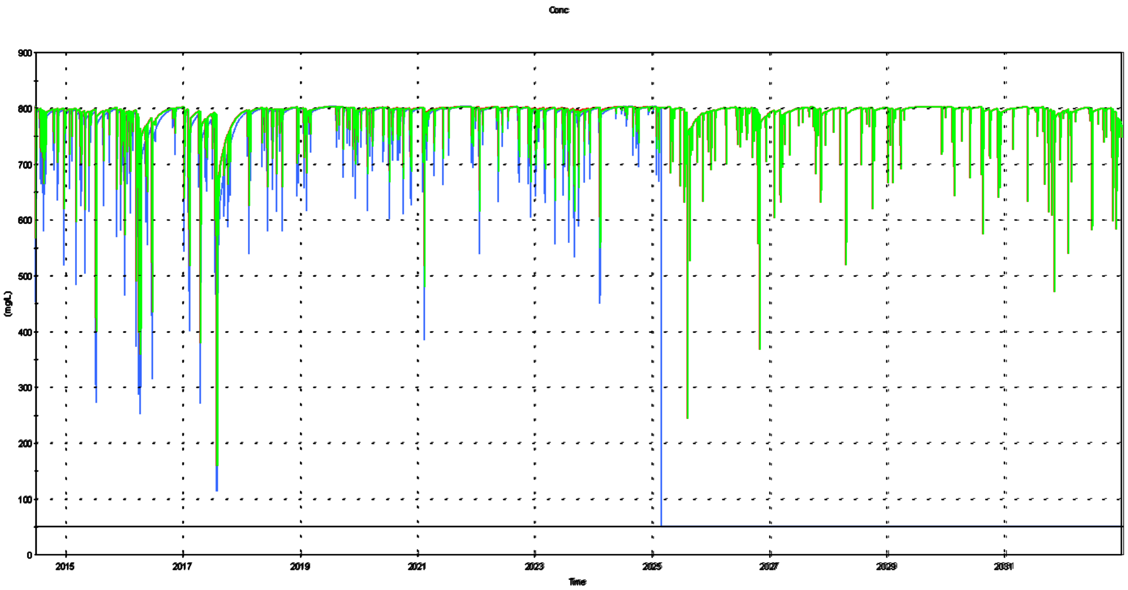


#014: Sawyers Swamp Creek below Springvale LDP009 (Flow, ML/d)



#014: Sawyers Swamp Creek below Springvale LDP009 (Salinity, mg/L)

LEGEND:

— WS1

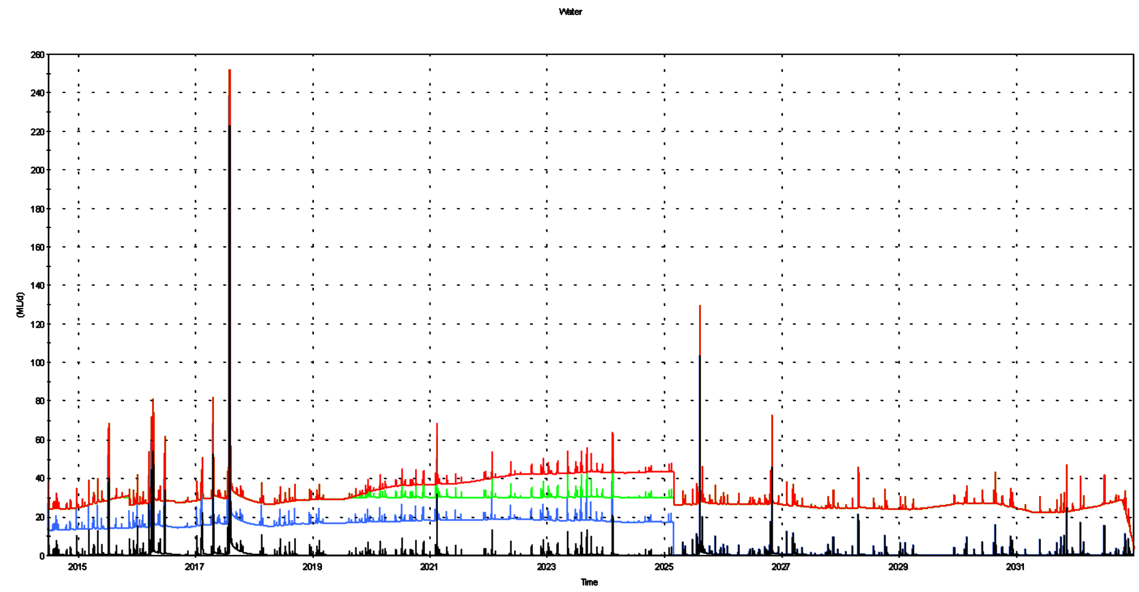
— WS2

— WS3

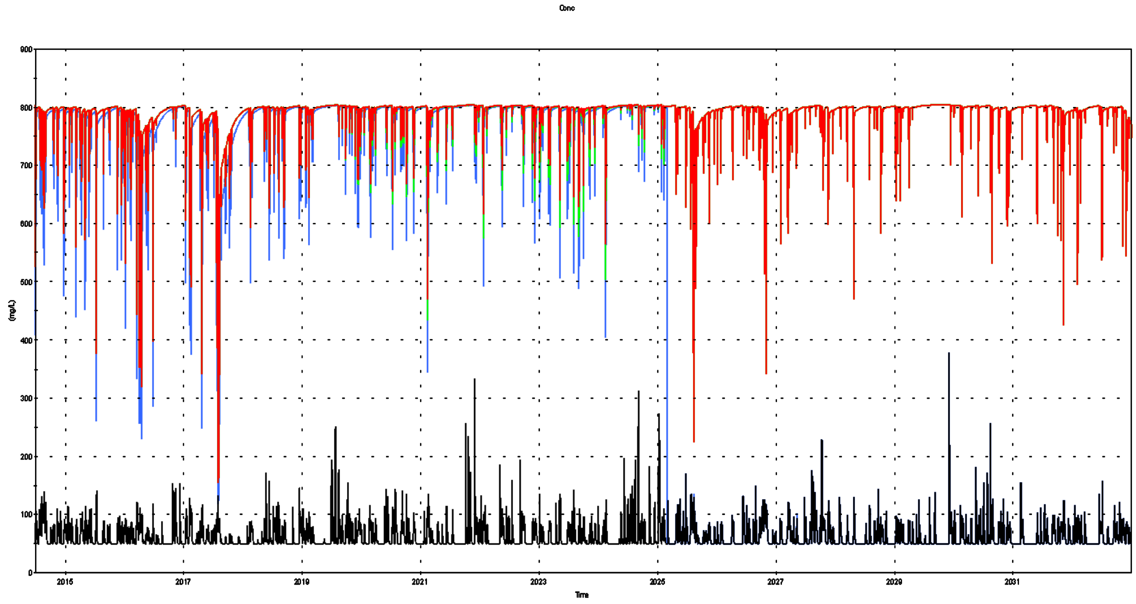
— Null Case

RPS

**MODEL PREDICTION RESULTS – SAWYERS SWAMP CREEK** FIGURE 3.10A



#166: Sawyers Swamp Creek above Coxs River (Flow, ML/d)



#166: Sawyers Swamp Creek above Coxs River (Salinity, mg/L)

LEGEND:

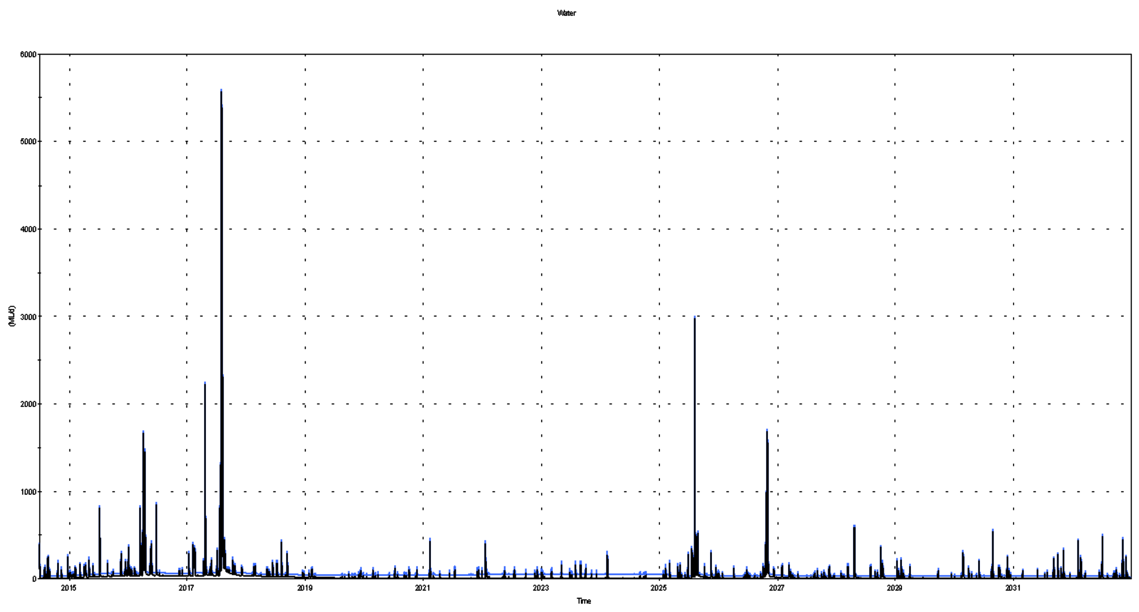
WS1

WS2

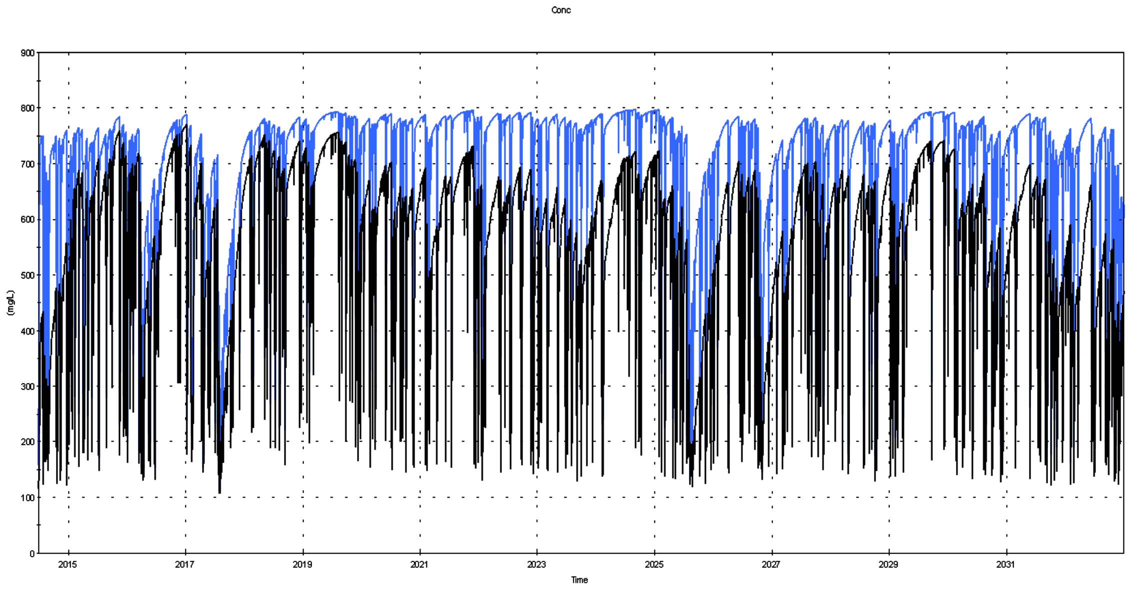
WS3

Null Case

**MODEL PREDICTION RESULTS – SAWYERS SWAMP CREEK** FIGURE 3.10B



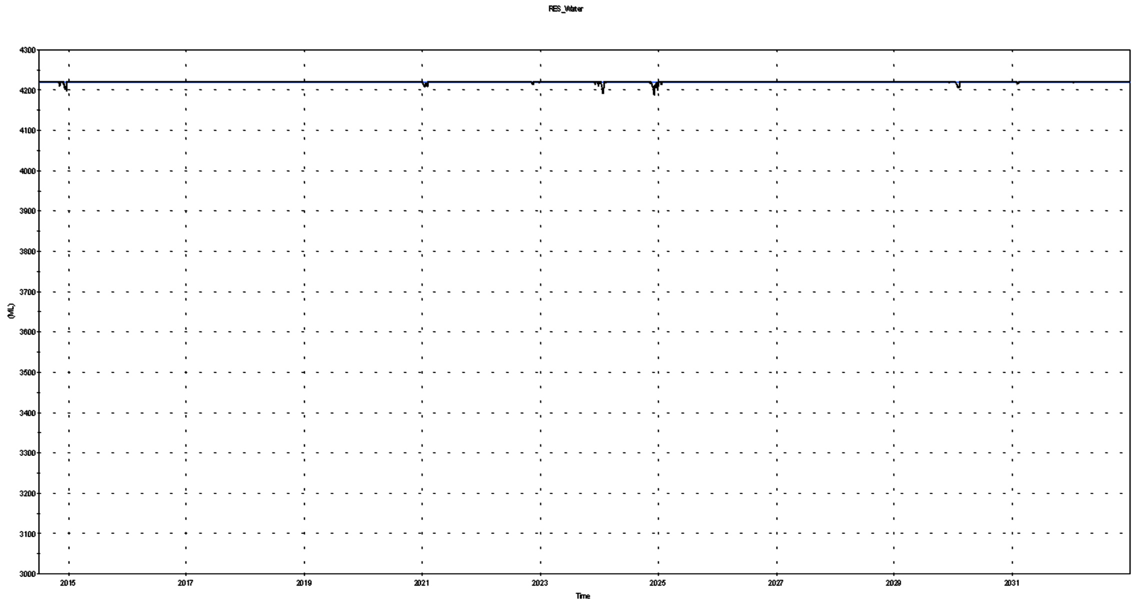
#047: Coxs River above Lake Wallace (Flow, ML/d; location of NSW Office of Water Gauge 212054)



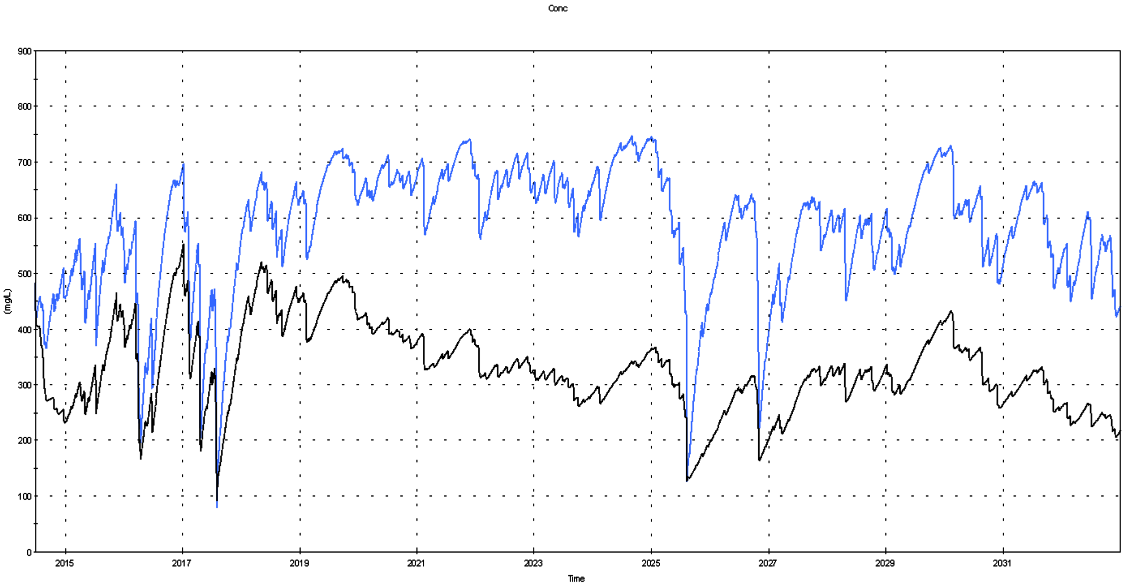
#047: Coxs River above Lake Wallace (Salinity, mg/L; location of NSW Office of Water Gauge 212054)

LEGEND:

— WS1, WS2a & WS2b
— Null Case



#074: Lake Wallace (Volume, ML)

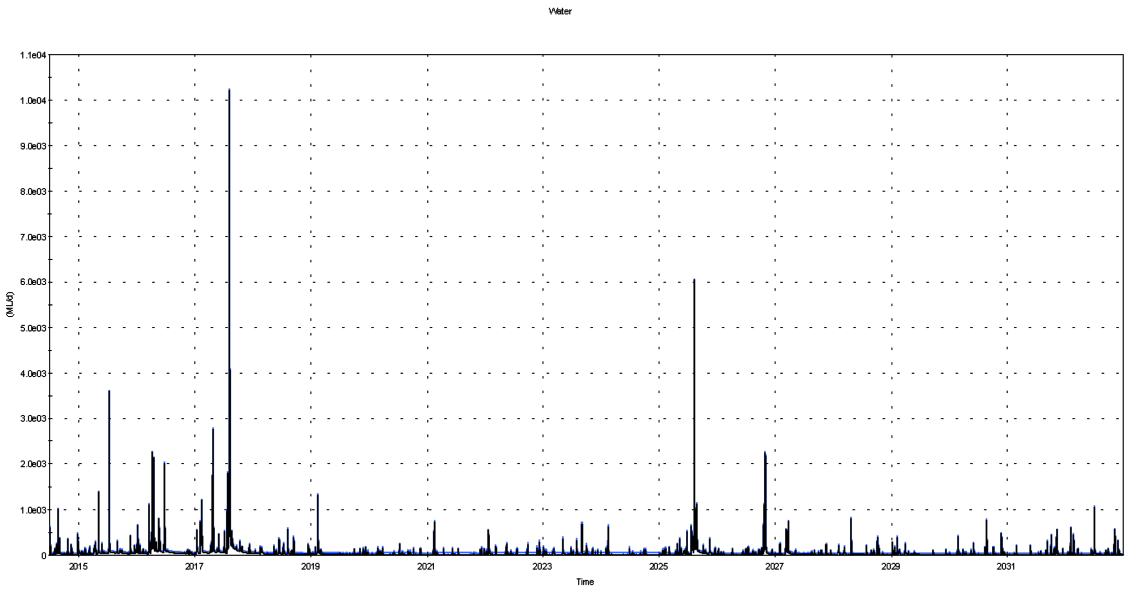


#074: Lake Wallace (Salinity, mg/L)

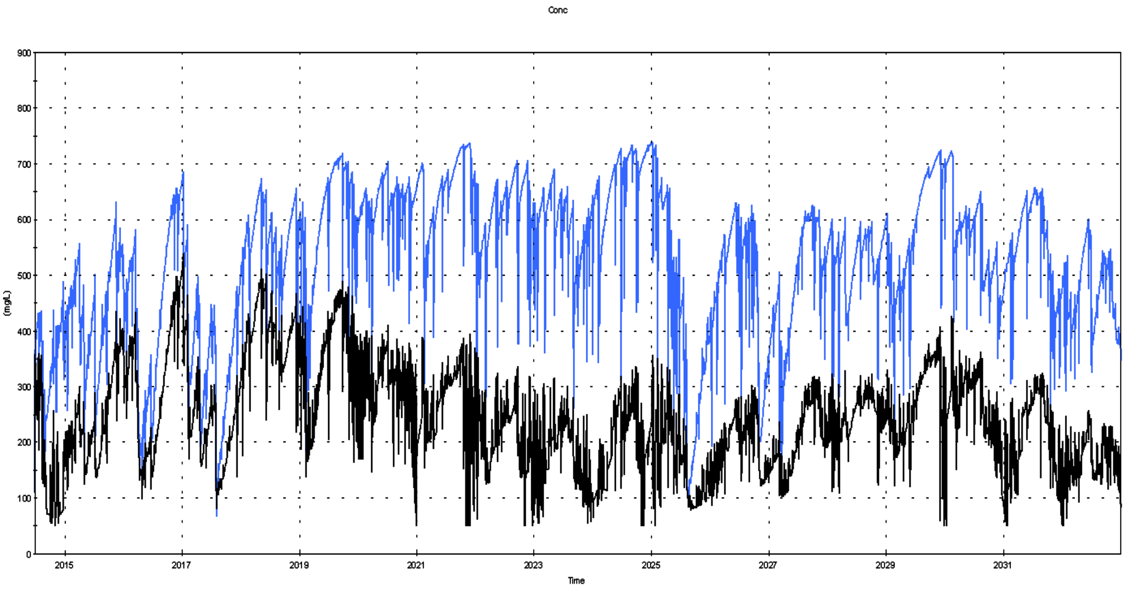
LEGEND:

WS1, WS2a & WS2b
Null Case

**MODEL PREDICTION RESULTS – LAKE WALLACE** FIGURE 3.11B



#154: Coxs River above Lake Lyell (Flow, ML/d; location of NSW Office of Water Gauge 212058)



#035: Coxs River above Lake Lyell (Salinity, mg/L; at Energy Australia Monitoring Location, COX5)

LEGEND:

| | |
|---|---|
| 🟦 | WS1, WS2a & WS2b |
| ■ | Null Case |

RPS

**MODEL PREDICTION RESULTS – LAKE LYELL AND ABOVE** FIGURE 3.12A

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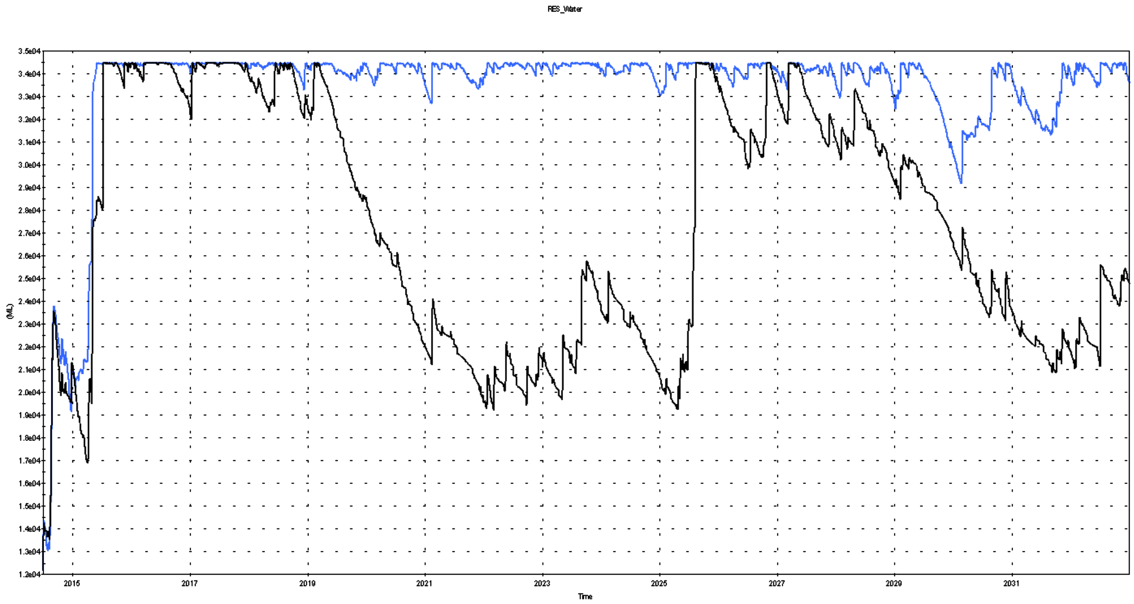
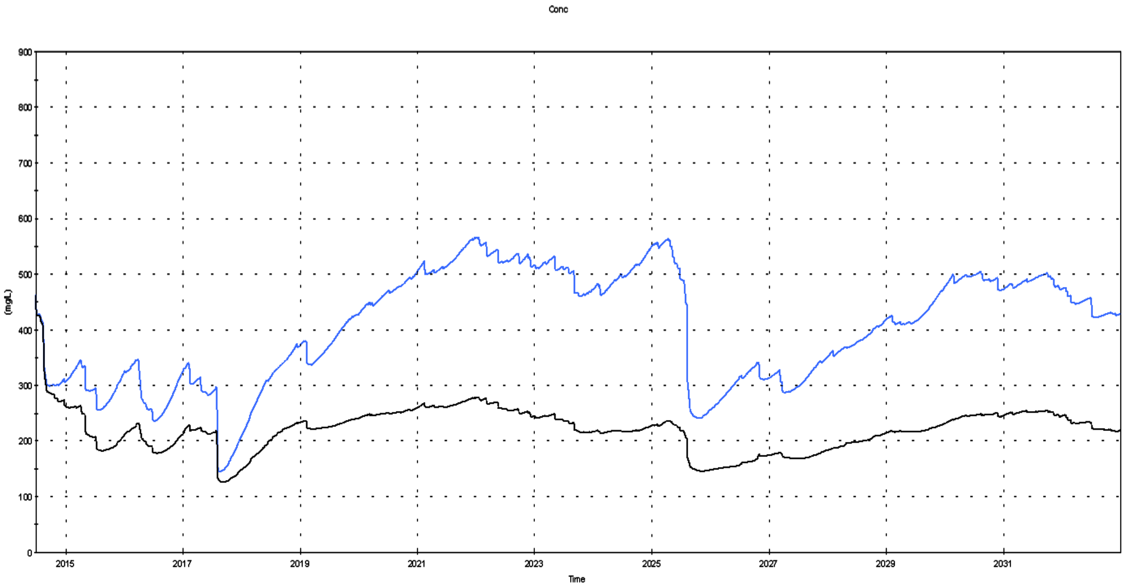


#174: Lake Lyell (Volume, ML)



#174: Lake Lyell (Salinity, mg/L)

LEGEND:

| | |
|---|---|
| 🟦 | WS1, WS2a & WS2b |
| ■ | Null Case |

**MODEL PREDICTION RESULTS – LAKE LYELL AND ABOVE** FIGURE 3.12B

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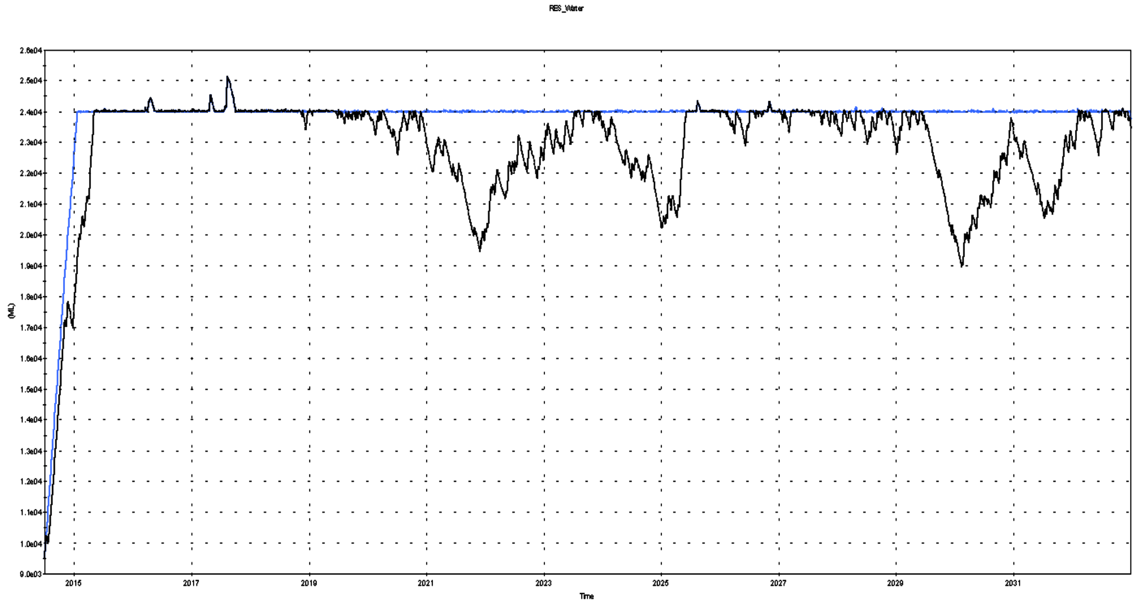
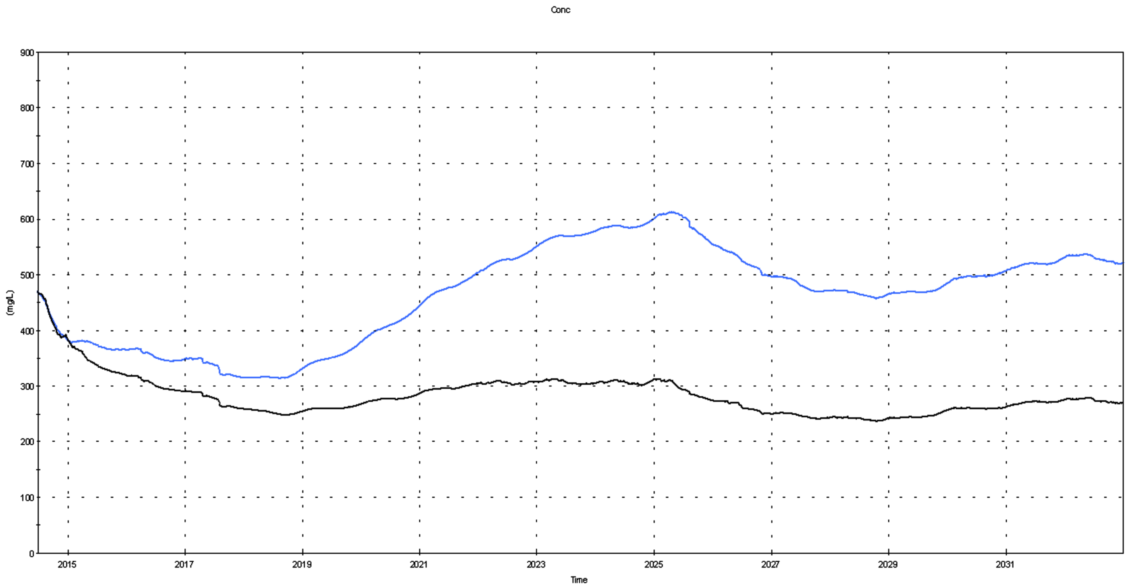


#272: Thompsons Creek Reservoir (Volume, ML)

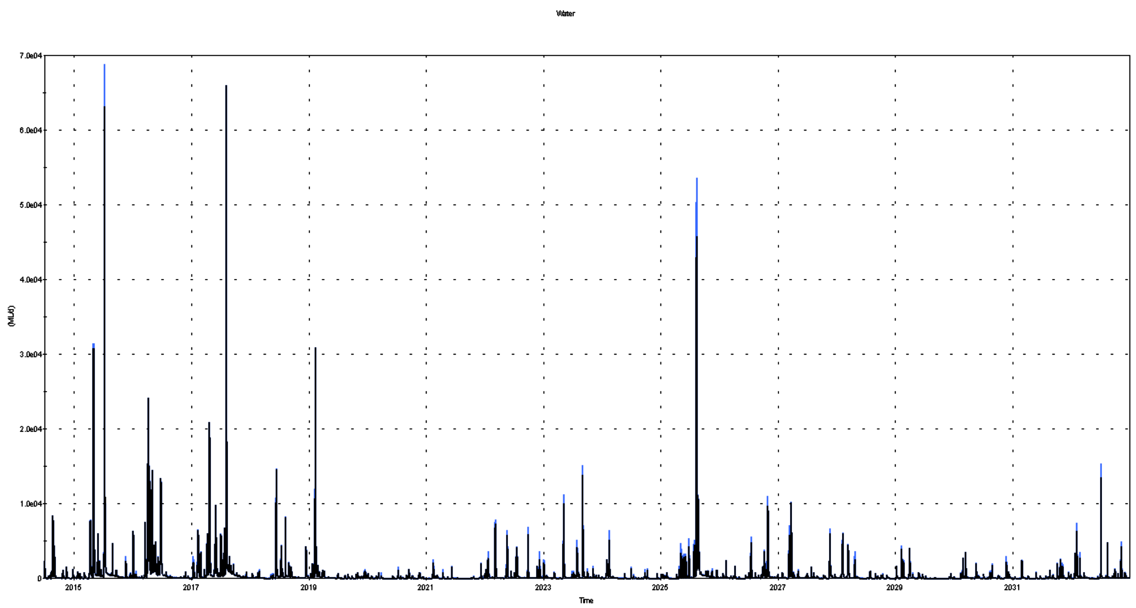


#272: Thompsons Creek Reservoir (Salinity, mg/L)

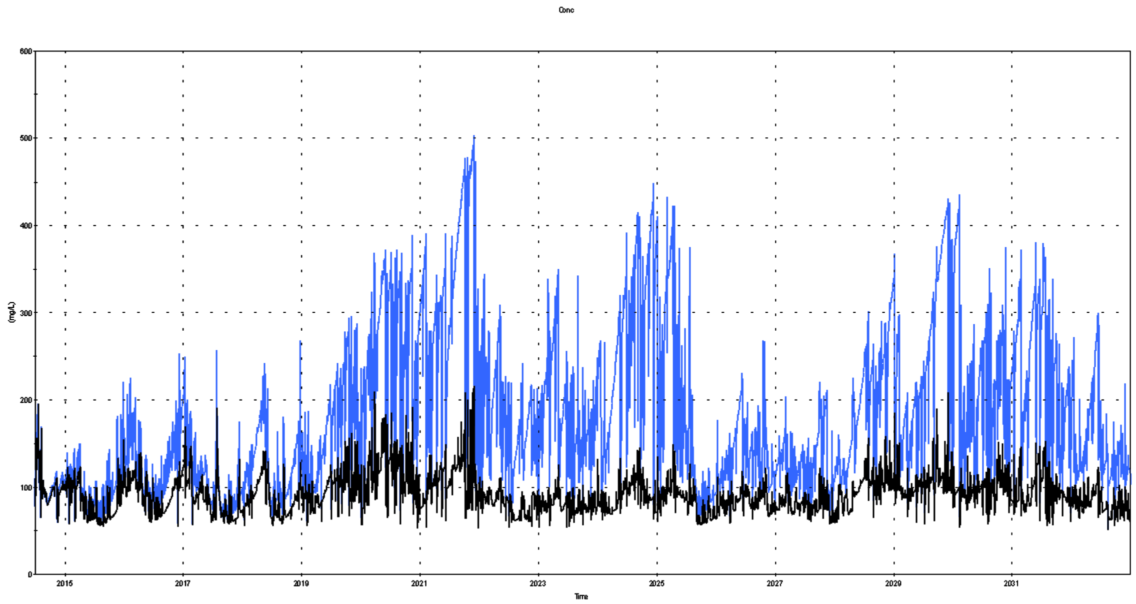
LEGEND:

| | |
|---|---|
| ― | WS1, WS2a & WS2b |
| ― | Null Case |

**MODEL PREDICTION RESULTS – THOMPSONS CREEK RESERVOIR** FIGURE 3.13



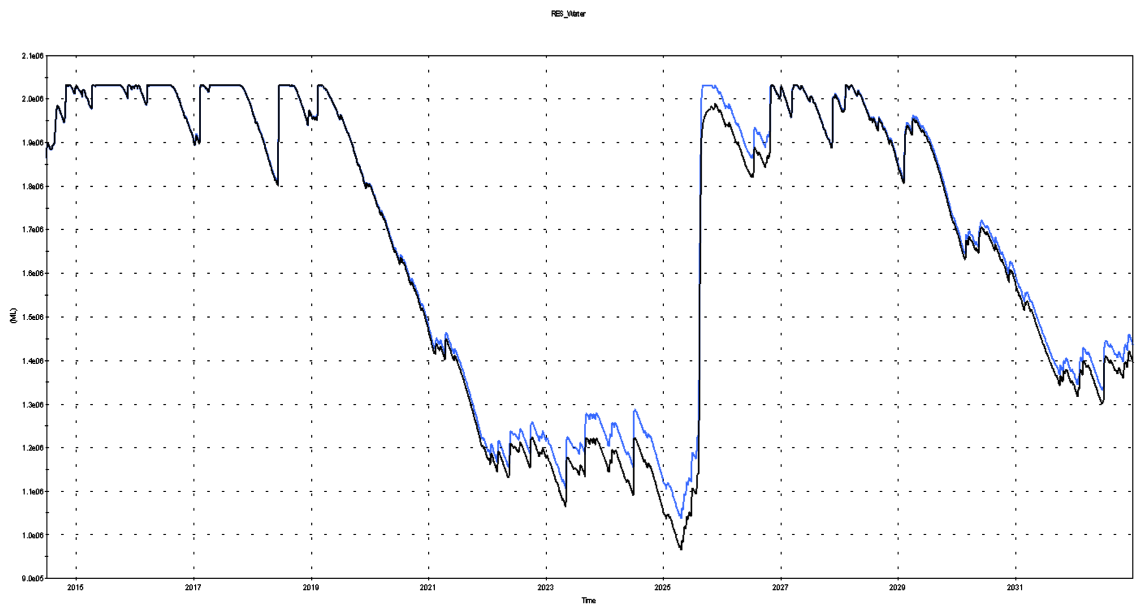
#225: Coxs River immediately above Lake Burragorang (Flow, ML/d)



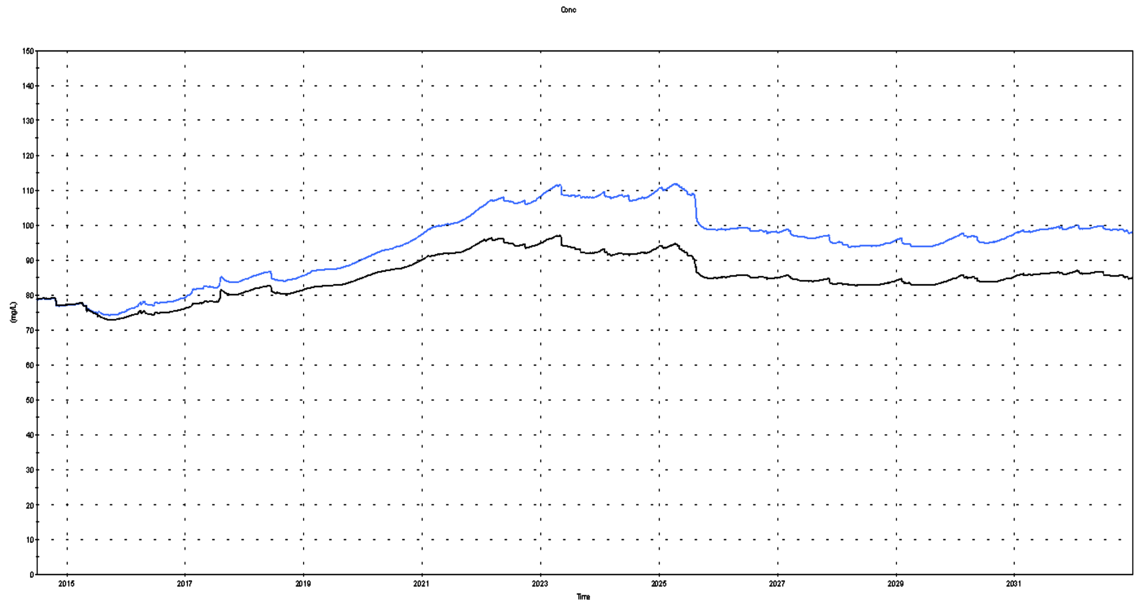
#225: Coxs River immediately above Lake Burragorang (Salinity, mg/L)

LEGEND:

| | |
|---|---|
| ▬ (blue) | WS1, WS2a & WS2b |
| ▬ | Null Case |



#280: Lake Burragorang (Volume, ML)



#074: Lake Burragorang (Salinity, mg/L)

LEGEND:

— WS1, WS2a & WS2b
— Null Case

**MODEL PREDICTION RESULTS – LAKE BURRAGORANG** FIGURE 3.14B

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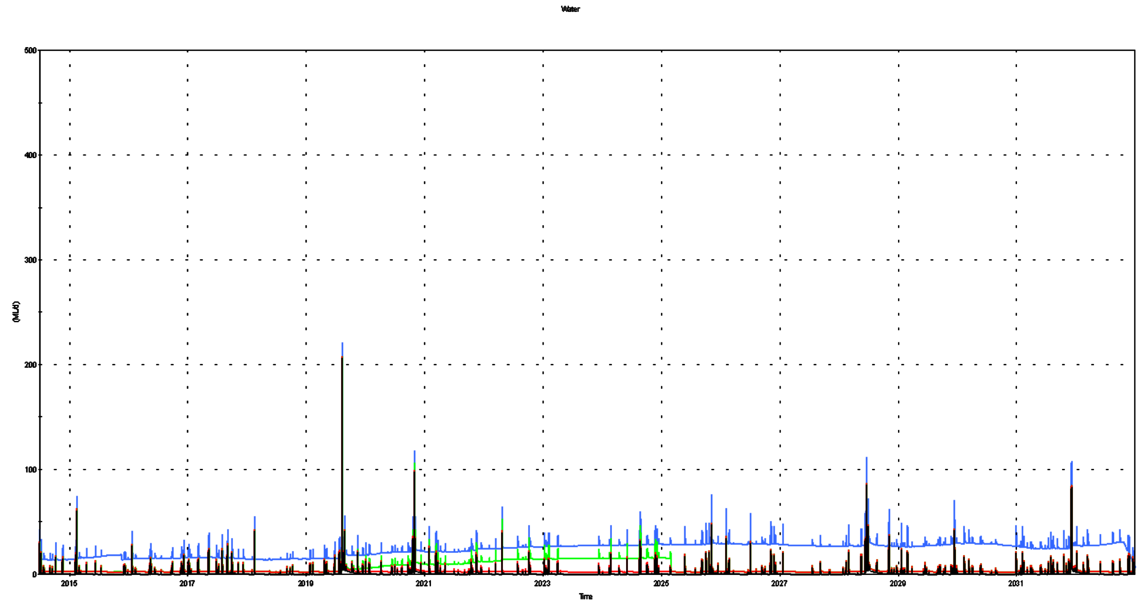
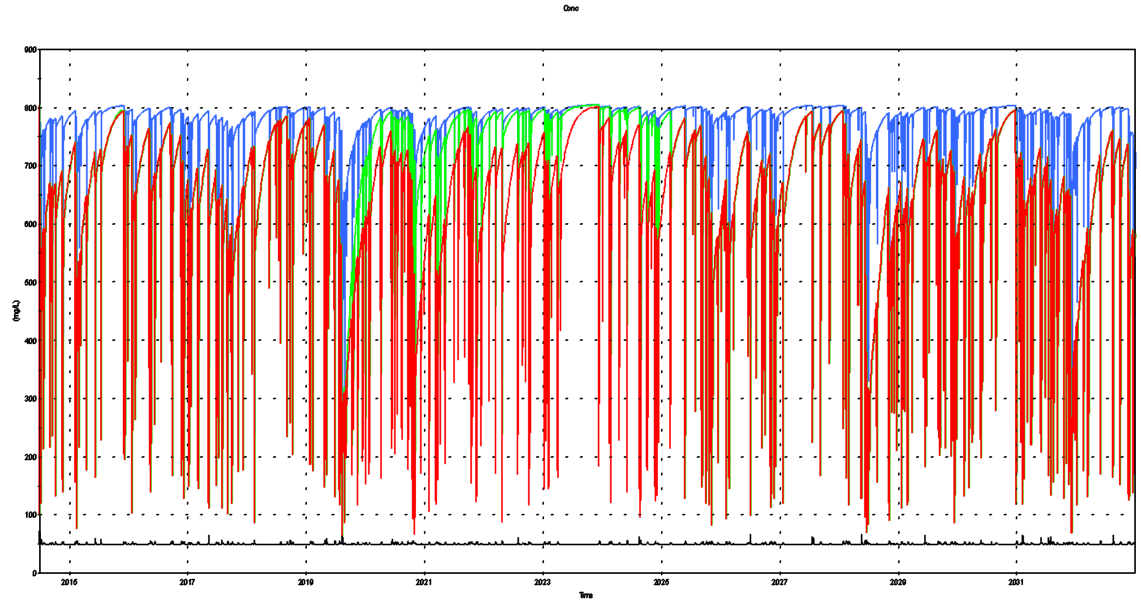


#011: Kangaroo Creek below Angus Place LDP001 (Flow, ML/d)



#011: Kangaroo Creek below Angus Place LDP001 (Salinity, mg/L)

LEGEND:

— WS1
— WS2
— WS3
— Null Case

**UNCERT (LOW RAINFALL) – KANGAROO CK & COXS R ABOVE WANGCOL** FIGURE 3.15

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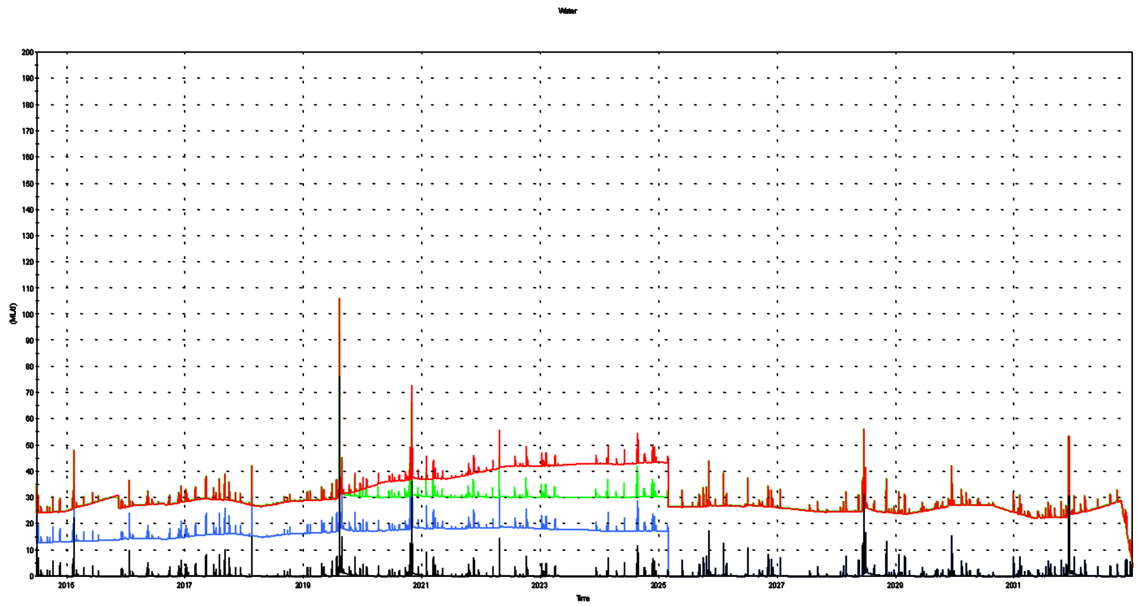
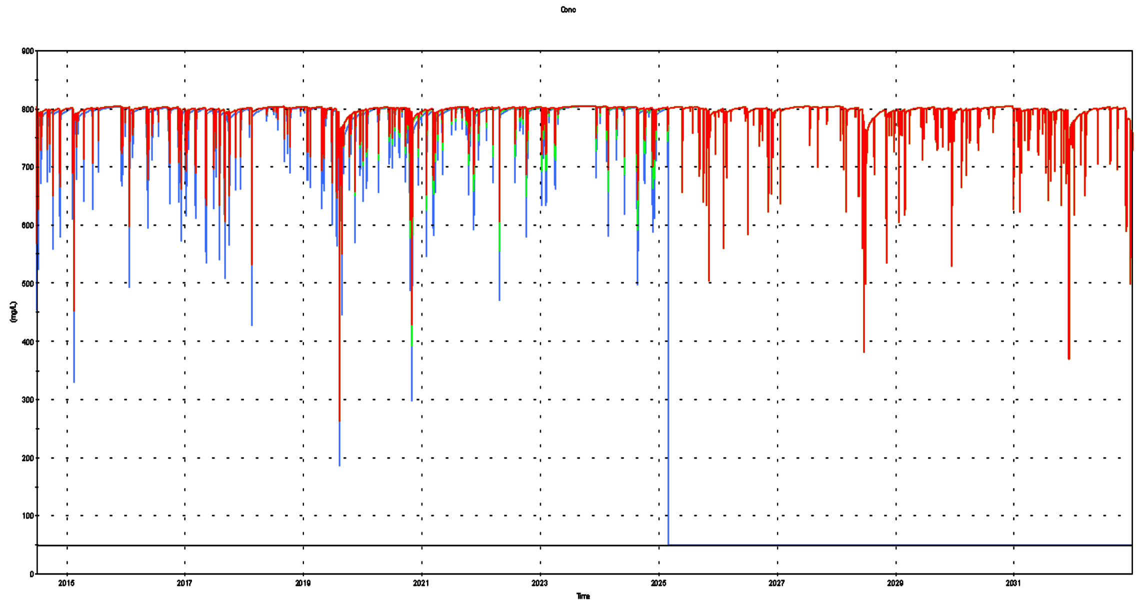


#014: Sawyers Swamp Creek below Springvale LDP009 (Flow, ML/d)

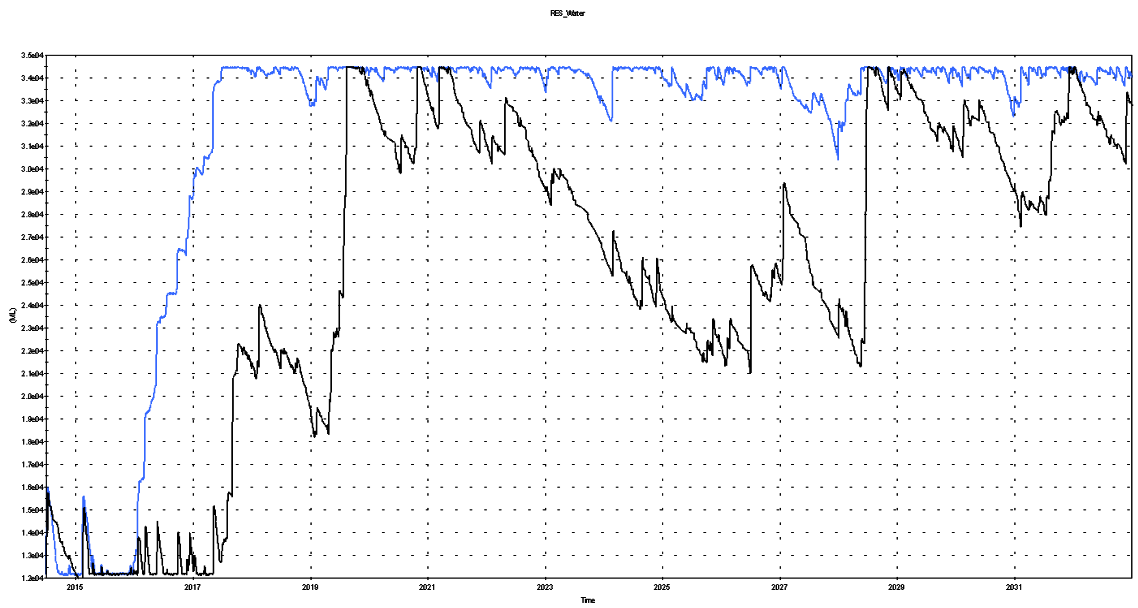


#014: Sawyers Swamp Creek below Springvale LDP009 (Salinity, mg/L)

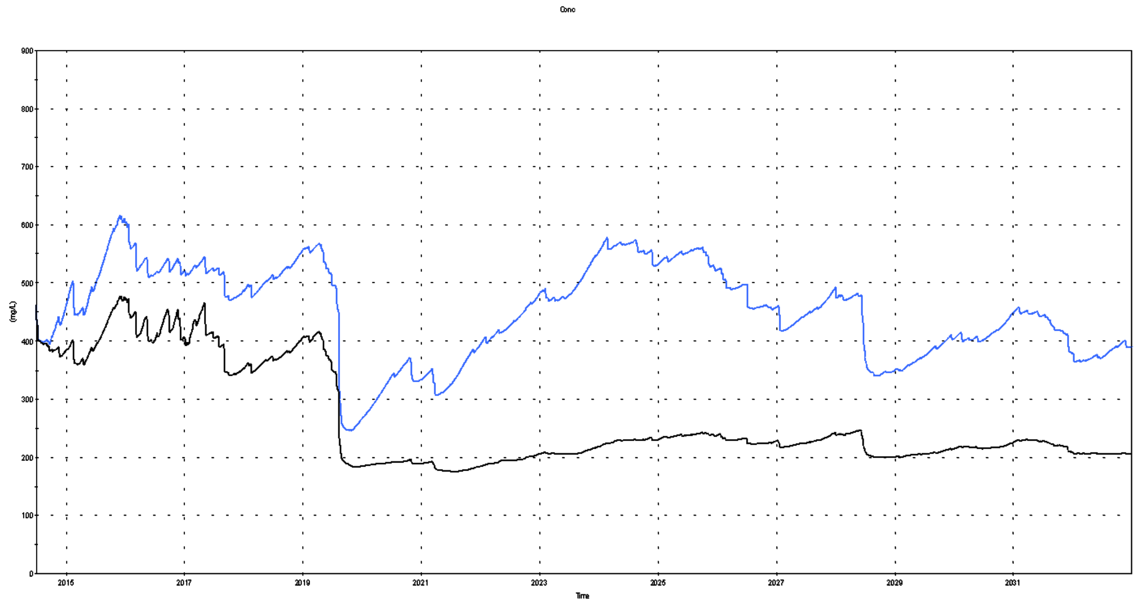
LEGEND:

— WS1
— WS2
— WS3
— Null Case

**UNCERTAINTY RESULTS (LOW RAINFALL) – SAWYERS SWAMP CREEK** FIGURE 3.16



#174: Lake Lyell (Volume, ML)



#174: Lake Lyell (Salinity, mg/L)

LEGEND:

— WS1, WS2a & WS2b

— Null Case

**UNCERTAINTY RESULTS (LOW RAINFALL) – LAKE LYELL AND ABOVE** FIGURE 3.17B

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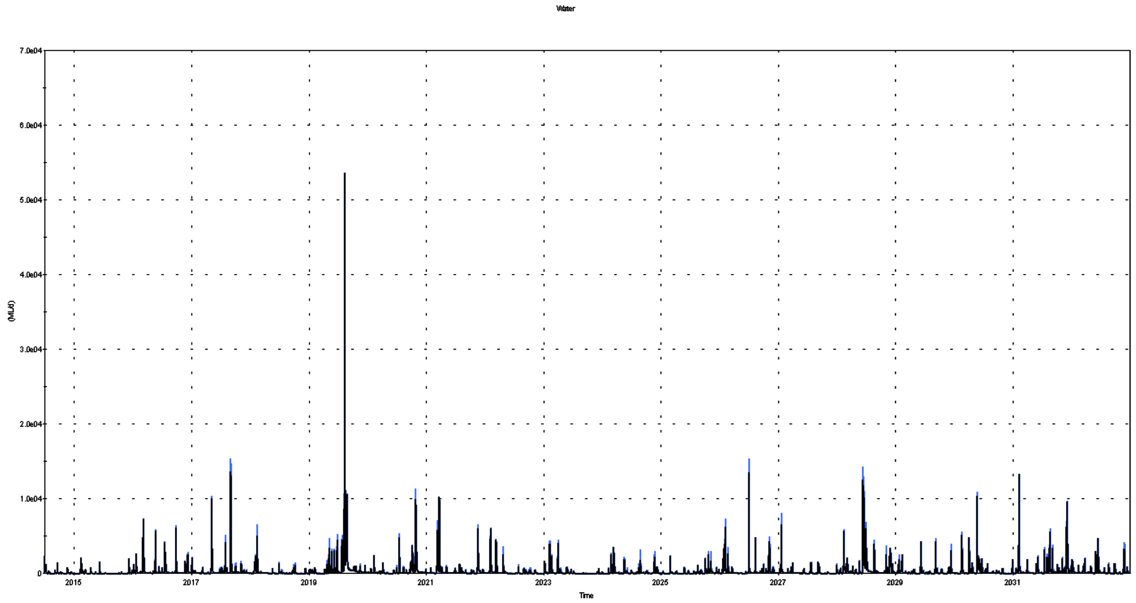
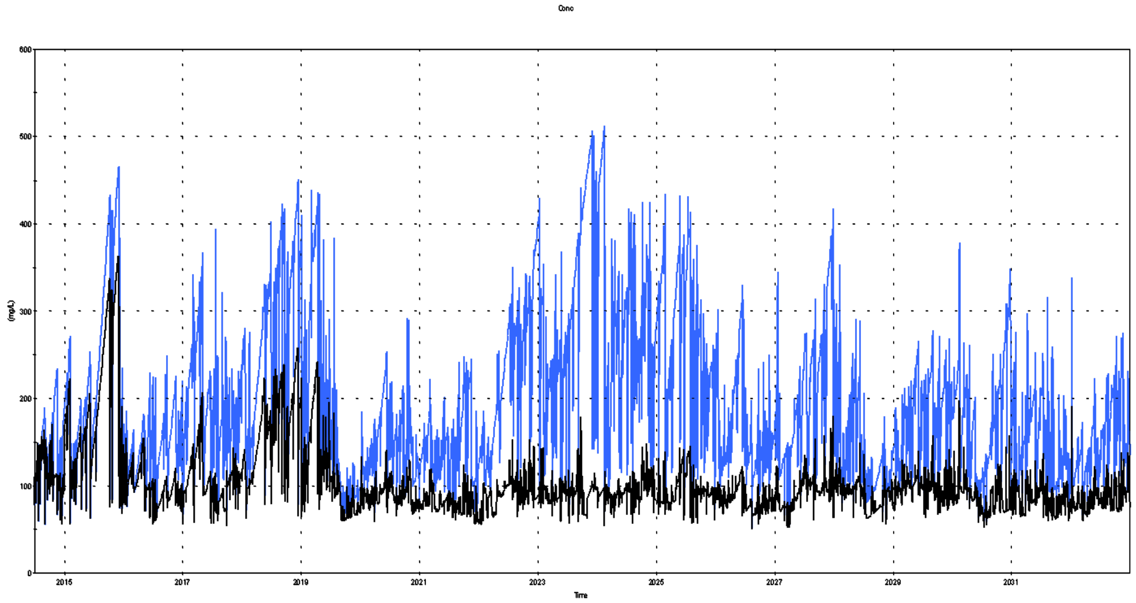


#225: Coxs River immediately above Lake Burragorang (Flow, ML/d)



#225: Coxs River immediately above Lake Burragorang (Salinity, mg/L)

LEGEND:

— WS1, WS2a & WS2b
— Null Case

**UNCERT (LOW RAINFALL) – LAKE BURRAGORANG AND ABOVE** FIGURE 3.18A

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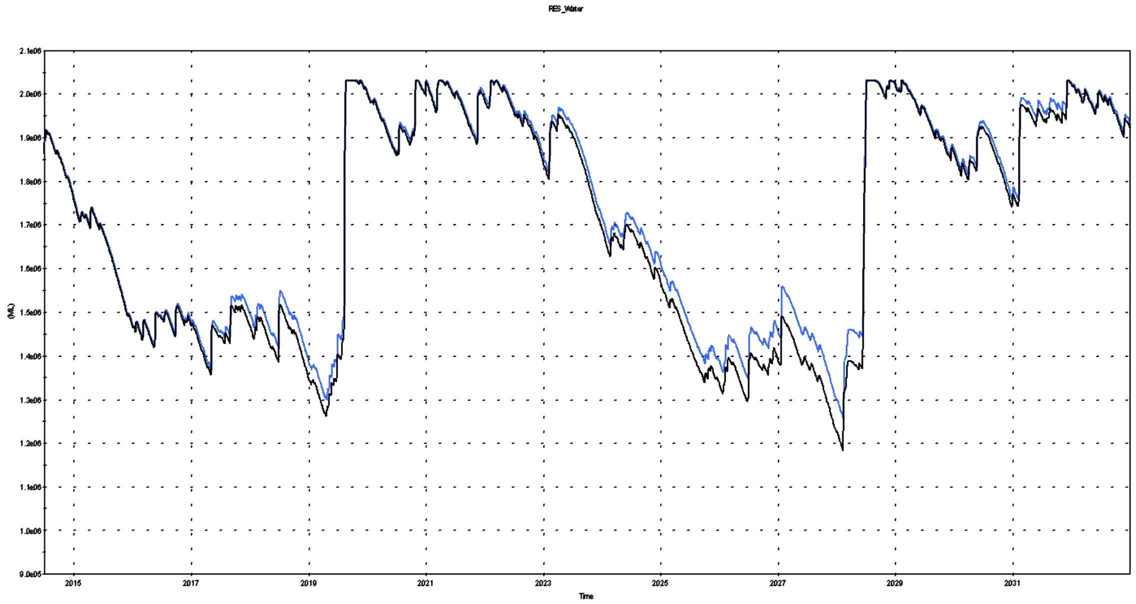
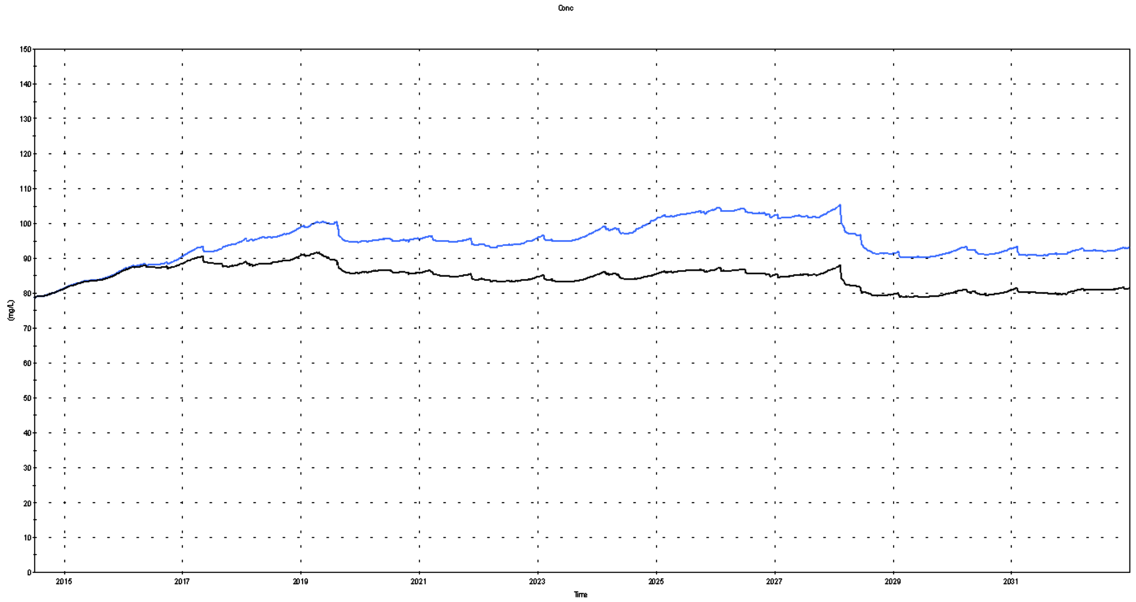


#280: Lake Burragorang (Volume, ML)

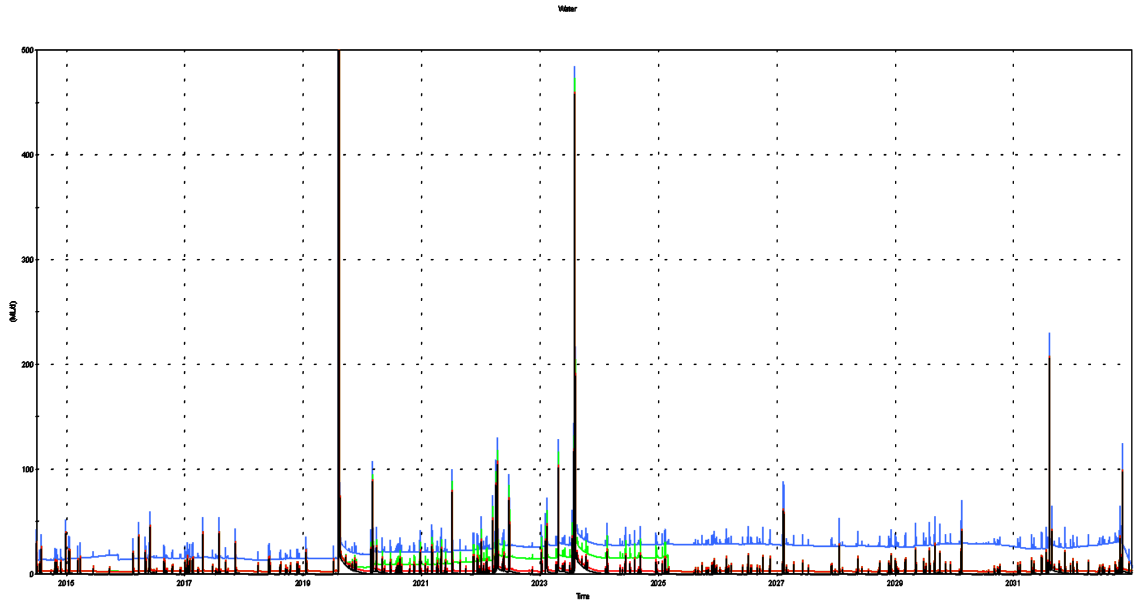


#074: Lake Burragorang (Salinity, mg/L)

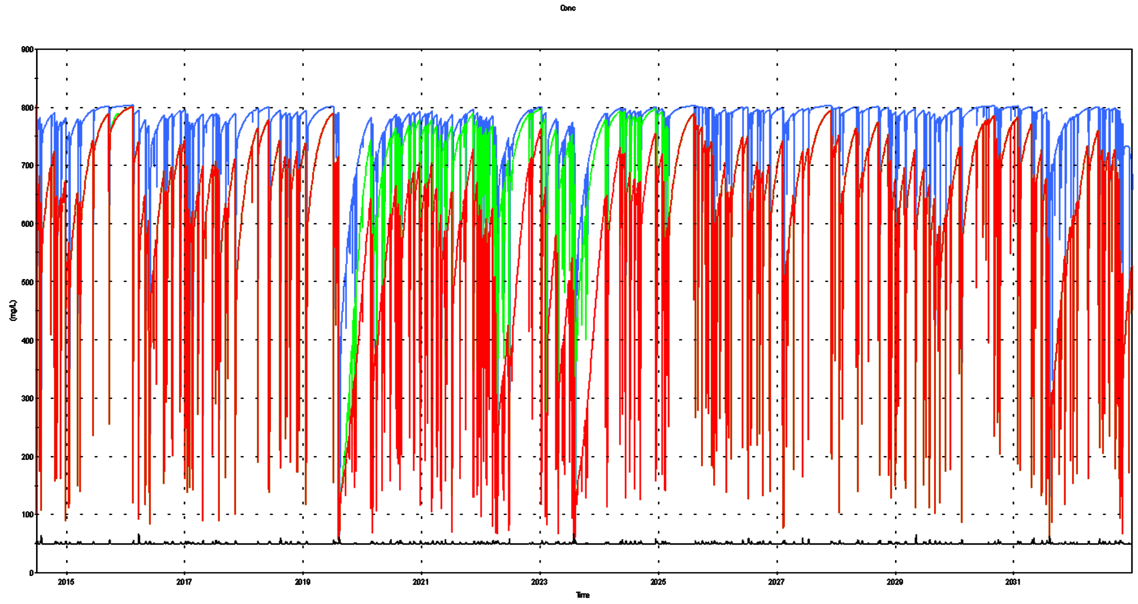
LEGEND:

| | |
|---|---|
| ▬ | WS1, WS2a & WS2b |
| ▬ | Null Case |

**UNCERTAINTY RESULTS (LOW RAINFALL) – LAKE BURRAGORANG** FIGURE 3.18B



#011: Kangaroo Creek below Angus Place LDP001 (Flow, ML/d)

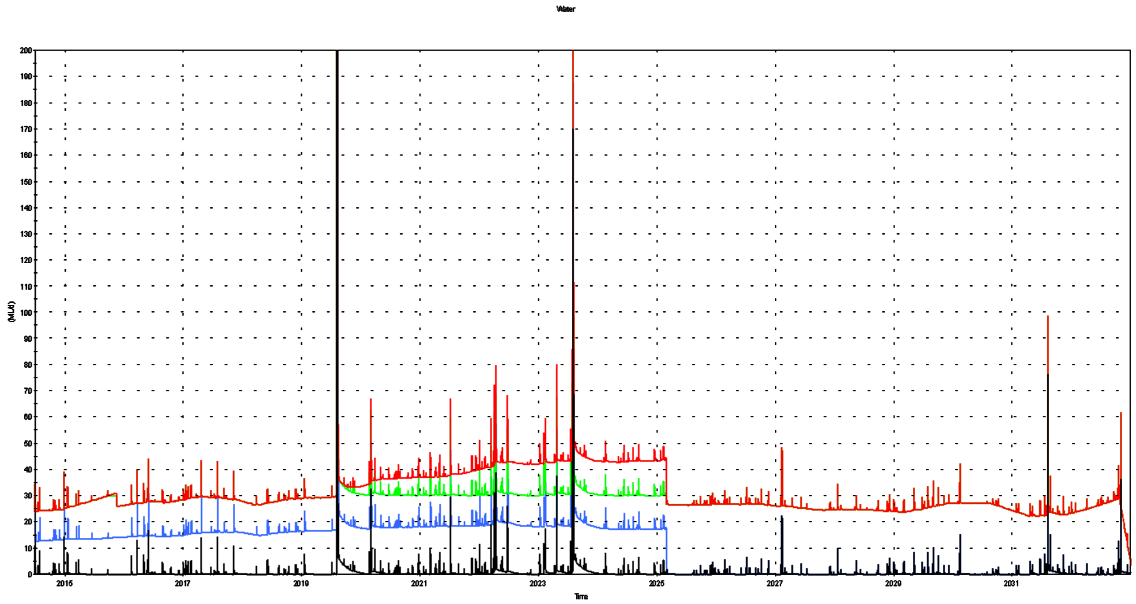


#011: Kangaroo Creek below Angus Place LDP001 (Salinity, mg/L)

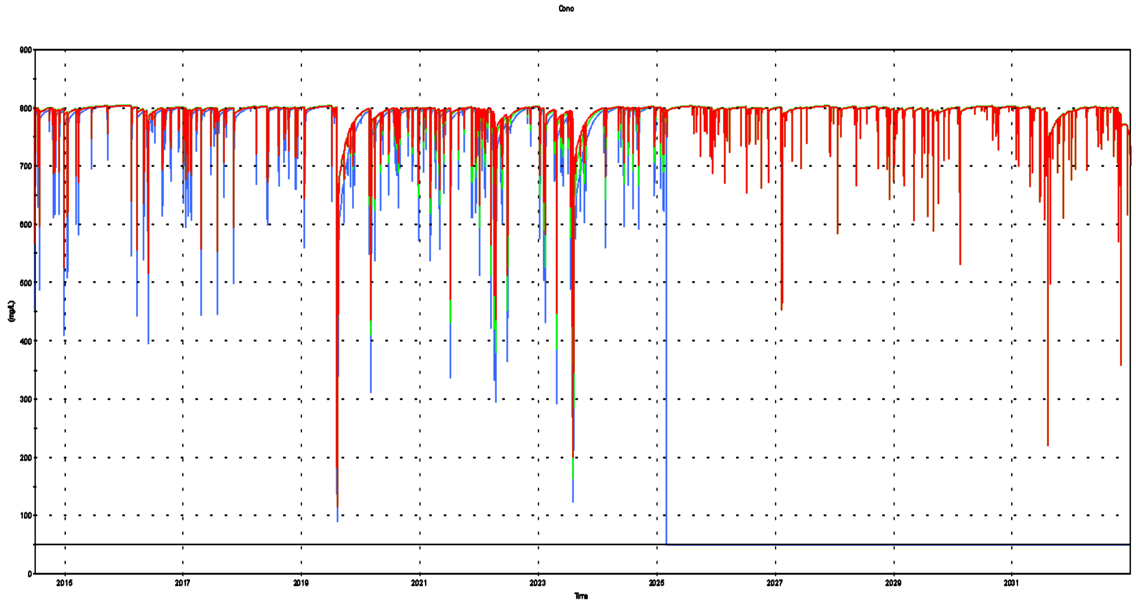
LEGEND:

— WS1
— WS2
— WS3
— Null Case

**UNCERT (HIGH RAINFALL) – KANGAROO CK & COXS R ABOVE WANGCOL** FIGURE 3.19



#014: Sawyers Swamp Creek below Springvale LDP009 (Flow, ML/d)



#014: Sawyers Swamp Creek below Springvale LDP009 (Salinity, mg/L)

LEGEND:

| | |
|---|---|
| 🟦 | WS1 |
| 🟩 | WS2 |
| 🟥 | WS3 |
| ▬ | Null Case |

**UNCERTAINTY RESULTS (HIGH RAINFALL) – SAWYERS SWAMP CREEK** FIGURE 3.20

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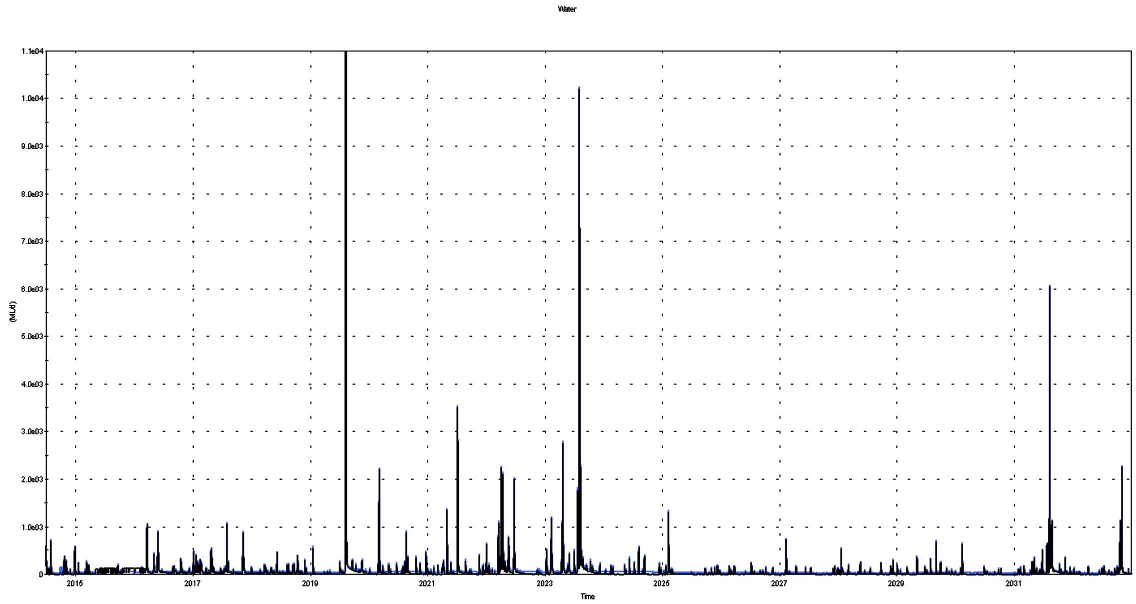
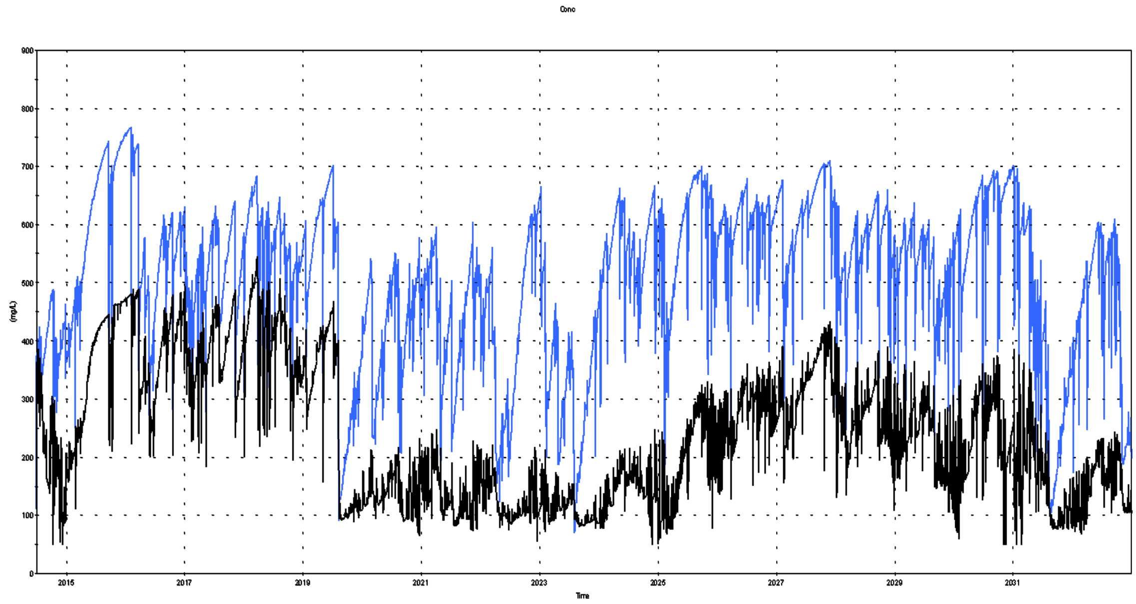


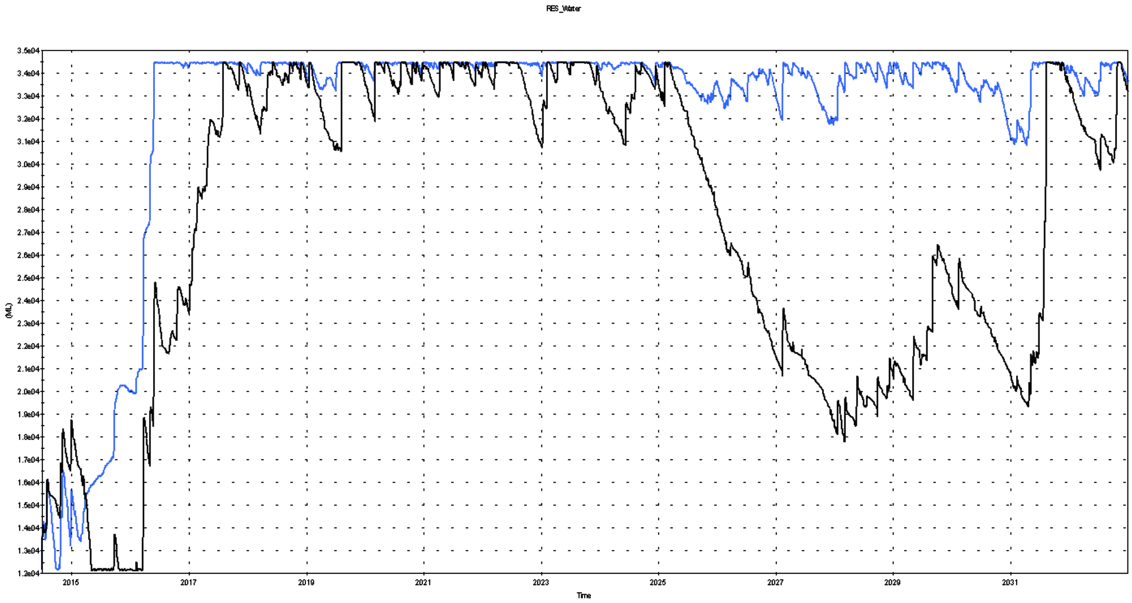
#154: Coxs River above Lake Lyell (Flow, ML/d; location of NSW Office of Water Gauge 212058)



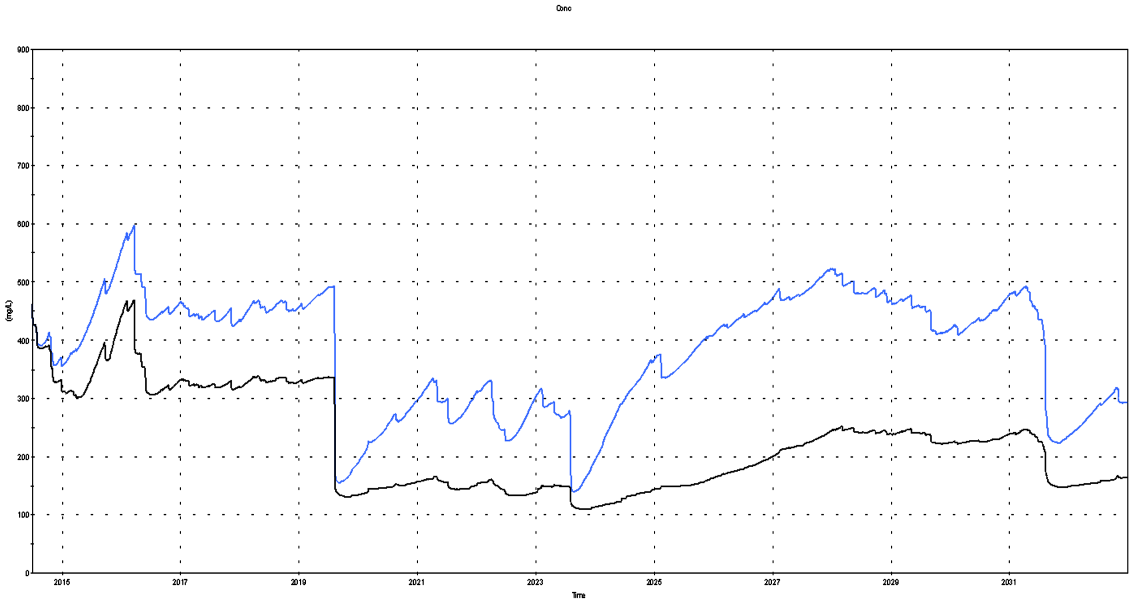
#035: Coxs River above Lake Lyell (Salinity, mg/L; at Energy Australia Monitoring Location, COX5)

| | LEGEND: |
|---|---|
| 🟦 | WS1, WS2a & WS2b |
| ⬛ | Null Case |

**UNCERTAINTY RESULTS (HIGH RAINFALL) – LAKE LYELL AND ABOVE** FIGURE 3.21A



#174: Lake Lyell (Volume, ML)



#174: Lake Lyell (Salinity, mg/L)

LEGEND:

WS1, WS2a & WS2b
Null Case

**UNCERTAINTY RESULTS (HIGH RAINFALL) – LAKE LYELL AND ABOVE** FIGURE 3.21B

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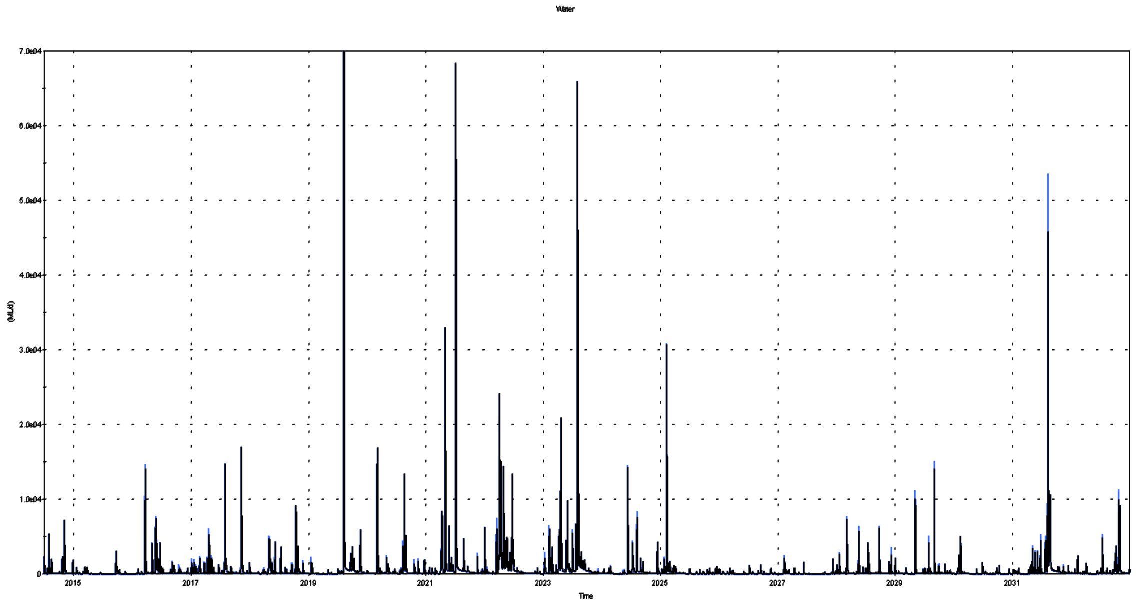
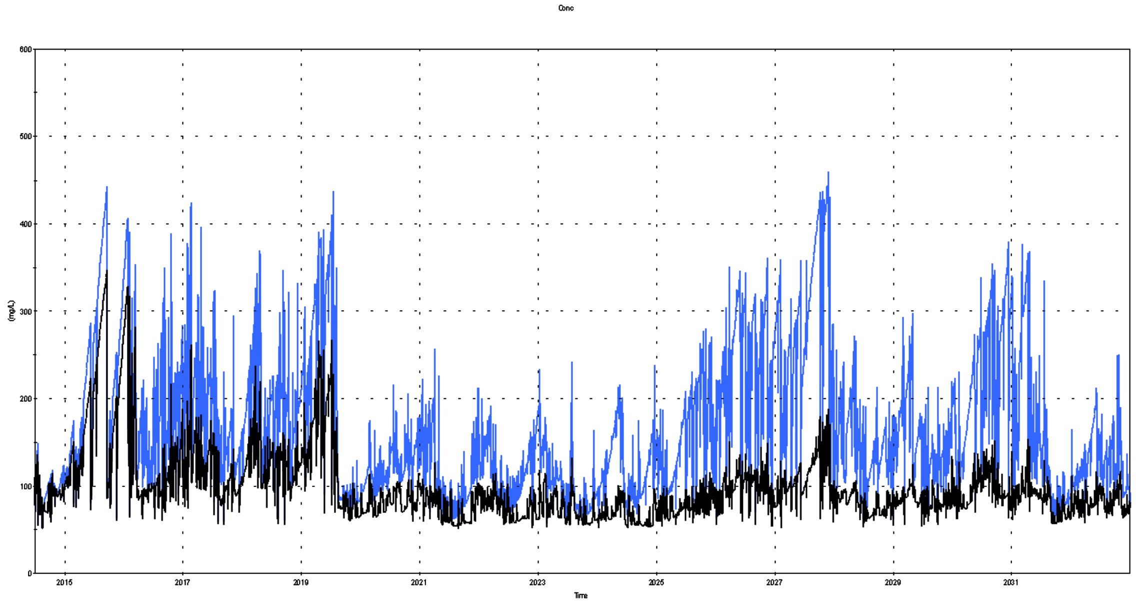


#225: Coxs River immediately above Lake Burragorang (Flow, ML/d)



#225: Coxs River immediately above Lake Burragorang (Salinity, mg/L)

LEGEND:

WS1, WS2a & WS2b

Null Case

**UNCERT (HIGH RAINFALL) – LAKE BURRAGORANG AND ABOVE** FIGURE 3.22A

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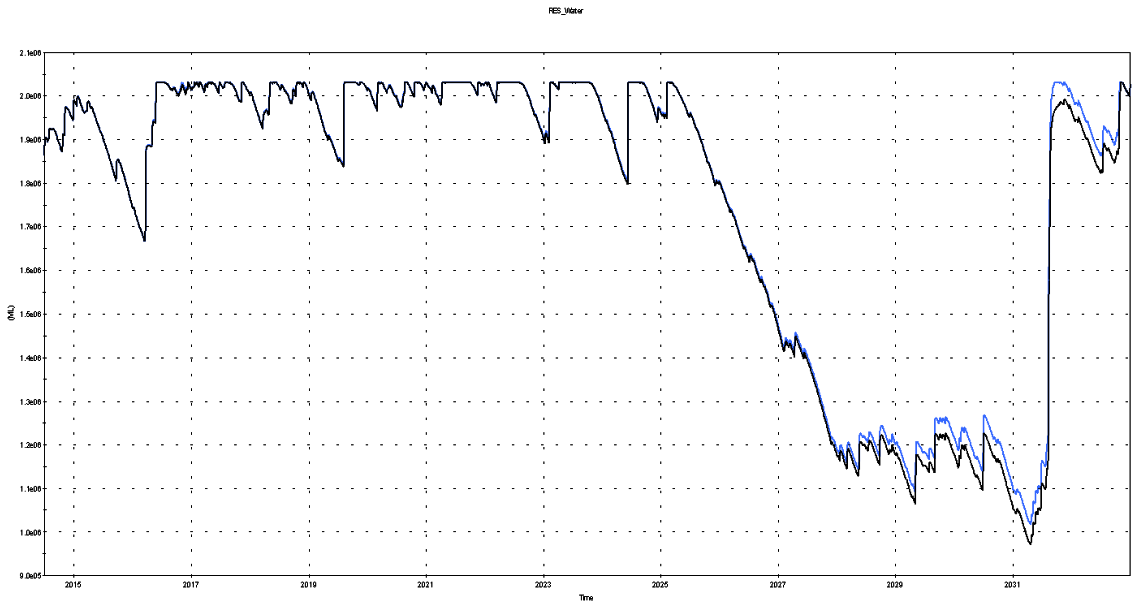
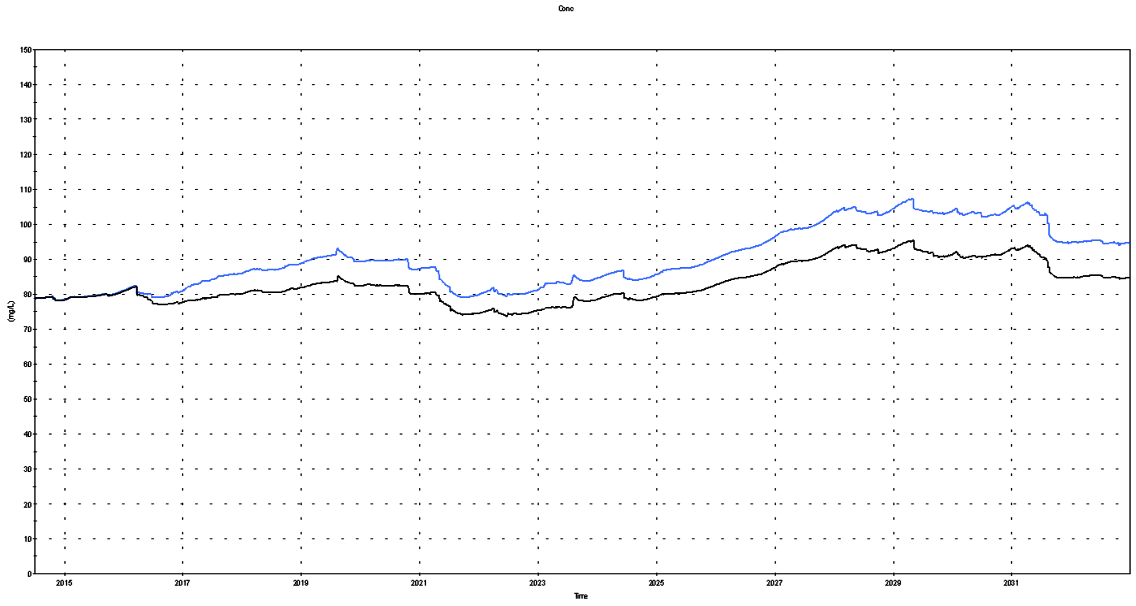


#280: Lake Burragorang (Volume, ML)



#074: Lake Burragorang (Salinity, mg/L)

LEGEND:

| | |
|---|---|
| ― | WS1, WS2a & WS2b |
| ― | Null Case |

**UNCERTAINTY RESULTS (HIGH RAINFALL) – LAKE BURRAGORANG** FIGURE 3.22B

RPS

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Our Ref: S188H/004e
Date: 1 October 2014

Nagindar Singh
Environmental Projects Coordinator – West
Centennial Coal Company Limited
Lidsdale House
1384 Castlereagh Highway
LIDSDALE NSW 2790

Dear Nagindar,

**RE: Springvale Colliery LDP009 SSTV Assessment**

## 1. Introduction

This document forms a technical Appendix to the Response to Submissions regarding the Springvale Colliery Extension Project *Environmental Impact Statement*, and specifically addresses concerns raised regarding the quality of the discharge water with respect to ANZECC and ARMCANZ (2000) guideline (the Guidelines) values.

LDP009, on Springvale Mine's EPL 3607, is the Springvale Delta Water Transfer Scheme (SDWTS) bypass point and discharges water into Sawyers Creek. The water is mine water make abstracted by dewatering bores Bore 6 and Bore 8 at Springvale Mine.

Sawyers Swamp Creek Ash Dam is a major artificial surface waterbody on the boundary between Springvale Mine and Angus Place Colliery. The dam is used for ash disposal from Wallerawang Power Station (when in operation). There is also an emergency / maintenance discharge point at this dam, associated with the SDWTS (LDP010). The bypass from the SDWTS is located immediately downstream of this dam (LDP009) as shown on Figure 1.

The purpose of this document is to assess the appropriateness of the ANZECC and ARMCANZ (2000) default guideline trigger values for application to the receiving waters of the LDP009 discharge. Site Specific Trigger Values (SSTV) may then be derived for the water quality downstream of LDP009 in accordance with the ANZECC and ARMCANZ (2000) methodology.

Trigger values focus on environmental protection and are effective tools in the early detection of potential impacts and provide guideline water quality criteria to be met downstream of a mixing zone.

A location map showing the relevant water bodies and monitoring locations is provided in Figure 1.

### 1.1 ANZECC and ARMCANZ 2000 Guidelines

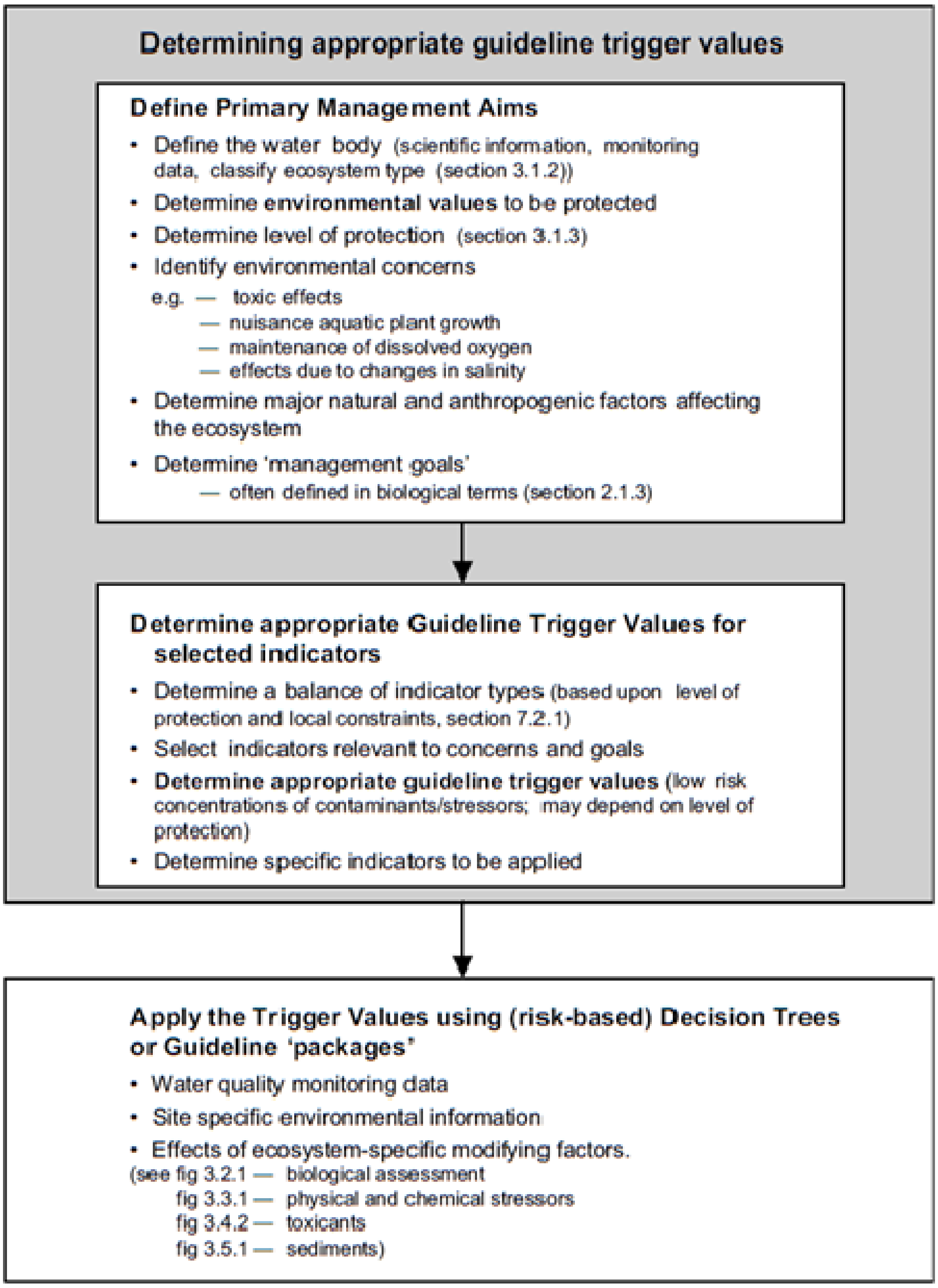
The ANZECC and ARMCANZ (2000) Guidelines provide a framework for assessing water quality, based on whether the physical, chemical and biological characteristics of a waterway support community environmental values and help to define the water quality needed to protect these values.

Trigger values are conservative assessment levels for the early identification of potential risk to environmental values. Local conditions vary naturally between waterways and it is usually necessary to tailor trigger values to local conditions or “local guideline levels”. ANZECC and ARMCANZ (2000) provide a process for the establishment of suitable SSTV.

The application of trigger values is not appropriate at the point of discharge or within the mixing zone of the receiving waters. Mixing zones are often defined as explicit areas around effluent discharges where the management goals of the ambient waters do not need to be achieved and hence the designated environmental values may not be protected. Trigger values should be applied downstream of the mixing zone.

## 2. Methodology

ANZECC and ARMCANZ (2000) have provided an assessment methodology (Figure 2) that summarises the documented methodology for the determination of appropriate guideline trigger values.



**Determining appropriate guideline trigger values**

**Define Primary Management Aims**

- Define the water body (scientific information, monitoring data, classify ecosystem type (section 3.1.2))
- Determine **environmental values** to be protected
- Determine level of protection (section 3.1.3)
- Identify environmental concerns
  e.g. — toxic effects
  — nuisance aquatic plant growth
  — maintenance of dissolved oxygen
  — effects due to changes in salinity
- Determine major natural and anthropogenic factors affecting the ecosystem
- Determine ‘management goals’
  — often defined in biological terms (section 2.1.3)

**Determine appropriate Guideline Trigger Values for selected indicators**

- Determine a balance of indicator types (based upon level of protection and local constraints, section 7.2.1)
- Select indicators relevant to concerns and goals
- **Determine appropriate guideline trigger values** (low risk concentrations of contaminants/stressors; may depend on level of protection)
- Determine specific indicators to be applied

**Apply the Trigger Values using (risk-based) Decision Trees or Guideline ‘packages’**

- Water quality monitoring data
- Site specific environmental information
- Effects of ecosystem-specific modifying factors.

(see fig 3.2.1 — biological assessment
fig 3.3.1 — physical and chemical stressors
fig 3.4.2 — toxicants
fig 3.5.1 — sediments)

**Figure 2: Flow Chart for the Determination of Appropriate Guideline Trigger Values**

## 2.1 Waterbody Definition

The assessment methodology first requires the definition of the waterbody in question so the correct set of values can be considered. This process requires assessment against the six ecosystem types that are outlined in the Guidelines. These are as follows:

- upland rivers and streams (>150 mAHD)
- lowland rivers (<150 mAHD)
- freshwater lakes and reservoirs
- wetlands
- estuaries
- coastal and marine.

The altitude of LDP009 is approximately 950 mAHD, therefore the upland river and streams values are to be used for consideration in this assessment.

## 2.2 Environmental Values

The environmental values that are to be protected must then be determined. The Guidelines define environmental values as the “particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and that require protection from the effects of pollution, waste discharges and deposits. Several environmental values may be designated for a specific waterbody”.

The Guidelines recognises the following environmental values:

- aquatic ecosystems
- primary industries (irrigation and general water uses, stock drinking water, aquaculture and human consumption of aquatic foods)
- recreation and aesthetics
- drinking water
- industrial water (no water quality guidelines are provided for this environmental value)
- cultural and spiritual values (no water quality guidelines are provided for this environmental value).

Given the industrial and agricultural activity within the Coxs River Catchment, along with the downstream situation of water supply reservoirs, there are a number of the stated environmental values that may apply to the catchment. Where this is the case the Guidelines advise a conservative approach by adopting the guideline values of the most sensitive of the applicable environmental values.

On that basis the guideline values for Aquatic Ecosystems are considered the most appropriate for use within the catchment containing LDP009.

## 2.3 Level of Protection

Determination of the “level of protection” addresses the current condition of the ecosystem and what level of change would be regarded as acceptable. The Guidelines propose the following three levels of ecosystem condition as a basis for application:

- **High conservation/ecological value systems –** Effectively unmodified or other highly-valued ecosystems, typically (but not always) occurring in national parks, conservation reserves or in remote and/or inaccessible locations. While there are no aquatic ecosystems in Australia and New Zealand that are entirely without some human influence, the ecological integrity of high conservation/ecological value systems is regarded as intact.
- **Slightly to moderately disturbed systems –** Ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity. The biological communities remain in a healthy condition and ecosystem integrity is largely retained. Typically, freshwater systems would have slightly to moderately cleared catchments and/or reasonably intact riparian vegetation. Slightly–moderately disturbed systems could include rural streams receiving run-off from land disturbed to varying degrees by grazing or pastoralism.

- **Highly disturbed systems –** These are measurably degraded ecosystems of lower ecological value. Examples of highly disturbed systems would be some shipping ports and sections of harbours serving coastal cities, urban streams receiving road and stormwater run-off, or rural streams receiving run-off from intensive horticulture.

Considering the environmental values within the local vicinity and downstream catchment of LDP009, the designation of “slightly to moderately disturbed ecosystem” has been applied to this assessment. One of the submissions commented on some reaches of the system being highly degraded, however, in trying to raise the overall condition of the system the slightly to moderate level is considered more appropriate

The trigger values provided in the Guidelines have been derived using a statistical distribution approach to estimate the concentrations of a variety of physical and chemical stressors that would protect a predetermined percentage of species.

The 95% protection level is most commonly applied to ecosystems that could be classified as slightly to moderately disturbed. A complete table of guideline trigger values is provided in Appendix A.

## 2.4 Assessing the Requirement for SSTV

The documented methodology for the application of the Guideline trigger values incorporates a degree of tailoring to the nature of the catchment where the discharge is taking place. However the Guidelines recognise that there can be significant variation in physical, chemical and biological characteristics between and within catchments which may require the derivation of SSTVs.

Following establishment of the appropriate Guideline trigger values for the waterbody in question, these values must be compared against water quality data collected upstream of the discharge point to understand background concentrations.

Where background values exceed Guideline trigger values, the 80th percentile concentration of the background data may be adopted as the SSTV.

## 2.5 Hardness Modified Trigger Values

Water hardness is known to influence the bioavailability of certain metals to aquatic organisms. The reduction in bioavailability of Cd, Cr(III), Cu, Ni, Pb and Zn as a function of hardness is described mathematically and presented in the Guidelines. The requirement for Hardness Modified Trigger Values (HMTV) has been assessed, where applicable, in this investigation.

## 2.6 Dilution Analysis

In the circumstance where downstream median data does not always comply with the adopted trigger values due to the influence of a discharge then a dilution analysis can be carried out.

The dilution analysis considers flow and water quality data of the upstream and discharged water to assess the likelihood that the discharge would be sufficiently diluted by the upstream water such that trigger values are met downstream. This analysis can also be extrapolated to approximate discharge volumes that would maintain the downstream water quality within the adopted trigger values.

## 2.7 Application to LDP009

There are two options for undertaking an SSTV analysis regarding discharge at Springvale Mine’s LDP009:

- Consider LDP009 discharging into Sawyers Creek and set SSTVs for median concentrations at the confluence of Sawyers Creek and Coxs River.
- Consider Sawyers Creek as the discharge and Coxs River as the receiving waters with SSTVs set for the median concentrations at a downstream Cox’s River monitoring location.
- Consider the diversion of the majority of Angus Place Colliery’s mine water make to Springvale Mine’s LDP009.

These options have been considered separately and the analysis and derived trigger values are presented in the following sections.

## 3. LDP009 Discharging into Sawyers Creek:

This scenario considers the discharge from LDP009 directly into Sawyers Creek. This approach is limited in that there is no upstream monitoring in Sawyers Creek so the assumption has been made that the upstream water quality is the same as Kangaroo Creek as they drain neighbouring catchments in similar environments. Furthermore, the downstream site, where the trigger values will be applied is LDP003 D/S, which is not only downstream of LDP009 but also downstream of Angus Place LDP003 (discharge site from Kerosene Vale) and Springvale LDP010 (Figure 1).

Angus Place LDP003 (EPL 467) discharges run-off from the Ash Placement and LDP010 is an emergency discharge point for Sawyers Creek Ash Dam. Whilst discharge volumes from these points are minimal compared to LDP009; the additional variables in the downstream water quality will cause difficulties in relating downstream water quality directly to LDP009 discharge.

The following monitoring locations have been used in this assessment:

- Upstream Site: Kangaroo Creek U/S
- Discharge Site: LDP009
- Downstream Site: LDP003 D/S.

### 3.1 Analyte Selection

The concentrations of a range of physical and chemical analytes are measured routinely at all monitoring locations shown on Figure 1. The median and 80th percentile concentrations are shown in Table 1 for the LDP009 discharge and the upstream and downstream monitoring locations. The numbers shown in bold represent concentrations exceeding the ANZECC 95% species protection trigger values. For reference, the raw water supply agreements from Warragamba Dam to Prospect Water Filtration Plant (WFP) and the Australian Drinking Water Guideline values have been included.

Analytes that show elevated concentrations in the upstream dataset require SSTV analysis. EC has also been considered as this water quality parameter has been raised as a key concern within the catchment.

Based on Table 1, the following parameter/analytes have been considered further:

- Electrical conductivity (EC)
- Aluminium (Al)
- Iron (Fe)
- Zinc (Zn)
- Copper (Cu).

### Exemptions

The Guideline value for silver (0.05 µg/L) is below the detection limit (0.001 mg/L) of the current laboratory analysis. There have only been two samples analysed in the downstream dataset and one in the upstream dataset, all of which have been below the detection limit, therefore this data has not been considered.

LDP009 has shown two isolated occurrences of elevated cyanide concentration, however this data is only from two samples and such concentrations are not evident in the downstream dataset. There is not enough data to verify the cyanide concentrations and as such, cyanide has not been considered further.

However, it is noted that cyanide will continue to be screened for to allow future assessment of positive results.

### Table 1: Summary Statistics for Relevant Water Quality Monitoring Locations

| Analyte | Kangaroo Creek (U/S) | | | | LDP009 | | | | LDP003 (D/S) | | | | Guideline Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Median** | **20th Percentile** | **80th percentile** | **Count** | **Median** | **20th percentile** | **80th percentile** | **Count** | **Median** | **20th percentile** | **80th percentile** | **Sample Count** | **ANZECC (95%)** | **Prospect WFP** | | **ADWG (mg/L)** | |
| | | | | | | | | | | | | | | **Min** | **Max** | **Min** | **Max** |
| pH (pH Unit) | 6.4 | 5.9 | 6.8 | 65 | 7.8 | 7.6 | 7.9 | 95 | 7.2 | 7.0 | 7.4 | 48 | | 6.3 | 7.9 | 6.5 | 8.5 |
| TSS | 5 | 1.7 | 10 | 62 | 6 | 4 | 12 | 95 | 1 | 1 | 5 | 48 | | | | | |
| TDS | 60.5 | 35 | 82.6 | 54 | 684 | 684 | 684 | 1 | 181 | 154 | 246 | 46 | | | | | 600 |
| Ec (µS/cm) | 69 | 53 | 89 | 65 | **1060** | **1020** | **1090** | 95 | 262 | 202 | 289 | 48 | 350 | | | | |
| Oil & Grease | 5 | 5 | 5 | 62 | 5 | 5 | 5 | 92 | 5 | 5 | 5 | 47 | | | | | |
| Manganese Filt | 0.1165 | 0.0352 | 0.4526 | 60 | 0.012 | 0.008 | 0.017 | 95 | 0.04 | 0.022 | 0.0822 | 44 | 1.9 | | 1.4 | | 0.5 |
| Iron Filt | **0.975** | **0.464** | **4.002** | 60 | 0.05 | 0.05 | 0.05 | 95 | 0.085 | 0.05 | 0.138 | 44 | 0.3* | | 3.5 | | |
| Turbidity (NTU) | 7 | 2 | 19.2 | 55 | 8 | 4 | 19.4 | 95 | 3 | 1 | 15 | 47 | | | 40 | | 5 |
| Aluminium | **0.12** | **0.07** | **0.204** | 54 | 0.01 | 0.01 | **0.06** | 95 | 0.01 | 0.01 | 0.014 | 44 | 0.055 | | 2.6 | | |
| Arsenic | 0.001 | 0.001 | 0.001 | 54 | **0.02** | **0.0142** | **0.026** | 47 | 0.001 | 0.001 | 0.001 | 44 | 0.013 | | | | 0.01 |
| Barium | 0.025 | 0.0176 | 0.0368 | 54 | | | | 0 | 0.015 | 0.0126 | 0.0184 | 44 | | | | | 2 |
| Boron Filtered | 0.05 | 0.05 | 0.05 | 49 | 0.07 | 0.06 | 0.08 | 47 | 0.13 | 0.112 | 0.15 | 37 | 0.37 | | | | 4 |
| Cadmium Filtered | 0.0001 | 0.0001 | 0.0001 | 54 | | | | 0 | 0.0001 | 0.0001 | 0.0001 | 44 | 0.0002 | | | | 0.002 |
| Calcium | 1 | 1 | 2 | 53 | | | | 0 | 14 | 11 | 16 | 44 | | | | | |
| Total Chromium Filtered | 0.001 | 0.001 | 0.001 | 3 | | | | 0 | 0.001 | 0.001 | 0.001 | 2 | 0.001 | | | | 0.05 |
| Chloride | 9 | 7 | 10.4 | 54 | | | | 0 | 10 | 8.6 | 12 | 44 | | | | | |
| Cobalt | 0.0035 | 0.002 | 0.005 | 2 | 0.001 | 0.001 | 0.001 | 1 | 0.001 | 0.001 | 0.001 | 1 | | | | | |
| Copper | **0.002** | 0.001 | **0.004** | 50 | 0.001 | 0.001 | **0.002** | 56 | **0.002** | 0.001 | **0.004** | 40 | 0.0014 | | | | 2 |
| Cyanide Total | 0.004 | 0.004 | 0.004 | 50 | **1.3** | **1.3** | **1.3** | 2 | 0.004 | 0.004 | 0.004 | 35 | 0.007 | | | | 0.08 |
| Lead | 0.001 | 0.001 | 0.001 | 54 | | | | 0 | 0.001 | 0.001 | 0.001 | 44 | 0.0034 | | | | 0.01 |
| Magnesium | 1 | 1 | 2 | 54 | | | | 0 | 9.5 | 8 | 11 | 44 | | | | | |
| Nickel Filtered | 0.001 | 0.001 | 0.002 | 54 | 0.004 | 0.003 | 0.004 | 47 | 0.004 | 0.002 | 0.005 | 44 | 0.011 | | | | 0.02 |
| Potassium | 2 | 1 | 2 | 54 | | | | 0 | 12 | 10 | 13 | 44 | | | | | |

| Analyte | Kangaroo Creek (U/S) | | | | LDP009 | | | | LDP003 (D/S) | | | | Guideline Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | 20th Percentile | 80th percentile | Count | Median | 20th percentile | 80th percentile | Count | Median | 20th percentile | 80th percentile | Sample Count | ANZECC (95%) | Prospect WFP | | ADWG (mg/L) | |
| | | | | | | | | | | | | | | Min | Max | Min | Max |
| Selenium | 0.01 | 0.01 | 0.01 | 2 | 0.01 | 0.01 | 0.01 | 1 | 0.01 | 0.01 | 0.01 | 1 | 0.011 | | | | 0.01 |
| Silver | **0.001** | **0.001** | **0.001** | 2 | 0.01 | 0.01 | 0.01 | 1 | **0.001** | **0.001** | **0.001** | 1 | 0.00005 | | | | 0.1 |
| Sodium | 7.5 | 6 | 8.4 | 54 | | | | 0 | 15 | 14 | 22.2 | 44 | | | | | |
| Total Sulphur (Sulphate) | 2 | 1 | 6 | 57 | | | | 0 | 66 | 53.6 | 76 | 44 | | | | | 500 |
| Uranium | 0.001 | 0.001 | 0.001 | 54 | 0.001 | 0.001 | 0.001 | 1 | 0.001 | 0.001 | 0.001 | 44 | | | | | 0.017 |
| Zinc Filtered | **0.01** | 0.006 | **0.019** | 56 | **0.013** | **0.0088** | **0.0204** | 70 | **0.013** | 0.0066 | **0.02** | 44 | 0.008 | | | | |
| Nitrogen (Ammonia) | 0.02 | 0.01 | 0.03 | 52 | | | | 0 | 0.01 | 0.01 | 0.03 | 43 | | | | | |
| Nitrite as N | 0.01 | 0.01 | 0.01 | 52 | | | | 0 | 0.01 | 0.01 | 0.01 | 43 | | | | | |
| Nitrate as N | 0.01 | 0.01 | 0.03 | 52 | | | | 0 | 0.02 | 0.01 | 0.076 | 43 | 0.7 | | | | 50 |
| Nitrate + Nitrite | 0.01 | 0.01 | 0.03 | 52 | | | | 0 | 0.02 | 0.01 | 0.076 | 43 | | | | | 3 |
| Total Nitrogen as N | 0.4 | 0.2 | 0.6 | 52 | | | | 0 | 0.2 | 0.1 | 0.46 | 43 | | | | | |
| Total Phosphorous | 0.02 | 0.01 | 0.06 | 52 | | | | 0 | 0.01 | 0.01 | 0.066 | 43 | | | | | |
| Carbonate Alkalinity | 1 | 1 | 1 | 54 | | | | 0 | 1 | 1 | 1 | 44 | | | | | |
| Bicarbonate Alkalinity | 11.5 | 5.6 | 20.8 | 54 | | | | 0 | 40 | 31 | 61 | 44 | | | | | |
| Hydroxide | 1 | 1 | 1 | 54 | | | | 0 | 1 | 1 | 1 | 44 | | 15 | 60 | | |
| Total Alkalinity | 11.5 | 5.6 | 20.8 | 54 | | | | 0 | 40.5 | 31 | 64.4 | 44 | | | | | |
| Total Hardness | 7 | 1 | 13 | 54 | | | | 0 | 76 | 62.6 | 85 | 44 | | 25 | 70 | | |
| Total Fluoride | 0.1 | 0.1 | 0.1 | 51 | 1.3 | 1.3 | 1.4 | 74 | 0.1 | 0.1 | 0.2 | 42 | | | | | 1.5 |

All units are in mg/L unless otherwise stated

* Low reliability trigger value due to insufficient data (ANZECC and ARMCANZ, 2000.  Section 8.3.7)

## 3.2 Analysis

Table 2 shows median concentrations of the selected analytes at the discharge and downstream monitoring locations and the 80th percentile background concentrations from the upstream data set. The numbers shown in bold represent concentrations exceeding the ANZECC 95% species protection trigger values.

The 80th percentile background concentrations have been compared to the Guideline values (95% species protection) and the maximum value taken as the trigger value for the downstream median concentrations. The numbers shown in bold represent concentrations exceeding the ANZECC 95% species protection trigger values.

Where appropriate, trigger values for Zinc and Copper are modified for hardness according to the following algorithms:

Zinc: $HMTV = TV (H/30)^{0.89}$

Copper: $HMTV = TV (H/30)^{0.85}$

Where:

HMTV = Hardness Modified Trigger Value

TV = Trigger Value

H = Hardness of water at downstream site

The results of the analysis are presented in Table 2.

**Table 2: SSTV Analysis Results: Sawyers Creek LDP003 D/S**

| **Analyte** | **Median** | | **80th Percentile** | **ANZECC 95%** | **TV** | **HMTV** | **Adopted TV** |
|---|---|---|---|---|---|---|---|
| | **LDP003 D/S** | **LDP009** | **Kangaroo Creek U/S** | | | | |
| EC (µS/cm) | 262 | **1060** | 89 | 350 | 350 | n/a | 350 |
| Al (mg/L) | 0.01 | 0.01 | **0.2** | 0.055 | 0.2 | n/a | 0.2 |
| Fe (mg/L) | 0.09 | 0.05 | **4.0** | 0.3 | 4.0 | n/a | 4.0 |
| Zn (mg/L) | **0.01** | **0.01** | **0.019** | 0.008 | 0.019 | n/a | 0.019 |
| Cu (mg/L) | **0.0015** | 0.001 | **0.004** | 0.0014 | 0.004 | n/a | 0.004 |

NB: Values in bold exceed ANZECC guideline value for 95% species protection.

Table 2 shows that concentrations of Aluminium, Iron, Zinc and Copper are elevated in the background data so the upstream 80th percentile concentrations have been adopted as SSTVs in place of the Guideline trigger values. No hardness modification is required.

The downstream concentrations of Aluminium, Zinc and Copper exceed the Guideline value but fall below the adopted trigger value.

The EC at the downstream monitoring location falls below the Guideline value; however it is not clear if this data incorporates LDP009 discharge. The full data set contains data from before the cessation of SDWTS, however following the cessation, the EC at the downstream site increased to approximately 600 to 700 µS/cm, which is low considering the discharge at LDP009 is two orders of magnitude greater than the background flows and has a median EC of 1060 µS/cm.

The LDP009 discharge EC exceeds the ANZECC 95% species protection trigger values. Whilst in the upstream dataset, EC falls below the ANZECC trigger value. A component of dilution is therefore required to enable the trigger value for EC to be met for the median conditions downstream.

### Dilution Requirements

The 80th percentile upstream EC value (Kangaroo Creek U/S data) is less than the Guideline value (350 µS/cm); therefore the Guideline value has been adopted as the most appropriate trigger value.

As shown in Table 2, the discharge median EC at LDP009 is greater than 350 µS/cm. It is therefore necessary to calculate the potential for discharged water to be diluted by Kangaroo Creek upstream water such that the water quality criteria are met and the downstream EC is maintained within the adopted trigger value.

A dilution factor analysis uses flow data to calculate the ratio of discharged water to background flows and, to ensure the methodology is conservative, considers the 80th percentile discharge concentrations being diluted by median upstream water concentrations.

Table 3 shows the discharge and upstream concentrations, the water quality criteria (Adopted TV) and the dilution factor required such that the downstream water quality meets the water quality criteria. Where the 80th percentile discharge concentration is less than the adopted trigger value, and hence within the downstream water quality criteria, there is no requirement for dilution.

**Table 3: Sawyers Creek/LDP009 Dilution Factor Analysis**

| Analyte | 80 Percentile LDP009 | Median Kangaroo Creek U/S | Adopted TV | Required Dilution Factor |
|---|---|---|---|---|
| EC (µS/cm) | 1090 | 69 | 350 | 2.6 |
| Al (mg/L) | 0.06 | 0.12 | 0.2 | n/a |
| Fe (mg/L) | 0.05 | 0.975 | 4.0 | n/a |
| Zn (mg/L) | 0.020 | 0.011 | 0.019 | 0.13 |
| Cu (mg/L) | 0.002 | 0.002 | 0.004 | n/a |

Table 3 shows that to meet the water quality criteria for EC, the discharged water requires dilution by upstream water at the ratio of 2.6:1 (units upstream water to units discharge water). For zinc, while the median concentration at LDP009 falls below the adopted trigger values, the 80th percentile is slightly elevated, requiring a dilution ratio of 0.13:1.

The likelihood of meeting this criteria based on flow data can be considered. The following analysis considers the likelihood of achieving a dilution factor of 2.6 for EC, i.e. the likelihood that the discharge quantity at LDP009 will make up approximately 28% and the background flow will make up approximately 72% of the total flow at the downstream site.

There is no flow monitoring on Sawyers Creek, however modelled flows from the Regional Water Quality Impact Assessment (RPS 2014a) indicate that flows are typically two orders of magnitude less than LDP009 discharge:

- Median flow in Sawyers: 0.2 ML/d (modelled data December 2012 to July 2013)
- Median discharge from LDP009: 19.95 ML/d (actual data December 2012 to July 2013).

Based on modelled and actual flow data; the degree to which discharge at LDP009 is diluted by Sawyers Creek is shown in Figure 3.

Figure 3 shows that a dilution factor of 2.6 is achieved approximately 5% of the time therefore the water quality criteria for EC will not be met 95% of the time.

In the case of zinc, the required dilution factor is met 95% of the time.

Where dilution is insufficient, the mixing zone criteria are not met in that the mixing zone extends from bank to bank. In this circumstance ANZECC recommends performing a “biological effects assessment” (e.g. Direct Toxicity Assessment). Research undertaken by Hart et al. (1991) shows that the TDS needs to be above 1000 mg/L before it can lead to toxic effects, this equates to an EC of approximately 1500 µS/cm.

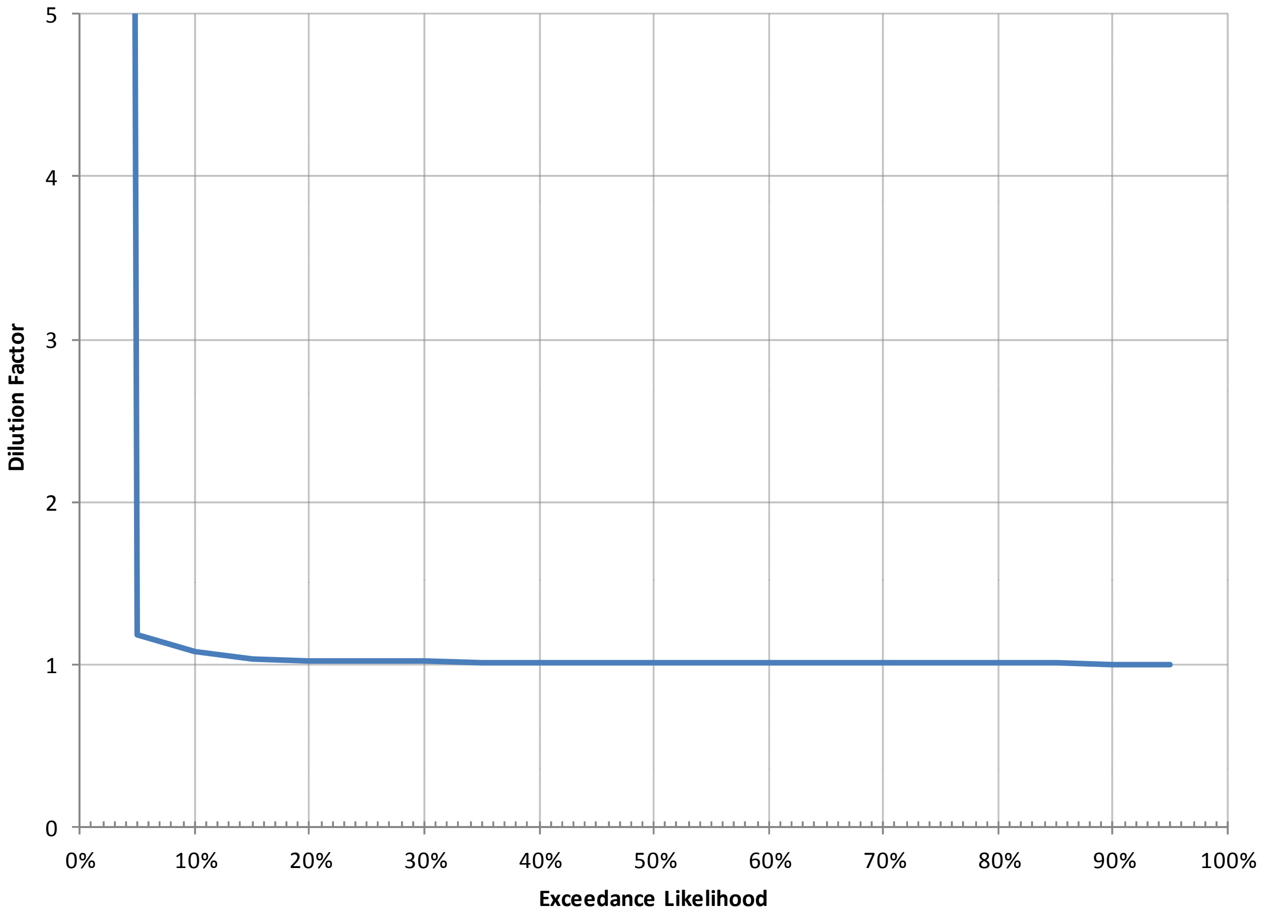


**Figure 3: Sawyers Creek/LDP009 Dilution Factor Exceedance Statistics**

## 4. Sawyers Creek Discharge into Coxs River

This scenario considers Sawyers Creek as a discharge into Coxs River. The upstream monitoring location on Coxs River (AP Coxs River D/S), as shown on Figure 1, is upstream of the confluence of Wangcol Creek and Coxs River. Therefore the upstream monitoring location used for this method is Node 60 (Figure 1), which is a node used in the Regional Water Quality Impact Assessment (RPS 2014a).

The modelled flow data at Node 60 has been used in conjunction with actual flow data from Wangcol Creek (SV LDP006 + Wangcol Creek Far Upstream) to derive flow data for AP Coxs River D/S (SV LDP006 is the licensed discharge point located within the Springvale Coal Services Site and discharges to Wangcol Creek). On this basis, the flow from Wangcol Creek contributes 85% of the flow at Node 60.

The relative flow contributions and respective water quality data from the two upstream monitoring locations have been used to derive water quality data for Node 60.

As shown in Section 3, the discharge at LDP009 is typically two orders of magnitude greater than background flow in Sawyers Creek. Furthermore, there is uncertainty around the LDP003 D/S data and the representation of LDP009 discharge. On that basis, the discharge of Sawyers Creek into Coxs River is assumed to be entirely comprised of LDP009 water.

The following monitoring locations have been used in this assessment:

- Upstream Site: Node 60
- Discharge Site: LDP009
- Downstream Site: SV Coxs River U/S.

Table 4 shows median concentrations of the selected analytes at the discharge and downstream monitoring locations and the 80th percentile background concentrations from the upstream data set. The numbers shown in bold represent concentrations exceeding the ANZECC 95% species protection trigger values.

The 80th percentile background concentrations have been compared to the Guideline values (95% species protection) and the maximum value taken as the trigger value for the downstream median concentrations.

Where appropriate, trigger values for Zinc and Copper are modified for hardness according to the following algorithms:

Zinc: $HMTV = TV\ (H/30)^{0.89}$

Copper: $HMTV = TV\ (H/30)^{0.85}$

Where:

HMTV = Hardness Modified Trigger Value

TV = Trigger Value

H = Hardness of water at downstream site

The results of the analysis are presented in Table 4.

**Table 4: SSTV Analysis Results: SV Coxs River U/S**

| Analyte | Median | | 80 Percentile | | | ANZECC 95% | TV | HMTV | Adopted TV |
|---|---|---|---|---|---|---|---|---|---|
| | SV Coxs River U/S | LDP009 | AP Coxs River D/S | Wangcol Creek Far D/S | Node 60* | | | | |
| EC (µS/cm) | **690** | **1060** | **855** | **1660** | **1539** | 350 | 1539 | n/a | 1539 |
| Al (mg/L) | 0.040 | 0.010 | **0.264** | **0.080** | **0.11** | 0.055 | 0.11 | n/a | 0.11 |
| Fe (mg/L) | 0.09 | 0.05 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | n/a | 0.3 |
| Zn (mg/L) | **0.014** | **0.013** | **0.016** | **0.083** | **0.07** | 0.008 | 0.07 | n/a | 0.07 |
| Cu (mg/L) | **0.0020** | 0.0010 | **0.0040** | N/A | **0.0040** | 0.0014 | 0.0040 | n/a | 0.004 |

NB: Values in bold exceed ANZECC guideline value for 95% species protection.
* Node 60 assumes 85/15 blend of Wangcol Creek and Coxs River water

Table 4 shows that concentrations of all analytes are elevated in the background data so the upstream 80th percentile concentrations have been adopted as SSTVs in place of the ANZECC guideline trigger values. No hardness modification is required.

The median downstream data for EC, Aluminium, Zinc and Copper exceed the Guideline trigger value but fall below the adopted trigger value.

## Dilution Requirements

Dilution analysis assumes 80th percentile discharge concentrations are being diluted by median upstream concentrations.

Table 5 shows the discharge and upstream concentrations and the adopted water quality criteria. As all 80th percentile discharge concentrations are less than the adopted trigger value, no dilution is required to achieve the downstream water quality criteria.

**Table 5: Coxs River/Sawyers Creek Dilution Factor Analysis**

| Analyte | 80 Percentile LDP009 | Median Node 60 | Adopted TV | Required Dilution Factor |
|---|---|---|---|---|
| EC (µS/cm) | 1090 | 990 | 1539 | n/a |
| Al (mg/L) | 0.06 | 0.045 | 0.11 | n/a |
| Fe (mg/L) | 0.05 | 0.22 | 0.3 | n/a |
| Zn (mg/L) | 0.02 | 0.033 | 0.07 | n/a |
| Cu (mg/L) | 0.002 | 0.002 | 0.004 | n/a |

Table 5 shows that there is no required dilution of the LDP009 discharge as the Coxs River at the confluence with Sawyers Creek as the upstream data shows elevated concentrations of the selected analytes.

## 5. Diversion of Angus Place Colliery's Mine Water to Springvale Mine's LDP009 via SDWTS

This scenario considers the additional discharge from Angus Place Colliery at LDP009 with respect to the scenario detailed in Section 4, whereby Sawyers Creek discharges to the Coxs River.

Table 6 shows the 80th percentile concentrations of LDP009 and LDP001. Based on median discharge rates of 20ML/d and 3.3ML/d respectively, the 80th percentile concentrations of the combined discharge have been derived.

From Table 6 it is apparent that the 80th percentile concentrations of the selected analytes in the blended discharge are below the adopted trigger values and therefore no dilution is required (i.e. negative dilution factor).

This analysis shows that the diversion of Angus Place mine water to Springvale LDP009 will maintain the downstream median concentrations to within the SSTV for the selected analytes.

Under the current plans; limited discharge will continue at Angus Place LDP001 at volumes approximately three orders of magnitude less than that transferred to Springvale LDP009 (RPS 2014b).

**Table 6: Coxs River/Sawyers Creek Dilution Factor Analysis – Including Angus Place LDP001**

| Analyte | 80 Percentile LDP009 | 80 Percentile LDP001 | 80 Percentile Combined Discharge | Median Node 60 | Adopted TV | Required Dilution Factor |
|---|---|---|---|---|---|---|
| EC (µS/cm) | 1090 | 1130 | 1096 | 990 | 1539 | n/a |
| Al (mg/L) | 0.06 | 0.05 | 0.059 | 0.045 | 0.11 | n/a |
| Fe (mg/L) | 0.05 | 0.08 | 0.054 | 0.22 | 0.3 | n/a |
| Zn (mg/L) | 0.02 | 0.056 | 0.025 | 0.033 | 0.07 | n/a |
| Cu (mg/L) | 0.002 | 0.0038 | 0.002 | 0.002 | 0.004 | n/a |

## 6. References

ANZECC/ARMCANZ, 2000, *National Water Quality Management Strategy: Australian Guidelines for Fresh and Marine Water Quality*.

Hart et al. 1991. *A review of the salt sensitivity of the Australian freshwater biota*. Hydrobiologia, March 1991, Volume 210, Issue 1-2, pp 105-144.

RPS, 2014a. Regional Water Quality Impact Assessment. Consultant Report Prepared for Centennial Coal Company Ltd, Reference No. S187E/021a.

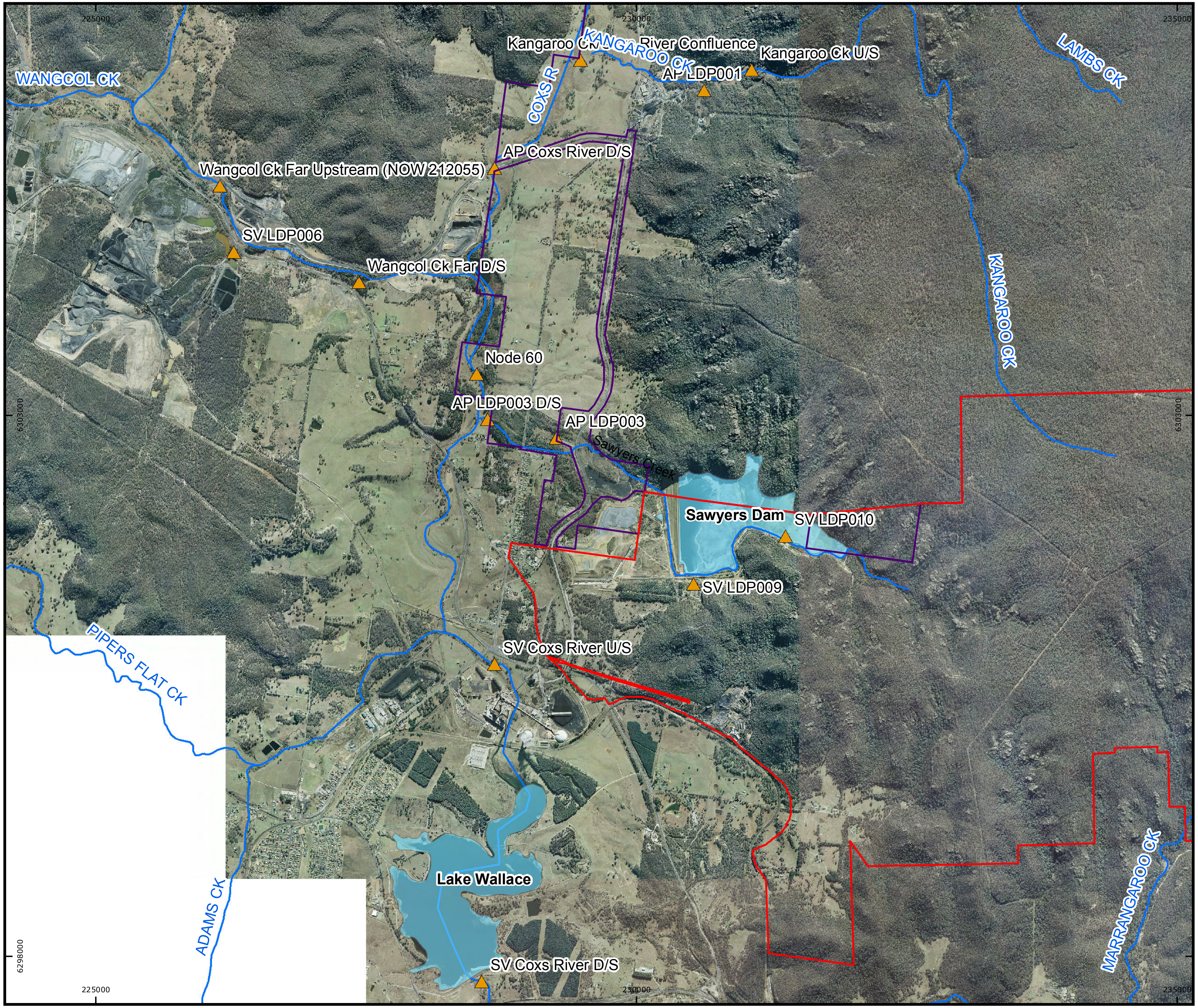
RPS, 2014b. Angus Place Mine Extension Project – Surface Water Impact Assessment. Consultant Report Prepared for Centennial Angus Place Pty Ltd, Reference No. S187D/021c, dated 9 February 2014.

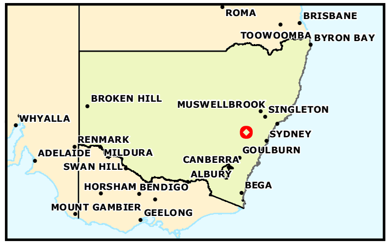
Yours sincerely
RPS Water Management

| | |
|---|---|
| *Sean* | *Greg* |
| Sean Daykin<br>Senior Hydrogeologist | Greg Sheppard<br>Principal Hydrogeologist |

enc:
Figure 1: SSTV Analysis Surface Water Monitoring Locations
Appendix A: ANZECC and ARMCANZ, 2000. Guideline Trigger Values

# FIGURES





**LEGEND**

- Springvale Project Application Area
- Angus Place Project Application Area
- ▲ Centennial Surface Water Monitoring Location
- River/Creek
- Lake/Dam

N

500 0 500 1,000

Metres

APPROX SCALE 1:50,000 @ A4

GDA 1994 MGA Zone 56

DATA SOURCES:
Centennial Coal
Australia/MapConnect
Land and Property Management Authority

RPS

Figure 1
**Surface Water Monitoring Locations**

S188H_004d_D001_All_SW_Monitoring_Locations.mxd Produced: JB Reviewed: JB Date: 28/08/2014

# APPENDIX A: TRIGGER VALUES

**Table 3.4.1** Trigger values for toxicants at alternative levels of protection. Values in grey shading are the trigger values applying to typical *slightly–moderately disturbed systems*; see table 3.4.2 and Section 3.4.2.4 for guidance on applying these levels to different ecosystem conditions.

| **Chemical** | **Trigger values for freshwater (µgL$^{-1}$)** | | | | **Trigger values for marine water (µgL$^{-1}$)** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Level of protection (% species)** | | | | **Level of protection (% species)** | | | |
| | **99%** | **95%** | **90%** | **80%** | **99%** | **95%** | **90%** | **80%** |
| **METALS & METALLOIDS** | | | | | | | | |
| Aluminium pH >6.5 | 27 | 55 | 80 | 150 | ID | ID | ID | ID |
| Aluminium pH <6.5 | ID | ID | ID | ID | ID | ID | ID | ID |
| Antimony | ID | ID | ID | ID | ID | ID | ID | ID |
| Arsenic (As III) | 1 | 24 | 94[C] | 360[C] | ID | ID | ID | ID |
| Arsenic (AsV) | 0.8 | 13 | 42 | 140[C] | ID | ID | ID | ID |
| Beryllium | ID | ID | ID | ID | ID | ID | ID | ID |
| Bismuth | ID | ID | ID | ID | ID | ID | ID | ID |
| Boron | 90 | 370[C] | 680[C] | 1300[C] | ID | ID | ID | ID |
| Cadmium H | 0.06 | 0.2 | 0.4 | 0.8[C] | 0.7[B] | 5.5[B, C] | 14[B, C] | 36[B, A] |
| Chromium (Cr III) H | ID | ID | ID | ID | 7.7 | 27.4 | 48.6 | 90.6 |
| Chromium (CrVI) | 0.01 | 1.0[C] | 6[A] | 40[A] | 0.14 | 4.4 | 20[C] | 85[C] |
| Cobalt | ID | ID | ID | ID | 0.005 | 1 | 14 | 150[C] |
| Copper H | 1.0 | 1.4 | 1.8[C] | 2.5[C] | 0.3 | 1.3 | 3[C] | 8[A] |
| Gallium | ID | ID | ID | ID | ID | ID | ID | ID |
| Iron | ID | ID | ID | ID | ID | ID | ID | ID |
| Lanthanum | ID | ID | ID | ID | ID | ID | ID | ID |
| Lead H | 1.0 | 3.4 | 5.6 | 9.4[C] | 2.2 | 4.4 | 6.6[C] | 12[C] |
| Manganese | 1200 | 1900[C] | 2500[C] | 3600[C] | ID | ID | ID | ID |
| Mercury (inorganic) B | 0.06 | 0.6 | 1.9[C] | 5.4[A] | 0.1 | 0.4[C] | 0.7[C] | 1.4[C] |
| Mercury (methyl) | ID | ID | ID | ID | ID | ID | ID | ID |
| Molybdenum | ID | ID | ID | ID | ID | ID | ID | ID |
| Nickel H | 8 | 11 | 13 | 17[C] | 7 | 70[C] | 200[A] | 560[A] |
| Selenium (Total) B | 5 | 11 | 18 | 34 | ID | ID | ID | ID |
| Selenium (SeIV) B | ID | ID | ID | ID | ID | ID | ID | ID |
| Silver | 0.02 | 0.05 | 0.1 | 0.2[C] | 0.8 | 1.4 | 1.8 | 2.6[C] |
| Thallium | ID | ID | ID | ID | ID | ID | ID | ID |
| Tin (inorganic, SnIV) | ID | ID | ID | ID | ID | ID | ID | ID |
| Tributyltin (as µg/L Sn) | ID | ID | ID | ID | 0.0004 | 0.006[C] | 0.02[C] | 0.05[C] |
| Uranium | ID | ID | ID | ID | ID | ID | ID | ID |
| Vanadium | ID | ID | ID | ID | 50 | 100 | 160 | 280 |
| Zinc H | 2.4 | 8.0[C] | 15[C] | 31[C] | 7 | 15[C] | 23[C] | 43[C] |
| **NON-METALLIC INORGANICS** | | | | | | | | |
| Ammonia D | 320 | 900[C] | 1430[C] | 2300[A] | 500 | 910 | 1200 | 1700 |
| Chlorine E | 0.4 | 3 | 6[A] | 13[A] | ID | ID | ID | ID |
| Cyanide F | 4 | 7 | 11 | 18 | 2 | 4 | 7 | 14 |
| Nitrate J | 17 | 700 | 3400[C] | 17000[A] | ID | ID | ID | ID |
| Hydrogen sulfide G | 0.5 | 1.0 | 1.5 | 2.6 | ID | ID | ID | ID |
| **ORGANIC ALCOHOLS** | | | | | | | | |
| Ethanol | 400 | 1400 | 2400[C] | 4000[C] | ID | ID | ID | ID |
| Ethylene glycol | ID | ID | ID | ID | ID | ID | ID | ID |
| Isopropyl alcohol | ID | ID | ID | ID | ID | ID | ID | ID |
| **CHLORINATED ALKANES** | | | | | | | | |
| **Chloromethanes** | | | | | | | | |
| Dichloromethane | ID | ID | ID | ID | ID | ID | ID | ID |
| Chloroform | ID | ID | ID | ID | ID | ID | ID | ID |
| Carbon tetrachloride | ID | ID | ID | ID | ID | ID | ID | ID |
| **Chloroethanes** | | | | | | | | |
| 1,2-dichloroethane | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,1,1-trichloroethane | ID | ID | ID | ID | ID | ID | ID | ID |

| **Chemical** | **Trigger values for freshwater ($\mu gL^{-1}$)** | | | | **Trigger values for marine water ($\mu gL^{-1}$)** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Level of protection (% species)** | | | | **Level of protection (% species)** | | | |
| | **99%** | **95%** | **90%** | **80%** | **99%** | **95%** | **90%** | **80%** |
| 1,1,2-trichloroethane | 5400 | 6500 | 7300 | 8400 | 140 | 1900 | 5800 [C] | 18000 [C] |
| 1,1,2,2-tetrachloroethane | ID | ID | ID | ID | ID | ID | ID | ID |
| Pentachloroethane | ID | ID | ID | ID | ID | ID | ID | ID |
| Hexachloroethane B | 290 | 360 | 420 | 500 | ID | ID | ID | ID |
| **Chloropropanes** | | | | | | | | |
| 1,1-dichloropropane | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2-dichloropropane | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,3-dichloropropane | ID | ID | ID | ID | ID | ID | ID | ID |
| **CHLORINATED ALKENES** | | | | | | | | |
| Chloroethylene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,1-dichloroethylene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,1,2-trichloroethylene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,1,2,2-tetrachloroethylene | ID | ID | ID | ID | ID | ID | ID | ID |
| 3-chloropropene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,3-dichloropropene | ID | ID | ID | ID | ID | ID | ID | ID |
| **ANILINES** | | | | | | | | |
| Aniline | 8 | 250 [A] | 1100 [A] | 4800 [A] | ID | ID | ID | ID |
| 2,4-dichloroaniline | 0.6 | 7 | 20 | 60 [C] | ID | ID | ID | ID |
| 2,5-dichloroaniline | ID | ID | ID | ID | ID | ID | ID | ID |
| 3,4-dichloroaniline | 1.3 | 3 | 6 [C] | 13 [C] | 85 | 150 | 190 | 260 |
| 3,5-dichloroaniline | ID | ID | ID | ID | ID | ID | ID | ID |
| Benzidine | ID | ID | ID | ID | ID | ID | ID | ID |
| Dichlorobenzidine | ID | ID | ID | ID | ID | ID | ID | ID |
| **AROMATIC HYDROCARBONS** | | | | | | | | |
| Benzene | 600 | 950 | 1300 | 2000 | 500 [C] | 700 [C] | 900 [C] | 1300 [C] |
| Toluene | ID | ID | ID | ID | ID | ID | ID | ID |
| Ethylbenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| o-xylene | 200 | 350 | 470 | 640 | ID | ID | ID | ID |
| *m*-xylene | ID | ID | ID | ID | ID | ID | ID | ID |
| *p*-xylene | 140 | 200 | 250 | 340 | ID | ID | ID | ID |
| *m*+*p*-xylene | ID | ID | ID | ID | ID | ID | ID | ID |
| Cumene | ID | ID | ID | ID | ID | ID | ID | ID |
| **Polycyclic Aromatic Hydrocarbons** | | | | | | | | |
| Naphthalene | 2.5 | 16 | 37 | 85 | 50 [C] | 70 [C] | 90 [C] | 120 [C] |
| Anthracene B | ID | ID | ID | ID | ID | ID | ID | ID |
| Phenanthrene B | ID | ID | ID | ID | ID | ID | ID | ID |
| Fluoranthene B | ID | ID | ID | ID | ID | ID | ID | ID |
| Benzo(a)pyrene B | ID | ID | ID | ID | ID | ID | ID | ID |
| **Nitrobenzenes** | | | | | | | | |
| Nitrobenzene | 230 | 550 | 820 | 1300 | ID | ID | ID | ID |
| 1,2-dinitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,3-dinitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,4-dinitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,3,5-trinitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-methoxy-2-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-methoxy-4-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-chloro-2-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-chloro-3-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-chloro-4-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-chloro-2,4-dinitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2-dichloro-3-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,3-dichloro-5-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,4-dichloro-2-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,4-dichloro-2-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |

| **Chemical** | **Trigger values for freshwater (µgL$^{-1}$)** | | | | **Trigger values for marine water (µgL$^{-1}$)** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Level of protection (% species)** | | | | **Level of protection (% species)** | | | |
| | **99%** | **95%** | **90%** | **80%** | **99%** | **95%** | **90%** | **80%** |
| 1,2,4,5-tetrachloro-3-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,5-dichloro-2,4-dinitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,3,5-trichloro-2,4-dinitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-fluoro-4-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| **Nitrotoluenes** | | | | | | | | |
| 2-nitrotoluene | ID | ID | ID | ID | ID | ID | ID | ID |
| 3-nitrotoluene | ID | ID | ID | ID | ID | ID | ID | ID |
| 4-nitrotoluene | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,3-dinitrotoluene | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,4-dinitrotoluene | 16 | 65 $^{C}$ | 130 $^{C}$ | 250 $^{C}$ | ID | ID | ID | ID |
| 2,4,6-trinitrotoluene | 100 | 140 | 160 | 210 | ID | ID | ID | ID |
| 1,2-dimethyl-3-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2-dimethyl-4-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 4-chloro-3-nitrotoluene | ID | ID | ID | ID | ID | ID | ID | ID |
| **Chlorobenzenes and Chloronaphthalenes** | | | | | | | | |
| Monochlorobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2-dichlorobenzene | 120 | 160 | 200 | 270 | ID | ID | ID | ID |
| 1,3-dichlorobenzene | 160 | 260 | 350 | 520 $^{C}$ | ID | ID | ID | ID |
| 1,4-dichlorobenzene | 40 | 60 | 75 | 100 | ID | ID | ID | ID |
| 1,2,3-trichlorobenzene B | 3 | 10 | 16 | 30 $^{C}$ | ID | ID | ID | ID |
| 1,2,4-trichlorobenzene B | 85 | 170$^{C}$ | 220$^{C}$ | 300$^{C}$ | 20 | 80 | 140 | 240 |
| 1,3,5-trichlorobenzene B | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2,3,4-tetrachlorobenzene B | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2,3,5-tetrachlorobenzene B | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2,4,5-tetrachlorobenzene B | ID | ID | ID | ID | ID | ID | ID | ID |
| Pentachlorobenzene B | ID | ID | ID | ID | ID | ID | ID | ID |
| Hexachlorobenzene B | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-chloronaphthalene | ID | ID | ID | ID | ID | ID | ID | ID |
| **Polychlorinated Biphenyls (PCBs) & Dioxins** | | | | | | | | |
| Capacitor 21 B | ID | ID | ID | ID | ID | ID | ID | ID |
| Aroclor 1016 B | ID | ID | ID | ID | ID | ID | ID | ID |
| Aroclor 1221 B | ID | ID | ID | ID | ID | ID | ID | ID |
| Aroclor 1232 B | ID | ID | ID | ID | ID | ID | ID | ID |
| Aroclor 1242 B | 0.3 | 0.6 | 1.0 | 1.7 | ID | ID | ID | ID |
| Aroclor 1248 B | ID | ID | ID | ID | ID | ID | ID | ID |
| Aroclor 1254 B | 0.01 | 0.03 | 0.07 | 0.2 | ID | ID | ID | ID |
| Aroclor 1260 B | ID | ID | ID | ID | ID | ID | ID | ID |
| Aroclor 1262 B | ID | ID | ID | ID | ID | ID | ID | ID |
| Aroclor 1268 B | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,3,4'-trichlorobiphenyl B | ID | ID | ID | ID | ID | ID | ID | ID |
| 4,4'-dichlorobiphenyl B | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,2',4,5,5'-pentachloro-1,1'-biphenyl B | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,4,6,2',4',6'-hexachlorobiphenyl B | ID | ID | ID | ID | ID | ID | ID | ID |
| Total PCBs B | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,3,7,8-TCDD B | ID | ID | ID | ID | ID | ID | ID | ID |
| **PHENOLS and XYLENOLS** | | | | | | | | |
| Phenol | 85 | 320 | 600 | 1200 $^{C}$ | 270 | 400 | 520 | 720 |
| 2,4-dimethylphenol | ID | ID | ID | ID | ID | ID | ID | ID |
| Nonylphenol | ID | ID | ID | ID | ID | ID | ID | ID |
| 2-chlorophenol T | 340 $^{C}$ | 490 $^{C}$ | 630 $^{C}$ | 870 $^{C}$ | ID | ID | ID | ID |
| 3-chlorophenol T | ID | ID | ID | ID | ID | ID | ID | ID |
| 4-chlorophenol T | 160 | 220 | 280 $^{C}$ | 360 $^{C}$ | ID | ID | ID | ID |
| 2,3-dichlorophenol T | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,4-dichlorophenol T | 120 | 160 $^{C}$ | 200 $^{C}$ | 270 $^{C}$ | ID | ID | ID | ID |

| Chemical | Trigger values for freshwater (µgL$^{-1}$) | | | | Trigger values for marine water (µgL$^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | Level of protection (% species) | | | | Level of protection (% species) | | | |
| | 99% | 95% | 90% | 80% | 99% | 95% | 90% | 80% |
| 2,5-dichlorophenol T | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,6-dichlorophenol T | ID | ID | ID | ID | ID | ID | ID | ID |
| 3,4-dichlorophenol T | ID | ID | ID | ID | ID | ID | ID | ID |
| 3,5-dichlorophenol T | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,3,4-trichlorophenol T | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,3,5-trichlorophenol T | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,3,6-trichlorophenol T | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,4,5-trichlorophenol T,B | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,4,6-trichlorophenol T,B | 3 | 20 | 40 | 95 | ID | ID | ID | ID |
| 2,3,4,5-tetrachlorophenol T,B | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,3,4,6- tetrachlorophenol T,B | 10 | 20 | 25 | 30 | ID | ID | ID | ID |
| 2,3,5,6- tetrachlorophenol T,B | ID | ID | ID | ID | ID | ID | ID | ID |
| Pentachlorophenol T,B | 3.6 | 10 | 17 | 27[A] | 11 | 22 | 33 | 55[A] |
| **Nitrophenols** | | | | | | | | |
| 2-nitrophenol | ID | ID | ID | ID | ID | ID | ID | ID |
| 3-nitrophenol | ID | ID | ID | ID | ID | ID | ID | ID |
| 4-nitrophenol | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,4-dinitrophenol | 13 | 45 | 80 | 140 | ID | ID | ID | ID |
| 2,4,6-trinitrophenol | ID | ID | ID | ID | ID | ID | ID | ID |
| **ORGANIC SULFUR COMPOUNDS** | | | | | | | | |
| Carbon disulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| Isopropyl disulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| n-propyl sulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| Propyl disulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| Tert-butyl sulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| Phenyl disulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| Bis(dimethylthiocarbamyl)sulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| Bis(diethylthiocarbamyl)disulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| 2-methoxy-4H-1,3,2-benzodioxaphosphorium-2-sulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| **Xanthates** | | | | | | | | |
| Potassium amyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| Potassium ethyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| Potassium hexyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| Potassium isopropyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| Sodium ethyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| Sodium isobutyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| Sodium isopropyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| Sodium sec-butyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| **PHTHALATES** | | | | | | | | |
| Dimethylphthalate | 3000 | 3700 | 4300 | 5100 | ID | ID | ID | ID |
| Diethylphthalate | 900 | 1000 | 1100 | 1300 | ID | ID | ID | ID |
| Dibutylphthalate B | 9.9 | 26 | 40.2 | 64.6 | ID | ID | ID | ID |
| Di(2-ethylhexyl)phthalate B | ID | ID | ID | ID | ID | ID | ID | ID |
| **MISCELLANEOUS INDUSTRIAL CHEMICALS** | | | | | | | | |
| Acetonitrile | ID | ID | ID | ID | ID | ID | ID | ID |
| Acrylonitrile | ID | ID | ID | ID | ID | ID | ID | ID |
| Poly(acrylonitrile-co-butadiene-co-styrene) | 200 | 530 | 800[C] | 1200[C] | 200 | 250 | 280 | 340 |
| Dimethylformamide | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2-diphenylhydrazine | ID | ID | ID | ID | ID | ID | ID | ID |
| Diphenylnitrosamine | ID | ID | ID | ID | ID | ID | ID | ID |
| Hexachlorobutadiene | ID | ID | ID | ID | ID | ID | ID | ID |
| Hexachlorocyclopentadiene | ID | ID | ID | ID | ID | ID | ID | ID |

| Chemical | | Trigger values for freshwater ($\mu gL^{-1}$) | | | | Trigger values for marine water ($\mu gL^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Level of protection (% species) | | | | Level of protection (% species) | | | |
| | | 99% | 95% | 90% | 80% | 99% | 95% | 90% | 80% |
| Isophorone | | ID | ID | ID | ID | ID | ID | ID | ID |
| **ORGANOCHLORINE PESTICIDES** | | | | | | | | | |
| Aldrin | B | ID | ID | ID | ID | ID | ID | ID | ID |
| Chlordane | B | 0.03 | 0.08 | 0.14 | 0.27 $^{C}$ | ID | ID | ID | ID |
| DDE | B | ID | ID | ID | ID | ID | ID | ID | ID |
| DDT | B | 0.006 | 0.01 | 0.02 | 0.04 | ID | ID | ID | ID |
| Dicofol | B | ID | ID | ID | ID | ID | ID | ID | ID |
| Dieldrin | B | ID | ID | ID | ID | ID | ID | ID | ID |
| Endosulfan | B | 0.03 | 0.2 $^{A}$ | 0.6 $^{A}$ | 1.8 $^{A}$ | 0.005 | 0.01 | 0.02 | 0.05 $^{A}$ |
| Endosulfan alpha | B | ID | ID | ID | ID | ID | ID | ID | ID |
| Endosulfan beta | B | ID | ID | ID | ID | ID | ID | ID | ID |
| Endrin | B | 0.01 | 0.02 | 0.04 $^{C}$ | 0.06 $^{A}$ | 0.004 | 0.008 | 0.01 | 0.02 |
| Heptachlor | B | 0.01 | 0.09 | 0.25 | 0.7 $^{A}$ | ID | ID | ID | ID |
| Lindane | | 0.07 | 0.2 | 0.4 | 1.0 $^{A}$ | ID | ID | ID | ID |
| Methoxychlor | B | ID | ID | ID | ID | ID | ID | ID | ID |
| Mirex | B | ID | ID | ID | ID | ID | ID | ID | ID |
| Toxaphene | B | 0.1 | 0.2 | 0.3 | 0.5 | ID | ID | ID | ID |
| **ORGANOPHOSPHORUS PESTICIDES** | | | | | | | | | |
| Azinphos methyl | | 0.01 | 0.02 | 0.05 | 0.11 $^{A}$ | ID | ID | ID | ID |
| Chlorpyrifos | B | 0.00004 | 0.01 | 0.11 $^{A}$ | 1.2 $^{A}$ | 0.0005 | 0.009 | 0.04$^{A}$ | 0.3 $^{A}$ |
| Demeton | | ID | ID | ID | ID | ID | ID | ID | ID |
| Demeton-S-methyl | | ID | ID | ID | ID | ID | ID | ID | ID |
| Diazinon | | 0.00003 | 0.01 | 0.2 $^{A}$ | 2 $^{A}$ | ID | ID | ID | ID |
| Dimethoate | | 0.1 | 0.15 | 0.2 | 0.3 | ID | ID | ID | ID |
| Fenitrothion | | 0.1 | 0.2 | 0.3 | 0.4 | ID | ID | ID | ID |
| Malathion | | 0.002 | 0.05 | 0.2 | 1.1 $^{A}$ | ID | ID | ID | ID |
| Parathion | | 0.0007 | 0.004 $^{C}$ | 0.01 $^{C}$ | 0.04 $^{A}$ | ID | ID | ID | ID |
| Profenofos | B | ID | ID | ID | ID | ID | ID | ID | ID |
| Temephos | B | ID | ID | ID | ID | 0.0004 | 0.05 | 0.4 | 3.6 $^{A}$ |
| **CARBAMATE & OTHER PESTICIDES** | | | | | | | | | |
| Carbofuran | | 0.06 | 1.2 $^{A}$ | 4 $^{A}$ | 15 $^{A}$ | ID | ID | ID | ID |
| Methomyl | | 0.5 | 3.5 | 9.5 | 23 | ID | ID | ID | ID |
| S-methoprene | | ID | ID | ID | ID | ID | ID | ID | ID |
| **PYRETHROIDS** | | | | | | | | | |
| Deltamethrin | | ID | ID | ID | ID | ID | ID | ID | ID |
| Esfenvalerate | | ID | 0.001* | ID | ID | ID | ID | ID | ID |
| **HERBICIDES & FUNGICIDES** | | | | | | | | | |
| **Bypyridilium herbicides** | | | | | | | | | |
| Diquat | | 0.01 | 1.4 | 10 | 80 $^{A}$ | ID | ID | ID | ID |
| Paraquat | | ID | ID | ID | ID | ID | ID | ID | ID |
| **Phenoxyacetic acid herbicides** | | | | | | | | | |
| MCPA | | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,4-D | | 140 | 280 | 450 | 830 | ID | ID | ID | ID |
| 2,4,5-T | | 3 | 36 | 100 | 290 $^{A}$ | ID | ID | ID | ID |
| **Sulfonylurea herbicides** | | | | | | | | | |
| Bensulfuron | | ID | ID | ID | ID | ID | ID | ID | ID |
| Metsulfuron | | ID | ID | ID | ID | ID | ID | ID | ID |
| **Thiocarbamate herbicides** | | | | | | | | | |
| Molinate | | 0.1 | 3.4 | 14 | 57 | ID | ID | ID | ID |
| Thiobencarb | | 1 | 2.8 | 4.6 | 8 $^{C}$ | ID | ID | ID | ID |
| Thiram | | 0.01 | 0.2 | 0.8 $^{C}$ | 3 $^{A}$ | ID | ID | ID | ID |
| **Triazine herbicides** | | | | | | | | | |
| Amitrole | | ID | ID | ID | ID | ID | ID | ID | ID |
| Atrazine | | 0.7 | 13 | 45 $^{C}$ | 150 $^{C}$ | ID | ID | ID | ID |

| **Chemical** | **Trigger values for freshwater ($\mu gL^{-1}$)** | | | | **Trigger values for marine water ($\mu gL^{-1}$)** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Level of protection (% species)** | | | | **Level of protection (% species)** | | | |
| | **99%** | **95%** | **90%** | **80%** | **99%** | **95%** | **90%** | **80%** |
| Hexazinone | ID | ID | ID | ID | ID | ID | ID | ID |
| Simazine | 0.2 | 3.2 | 11 | 35 | ID | ID | ID | ID |
| **Urea herbicides** | | | | | | | | |
| Diuron | ID | ID | ID | ID | ID | ID | ID | ID |
| Tebuthiuron | 0.02 | 2.2 | 20 | 160[C] | ID | ID | ID | ID |
| **Miscellaneous herbicides** | | | | | | | | |
| Acrolein | ID | ID | ID | ID | ID | ID | ID | ID |
| Bromacil | ID | ID | ID | ID | ID | ID | ID | ID |
| Glyphosate | 370 | 1200 | 2000 | 3600[A] | ID | ID | ID | ID |
| Imazethapyr | ID | ID | ID | ID | ID | ID | ID | ID |
| Ioxynil | ID | ID | ID | ID | ID | ID | ID | ID |
| Metolachlor | ID | ID | ID | ID | ID | ID | ID | ID |
| Sethoxydim | ID | ID | ID | ID | ID | ID | ID | ID |
| Trifluralin B | 2.6 | 4.4 | 6 | 9[A] | ID | ID | ID | ID |
| **GENERIC GROUPS OF CHEMICALS** | | | | | | | | |
| **Surfactants** | | | | | | | | |
| Linear alkylbenzene sulfonates (LAS) | 65 | 280 | 520[C] | 1000[C] | ID | ID | ID | ID |
| Alcohol ethoxyolated sulfate (AES) | 340 | 650 | 850[C] | 1100[C] | ID | ID | ID | ID |
| Alcohol ethoxylated surfactants (AE) | 50 | 140 | 220 | 360[C] | ID | ID | ID | ID |
| **Oils & Petroleum Hydrocarbons** | ID | ID | ID | ID | ID | ID | ID | ID |
| **Oil Spill Dispersants** | | | | | | | | |
| BP 1100X | ID | ID | ID | ID | ID | ID | ID | ID |
| Corexit 7664 | ID | ID | ID | ID | ID | ID | ID | ID |
| Corexit 8667 | | ID | ID | ID | ID | ID | ID | ID |
| Corexit 9527 | ID | ID | ID | ID | 230 | 1100 | 2200 | 4400[A] |
| Corexit 9550 | ID | ID | ID | ID | ID | ID | ID | ID |

**Notes:** Where the final water quality guideline to be applied to a site is below current analytical practical quantitation limits, see Section 3.4.3.3 for guidance.

Most trigger values listed here for metals and metalloids are *High reliability* figures, derived from field or chronic NOEC data (see 3.4.2.3 for reference to Volume 2). The exceptions are *Moderate reliability* for freshwater aluminium (pH >6.5), manganese and marine chromium (III).

Most trigger values listed here for non-metallic inorganics and organic chemicals are *Moderate reliability* figures, derived from acute $LC_{50}$ data (see 3.4.2.3 for reference to Volume 2). The exceptions are *High reliability* for freshwater ammonia, 3,4-DCA, endosulfan, chlorpyrifos, esfenvalerate, tebuthiuron, three surfactants and marine for 1,1,2-TCE and chlorpyrifos.

* = *High reliability* figure for esfenvalerate derived from mesocosm NOEC data (no alternative protection levels available).

A = Figure may not protect key test species from acute toxicity (and chronic) — check Section 8.3.7 for spread of data and its significance. ‘A’ indicates that trigger value > acute toxicity figure; note that trigger value should be <1/3 of acute figure (Section 8.3.4.4).

B = Chemicals for which possible bioaccumulation and secondary poisoning effects should be considered (see Sections 8.3.3.4 and 8.3.5.7).

C = Figure may not protect key test species from chronic toxicity (this refers to experimental chronic figures or geometric mean for species) — check Section 8.3.7 for spread of data and its significance. Where grey shading and ‘C’ coincide, refer to text in Section 8.3.7.

D = Ammonia as TOTAL ammonia as [$NH_3$-N] at pH 8. For changes in trigger value with pH refer to Section 8.3.7.2.

E = Chlorine as total chlorine, as [Cl]; see Section 8.3.7.2.

F = Cyanide as un-ionised HCN, measured as [CN]; see Section 8.3.7.2.

G = Sulfide as un-ionised $H_2S$, measured as [S]; see Section 8.3.7.2.

H = Chemicals for which algorithms have been provided in table 3.4.3 to account for the effects of hardness. The values have been calculated using a hardness of 30 mg/L $CaCO_3$. These should be adjusted to the site-specific hardness (see Section 3.4.3).

J = Figures protect against toxicity and do not relate to eutrophication issues. Refer to Section 3.3 if eutrophication is the issue of concern.

ID = Insufficient data to derive a reliable trigger value. Users advised to check if a low reliability value or an ECL is given in Section 8.3.7.

T = Tainting or flavour impairment of fish flesh may possibly occur at concentrations below the trigger value. See Sections 4.4.5.3/3 and 8.3.7.

# Regional Biodiversity Strategy

## Western Projects

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## Approval for Issue

| Name | Signature | Date |
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| Paul Hillier | | 01/10/2014 |

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# 1.0 Introduction

RPS has been engaged to provide Centennial Coal with a response to the Director-General's requirements issued for the Angus Place and Springvale projects on 6th November 2012 and the Neubeck Coal Project on 30th August 2013 which included:

> *An offset strategy, which is clearly quantified, to ensure that the development maintains or improves the terrestrial and aquatic biodiversity values of the region in the medium to long term.*

An offset package is also required, where impacts cannot be avoided or mitigated to compensate for any predicted or potential residual significant impacts on Matters of National Environmental Significance, as part of the supplementary Director-General's requirements issued by NSW Department of Planning and Infrastructure (DoPI) for each of the three Projects.

This Regional Biodiversity Strategy also seeks to provide compensatory measures for the impacts associated with the following Centennial projects:

- Springvale Bore 8;
- Angus Place Ventilation Facility;
- Springvale Western Coal Services; and
- Clarence Reject Emplacement Area (REA 6).

Provisions of offsets are required as part of the conditions of consent for the four above listed projects. This document quantifies the direct and indirect impacts of the above relevant projects. It also provides details of how the direct and indirect residual impacts will be offset, what additional supplementary measures are proposed, and how those offsets will be secured and managed. This document also provides a discussion on how the offset measures proposed by Centennial Coal will satisfy both the state and federal offset principles.

# 2.0 Government Policy on Biodiversity Offsetting

Offsets are used to compensate for the residual adverse impacts of a Project on the environment. Offsets are used to balance the residual impacts after avoidance and mitigation measures have been implemented. For assessments under the EPBC Act, offsets are required if these residual impacts are significant. Significance of the residual impact is tested against the Department of the Environment's Significant Impact Guidelines for Matters of National Environmental Significance (MNES) and offsets should be related to the conservation priority of the impacted species/community.

Offsets are typically packaged into 'direct offset' which provides a measurable conservation gain to compensate for the residual impacts, and 'indirect or supplementary offset' which add value to the existing knowledge base of an impacted species/community.

Offsets that deliver social, economic and/or environmental co-benefits are encouraged by both the State and Federal governments. These include offsets that increase land connectivity or offsets that protect and manage privately owned land for conservation purposes.

## 2.1 NSW Biodiversity Offsets Policy for Major Projects

NSW Biodiversity Offsets Policy for Major Projects (the Offsets Policy) and the related Framework for Biodiversity Assessment (FBA) has been produced by the NSW government to clarify, standardise and improve biodiversity offsetting for major project approvals. The Offsets Policy applies to state significant development and state significant infrastructure under the Environmental Planning and Assessment Act 1979.

The NSW Biodiversity Offset Policy for major projects was approved by cabinet and released in August 2014. The policy will initially be implemented for a transitional period of 18 months. After that time, legislative changes will be made to formalise the approach to Biodiversity Assessment and offsetting outlined in the Policy.

The policy does not apply to the projects within this Strategy, as DGRs were issued in 2012, well before the policy was released. Regardless, Centennial Coal has undertaken a review of the policy and, where possible, has aligned the Strategy with the policy principles.

Specifically the Strategy:

- Uses the BioBanking Assessment Methodology (BBAM) and an accredited ecological consultant to assess development and offset land;
- Targets offsets to biodiversity values being lost. Where this is not possible, higher conservation priorities have been included in the package;
- Offsets will be enduring and the security mechanisms meet the criteria set out in Section 3 of Appendix 1.

The Offsets Policy is underpinned by six principles. Centennial has taken these principles into consideration for the major projects, as detailed in **Table 1** below, when designing this biodiversity strategy.

**Table 1 Action Summary for the NSW Biodiversity Offsets Policy for Centennial Major Projects**

| NSW Offset Principles for Major Projects (State Significant Development and Infrastructure) | | |
|---|---|---|
| **Principle** | **Springvale and Angus Place** | **Neubeck** |
| Before offsets are considered, impacts must first be avoided and unavoidable impacts minimised through mitigation | Chapter 8 of the respective EISs discusses the constraints to the mine design that have been identified and included in mine planning | Chapter 8 of the EIS discusses the constraints to the mine design that have been identified and included in mine planning considerations. |

| NSW Offset Principles for Major Projects (State Significant Development and Infrastructure) | | |
|---|---|---|
| **Principle** | **Springvale and Angus Place** | **Neubeck** |
| measures. Only then should offsets be considered for the remaining impacts | considerations.<br>These constraints have resulted in there being no significant impacts on biodiversity values as a result of the Projects.<br>The proposed avoidance measures has successfully avoided all TSC Act listed threatened species. Additionally, all direct clearing impacts to Endangered Ecological Communities (EEC) have been avoided, with the exception of 0.22 hectares (ha) of the EEC Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland.<br>Mine design, including positioning of longwalls and reduction in void width ensures that significant subsidence impacts to sensitive biodiversity values are also avoided. | Avoidance and mitigation includes a Wangcol Creek rehabilitation program, which will avoid and retain much of the site's biodiversity values, including areas of two EECs.<br>The offset package proposed includes provision of land to compensate for the direct impacts to vegetation (including two EECs), recorded and potentially occurring threatened fauna species, *Eucalyptus cannonni, Eucalyptus aggregata* and *Thesium australe*. |
| Offset requirements should be based on a reliable and transparent assessment of losses and gains | This report assesses several key variables to compare impacts to offset sites suitability, including:<br>▪ vegetation areas;<br>▪ habitat area for fauna species;<br>▪ counts of flora species; and<br>▪ indicative ecosystem credits and species credits generated using the BBAM. | |
| Offsets must be targeted to the biodiversity values being lost or to higher conservation priorities | This report analyses the above variables in terms of the potential to satisfy like for like populations and habitats. Vegetation within conservation areas have been matched with those being impacted wherever possible. | |
| Offsets must be additional to other legal requirements | All offsets proposed as part of this Strategy are not part of any other legal requirement of any development project not covered by this Strategy. | |
| Offsets must be enduring, enforceable and auditable | Various protection mechanisms are proposed based on the requirements of each conservation site. All have been demonstrated as enduring, enforceable and auditable in **Section 5.9**. | |
| Supplementary measures can be used in lieu of offsets | Supplementary measures, as identified in this report, have been included to complement the offset package and to reduce the monitoring effort required to establish impacts, see **Section 6** of this report. | |
| Offsets can be discounted where significant social and economic benefits accrue to NSW as a consequence of the proposal | The offsets required for the projects have been quantified in the context of the biodiversity values, for which the offset land holds high conservation priorities. With the social and economic contributions proposed by the projects (discussed in Chapter 6 of the respective EISs), the offset package itself provides significant social and economic benefits to the NSW community through:<br>▪ conservation in perpetuity of high priority biodiversity values<br>▪ proximity of offset land to existing reservations<br>▪ provision of financial support to achieve agreed criteria for conservation<br>▪ provision of access to conserved land for tourism and recreational purposes<br>▪ investment in research, recovery and maintenance plans to understand potential threats to conservation outcomes and integrate this understanding with values of adjacent National Parks, World Heritage Areas and National Heritage Places<br>The biodiversity strategy presented in the respective EISs presents an opportunity cost to Centennial, however, it also provides a long term benefit to the community. | |

## 2.2 Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy

**Table 2 Action Summary for the EPBC Act Environmental Offsets Policy for Centennial Major Projects**

| Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy | | |
|---|---|---|
| **Principle** | **Springvale and Angus Place** | **Neubeck** |
| Suitable offsets must deliver an overall conservation outcomes that improves or maintains the viability of the protected matter | As there are no direct impacts to protected matters, and the residual impacts following avoidance and mitigation measures are not significant, direct offsets are not required. Regardless, the offset package proposed includes provision of land to compensate for the potential impacts to Temperate Highland Peat Swamps on Sandstone (THPSS). | This Strategy includes provision of land to compensate for the direct impacts to *Thesium australe*. This Strategy also provides compensatory measures for those EPBC Act listed species that were found to have known or potential habitat within the Neubeck Project Area, namely Regent Honeyeater, Spotted-tailed Quoll, Koala and Large-eared Pied Bat. |
| Suitable offsets must be built around direct offsets but may include other compensatory measures | As there are no direct impacts to protected matters, and the residual impacts following avoidance and mitigation measures are not significant, direct offsets are not required. Regardless, the offset package proposed includes measures to mitigate and if required, offset Temperate Highland Peat Swamps on Sandstone (THPSS).<br>Further compensatory measures will be implemented, supporting clear conservation objectives and reducing the monitoring related impacts to the Newnes Plateau. | This Strategy includes provision of land to compensate for the direct impacts to *Thesium australe* (listed as vulnerable under the EPBC Act). This Strategy also provides compensatory measures for those EPBC Act listed species that were found to have known or potential habitat within the Neubeck Project Area, namely Regent Honeyeater, Spotted-tailed Quoll, Koala and Large-eared Pied Bat. |
| Suitable offsets must be of a size and scale proportionate to the residual impacts of the protected matter | This Strategy has been prepared to analyse the suitability of proposed offsets and supplementary measures both in terms of size and value. | |
| Suitable offsets must effectively account for and manage the risks of the offset not succeeding | To ensure success of the strategy, Centennial is providing land already owned by the company with high conservation value. Centennial will also develop completion criteria for the offset land as outlined in this strategy.<br>In the unlikely event that the offset does not succeed, Centennial will include provision for offset management in the security held by the Division of Resources and Energy under the *Mining Act 1992*. | |
| Suitable offsets must be additional to what is already required, determined by law or planning regulations, or agreed to under other schemes or programs | The proposed offset lands are not associated with any other offset requirements or proposals. | |
| Suitable offsets must be efficient, effective, timely, transparent, scientifically robust and reasonable | As the land is owned by Centennial Coal, the offset can be secured for the life of the Projects immediately upon grant of consent. The offset land is effective as, outlined in this strategy, the land provides connectivity to the Airly State Forest, Ben Bullen State Forest, the Capertee National Park and the Mugii Murum-ban State Conservation Area and the Greater Blue Mountains World Heritage Area. Management actions and completion criteria identified in this strategy will result in effective and timely offset security. | |
| Suitable offsets must have transparent governance arrangements including being able to be readily measured, monitored, audited and enforced | The offsets lands are owned by subsidiaries of Centennial Coal Company, and as such a baseline condition against which the success of completion criteria can be measured, has been undertaken. This, along with a restrictive covenant arrangement for the land, or consent requirements, will ensure the offset can be measured, monitored and audited in accordance with the completion criteria | |

| Environment Protection and Biodiversity Conservation Act 1999<br>Environmental Offsets Policy | | |
|---|---|---|
| **Principle** | **Springvale and Angus Place** | **Neubeck** |
| | described in this Strategy.<br>There are no future development proposals for the land. There are no mineral titles on the land. Centennial holds a coal lease over part of the offset area; however there are no recoverable coal reserves. There is an existing petroleum extraction licence (PEL) over part of the offset land, and a PEL application over the remaining land. | |

# 3.0 Western Projects Overview

This section provides an overview of the outcomes of each proposed or existing development covered by this Regional Strategy. This section should be read in conjunction with the respective EIS documents. The locations of all projects are provided in **Figure 1**.

## 3.1 Springvale Mine Extension Project

The Project involves the extension of current mining operations, using longwall mining techniques, to the east and the south-west of the existing workings. The mining activities included:

- Continued extraction of up to 4.5 million tonnes per annum (Mtpa) of ROM coal from the Lithgow Seam underlying the Project Application Area;
- Development of underground access headings and roadways from the current mining area to the east to allow access to the proposed mining areas;
- Secondary extraction undertaken by retreat longwall mining technique for the proposed longwalls LW416 to LW432 and LW501 to LW503;
- Continuation of the use of existing ancillary surface facilities at the Springvale pit-top;
- Continuation of management of the handling of ROM coal through a crusher and screening plant at the Springvale pit-top, and the subsequent loading of the coal onto the existing overland conveyor system for dispatch to offsite locations;
- Continuation of operation and maintenance to the existing ancillary surface infrastructure for ventilation, electricity, water, materials supply, and communications at the Springvale pit-top and on Newnes Plateau;
- Installation and operatation of two additional dewatering bore facilities (Bores 9 and 10) on Newnes Plateau and the associated power and pipeline infrastructure, and upgrade of the existing tracks and construction of two new sections of access tracks to Bores 9 and 10 facilities;
- Construction of a downcast ventilation borehole at the Bore 10 facility location;
- Establishment of a services borehole area;
- Upgrade of the existing Springvale Delta Water Transfer Scheme (SDWTS) comprising construction of new sections of the trenched pipelines to increase the water delivery capacity of SDWTS from the existing 30 ML/day to up to 50 ML/day;
- Management of mine inflows using a combination of direct water transfer to the Wallerawang Power Station, via the SDWTS, and discharge through Angus Place Mine’s licensed discharge point LDP001 and Springvale Mine’s LDP009;
- Continuation to existing and initiate new environmental monitoring programs;
- Continuation of 24 hours per day, seven days per week operation;
- Continuation to provide employment to a full time workforce of up to 310 persons;
- Progressive rehabilitation of disturbed areas at infrastructure sites no longer required for mining operations;
- life-of-mine rehabilitation undertaken at the Springvale pit-top and the Newnes Plateau infrastructure disturbance areas to create final landforms commensurate with the surrounding areas and the relevant zonings of the respective areas; and
- Transfer of the operational management of coal processing and distribution infrastructure to the WCS Project.

### 3.1.1 Impact Assessment

The Project proposes minor impact on native vegetation. **Table 3** outlines the area of impact on native vegetation which totalled approximately 18.02 ha. Of this, approximately 0.22 ha of Map Unit (MU) 11 Tableland Gully Snow Gum – Ribbon Gum Montane Grassy Forest, which is commensurate with the EEC *Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes Bioregions* is proposed to be removed to allow for the Project.

**Table 3 Springvale Mine Extension Project Vegetation Impacts**

| Vegetation Community | Proposed Clearing Area (ha) |
|---|---:|
| 7 Newnes Plateau Narrow-leaved Peppermint - Mountain Gum - Brown Stringybark Layered Forest | 1.50 |
| 8 Newnes Sheltered Peppermint - Brown Barrel Shrubby Forest | 0.73 |
| 11 Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest | 0.22 |
| 26 Newnes Plateau Narrow-leaved Peppermint - Silver-top Ash Layered Open Forest | 5.44 |
| 26a Newnes Plateau Gum Hollows varient: Brittle Gum - Mountain Gum, Scribbly Gum - Snow Gum Shrubby Open Forest | 1.09 |
| 28 Sandstone Plateau And Ridge Scribbly Gum - Silver-top Ash Shrubby Woodland | 2.29 |
| 29 Sandstone Slopes Sydney Peppermint Shrubby Forest | 0.10 |
| 44 Sandstone Plateaux Tea Tree - Dwarf Sheoak - Banksia Rocky Heath | 0.07 |
| ***Sub-total*** | ***11.44*** |
| 59 Non-native Vegetation - Pine plantation / woodlot / shelter | 0.06 |
| 62 Cleared and Severely Disturbed Lands | 6.52 |
| **Total** | **18.02** |

A total of 76.57 ha of THPSS occurs within the 26.5 Degree Angle of Draw of the proposed Springvale longwalls. This is made up of 62.68 ha of Map Unit (MU) 50 Newnes Plateau Shrub Swamp, 13.31 ha of 51 Newnes Plateau Hanging Swamp and 0.58 ha of 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath. Tilts and strains greater than 0.05mm/m and 2mm/m respectively occur 90% of the time within this 26.5 Degree Angle of Draw.

This Project is not expected to have a significant impact upon any shrub swamps or hanging swamps. This prediction is supported by a high level of confidence in subsidence predictions as shown by post-mining subsidence monitoring data. A detailed discussion on the levels of evidence that has informed this position and the resultant consideration for the need for an offset to be provided for THPSS is further discussion in **Section 3.10**.

### 3.1.2 Mitigation Measures

Proposed mitigation measures for this project are summaries in **Table 4**.

**Table 4 Mitigation measures for the Springvale Mine Extension Project**

| Impact | Mitigation Measures |
|---|---|
| **Direct Impacts** | |
| Impacts to flora (loss of species and habitat) | For those areas where hard surfaces are required, undertake stockpiling of soil to enable reestablishment of viable habitat following infrastructure decommissioning. |
| | During clearing, and where it would not interfere with operations, the removal of vegetation should be limited to |

| Impact | Mitigation Measures |
|---|---|
| | above ground parts as much as possible. This will enable any vegetation that is able to resprout once works are completed to do so. |
| Impacts to fauna (loss of species and habitat) | Where possible, clearing activities will be timed to avoid removal of hollow-bearing trees during breeding season of threatened species. |
| | Employment of best practice methods for felling of hollow-bearing trees. |
| | Prioritise the retention of hollow-bearing tree within Asset Protection Zones associated with the dewatering bore sites. |
| | Placement of hollow logs and felled hollow-bearing trees within adjacent uncleared vegetation to provide additional habitat resources for terrestrial fauna. |
| **Indirect Impacts (reduction in quality of habitats)** | |
| Erosion and Sedimentation | Limiting the amount of exposed surfaces that may become eroded by weather and operations. |
| | Installation of erosion and runoff control measures around cleared and operational areas. |
| Dust | Implementation of dust control measures to protect adjacent retained vegetation communities |
| Weed Incursion | Strict weed management, monitoring and control practices should to be implemented to minimise the spread of exotic species into natural areas within the sites. |

## 3.2 Angus Place Mine Extension Project

The Project involves the extension of current mining operations, using longwall mining techniques, to the east and the south-west of the existing workings. The mining activities include:

- Continued extraction of up to 4 million tonnes per annum (Mtpa) of ROM coal from the Lithgow Seam underlying the Project Application Area;
- Development of underground access headings and roadways from the current mining area to the east to allow access to the proposed mining areas;
- Secondary extraction undertaken by retreat longwall mining technique for the proposed longwall panels LW1001 to LW1019;
- Continuation of the use of existing ancillary surface facilities at the Angus Place pit-top;
- Continuation of management of the handling of ROM coal through a crusher and screening plant at the Springvale pit-top, and the subsequent loading of the coal onto the existing overland conveyor system for dispatch to offsite locations;
- Continuation of operation and maintenance to the existing ancillary surface infrastructure for ventilation, electricity, water, materials supply, and communications at the Angus Place pit-top and on Newnes Plateau;
- Installation and operation of seven additional dewatering borehole facilities on Newnes Plateau and the associated power and pipeline infrastructure;
- upgrade and extension of the existing access tracks from Sunnyside Ridge Road to the dewatering

borehole facilities;

- installation and operation of dewatering reinjection boreholes and pipeline infrastructure at the existing Ventilation Facility site (APC-VS2);
- construction and operation of a downcast ventilation shaft (APC-VS3) and upgrade of the existing access track to the proposed facility from Sunnyside Ridge Road;
- management of mine inflows using a combination of direct water transfer to the Wallerawang Power Station, via the SDWTS, and discharge through Angus Place Colliery's licensed discharge point LDP001 and Springvale Colliery's LDP009;
- Continuation to existing and initiate new environmental monitoring programs;
- Continuation of 24 hours per day, seven days per week operation;
- Continuation to provide employment to a full time workforce of up to 225 persons and 75 contractors;
- Progressive rehabilitation of disturbed areas at infrastructure sites no longer required for mining operations;
- life-of-mine rehabilitation undertaken at the Angus Place pit-top and the Newnes Plateau infrastructure disturbance areas to create final landforms commensurate with the surrounding areas and the relevant zonings of the respective areas; and
- Transfer of the operational management of coal processing and distribution infrastructure to the Centennial Western Coal Services Project.

### 3.2.1 Impact Assessment

The Project proposes a minor impact on native vegetation. The following table outlines the area of impact on native vegetation which totalled approximately 23.24 ha. None of the vegetation communities within the proposed clearing area were commensurate with Endangered Ecological Communities. The direct loss of threatened flora will be avoided as a result of the proposal design. The areas of vegetation proposed to be cleared are provided in **Table 5**.

**Table 5 Angus Place Mine Extension Project Vegetation Impacts**

| Vegetation Community | Proposed Clearing Area (ha) |
|---|---|
| 07 Newnes Plateau Narrow - Leaved Peppermint - Mountain Gum - Brown Stringybark Layered Forest | 1.10 |
| 14 Tableland Mountain Gum - Snow Gum - Daviesia Montane Open Forest | 0.16 |
| 26 Newnes Plateau Narrow-leaved Peppermint - Silvertop Ash Shrubby Woodland on Ridges | 8.20 |
| 26a Newnes Plateau Gum Hollows varient: Brittle Gum - Mountain Gum, Scribbly Gum - Snow Gum Shrubby Open Forest | 0.11 |
| 28 Sandstone Plateau and Ridge Scribbly Gum - Silvertop Ash Shrubby Woodland | 5.45 |
| 29 Sandstone Slopes Sydney Peppermint Shrubby Forest | 1.84 |
| 30 Exposed Blue Mountains Sydney Peppermint - Silvertop Ash Shrubby Woodland | 6.38 |
| **Total** | **23.24** |

A total of 20.04 ha of THPSS occur within the 26.5 Degree Angle of Draw of the proposed Angus Place longwalls. This is made up of 10.33 ha of Map Unit (MU) 50 Newnes Plateau Shrub Swamp and 9.71 ha of 51 Newnes Plateau Hanging Swamp. This Project is not expected to have a significant impact upon any shrub swamps or hanging swamps. This prediction is supported by a high level of confidence in subsidence predictions as shown by post-mining subsidence monitoring data. A detailed discussion on the levels of evidence that has informed this position and the resultant consideration for the need for an offset to be provided for THPSS is further discussion in **Section 3.10**.

### 3.2.2 Mitigation Measures

Proposed mitigation measures for this project are summaries in **Table 6**.

**Table 6 Mitigation measures for the Angus Place Mine Extension Project**

| Impact | Mitigation Measures |
|---|---|
| **Direct Impacts** | |
| Impacts to flora (loss of species and habitat) | For those areas where hard surfaces are required, undertake stockpiling of soil to enable reestablishment of viable habitat following infrastructure decommissioning. |
| | During clearing, and where it would not interfere with operations, the removal of vegetation should be limited to above ground parts as much as possible. This will enable any vegetation that is able to resprout once works are completed to do so. |
| Impacts to fauna (loss of species and habitat) | Where possible, clearing activities will be timed to avoid removal of hollow-bearing trees during breeding season of threatened species. |
| | Employment of best practice methods for felling of hollow-bearing trees. |
| | Prioritise the retention of hollow-bearing tree within Asset Protection Zones associated with the dewatering bore sites. |
| | Placement of hollow logs and felled hollow-bearing trees within adjacent uncleared vegetation to provide additional habitat resources for terrestrial fauna. |
| **Indirect Impacts (reduction in quality of habitats)** | |
| Erosion and Sedimentation | Limiting the amount of exposed surfaces that may become eroded by weather and operations. |
| | Installation of erosion and runoff control measures around cleared and operational areas. |
| Dust | Implementation of dust control measures to protect adjacent retained vegetation communities. |
| Weed Incursion | Strict weed management, monitoring and control practices should to be implemented to minimise the spread of exotic species into natural areas within the sites. |

## 3.3 Neubeck Coal Project

The primary components of the Neubeck Coal Project are:

- Extraction of coal using open cut mining methods from the Lithgow, Lidsdale, Irondale and Middle Irondale seams within the Project Application Area at a rate of up to 1.2 Mtpa;
- Extraction of up to 11 Mt ROM coal for up to 11 years;
- Disposal of reject material from the Springvale Coal Services Site in the final void within the Project Application Area following the completion of coal extraction;
- Development of infrastructure to support open cut mining operations, including demountable site offices, bathhouse, workshop facility, vehicle washdown and refuelling facilities, water management infrastructure, coal crushing facility and coal stockpiles, electricity and communication infrastructure,

access roads, and related infrastructure;

- Relocation of the Mount Piper Haul Road;
- Construction of a low level crossing across Wangcol Creek to gain access to the mining area from the administration area;
- Employment of a workforce totalling 83 full time employees;
- Transfer of ROM coal following crushing and screening directly to the Wallerawang and Mount Piper Power Stations by road transport using private haul roads;
- Transfer of ROM coal to Springvale Coal Services Site by road transport using private haul roads; Transport of overburden and interburden material by private haul road to the reject emplacement area at Springvale Coal Services or Mount Piper Power Station's existing ash emplacement area for use as capping material;
- Progressive rehabilitation of all disturbed areas; and
- A Project life of 25 years.

### 3.3.1 Impact Assessment

The Project will have a moderate impact on native vegetation. The following table outlines the area of impact on native vegetation which totals approximately 82.63 ha. Of this, approximately 12.64 ha of MU 11 Tableland Gully Snow Gum – Ribbon Gum Montane Grassy Forest and 4.23 ha of MU 15 Tableland Hollows Black Gum – Black Sally Grassy Open Forest, both of which are commensurate with the EEC *Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes Bioregions* was removed to allow for the Project.

**Table 7 Neubeck Coal Project Vegetation Impacts**

| Map Unit | Community Name | Area (ha) |
|---|---|---|
| MU11 | Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest | 12.64 |
| MU15 | Tableland Hollows Black Gum - Black Sally Open Forest | 4.23 |
| MU32 | Tableland Hills Scribbly Gum - Narrow-leaved Stringybark Shrubby Open Forest | 2.59 |
| MU33 | Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest | 15 |
| MU35 | Tableland Gully Mountain Gum - Broad-leaved Peppermint Grassy Forest | 9.11 |
| MU37 | Coxs Permian Red Stringybark - Brittle Gum Woodland | 38.87 |
| MU53 | Mountain Hollow Grassy Fen | 0.19 |
| **Sub-total** | | **82.63** |
| **Cleared Land** | | |
| MU11 (DNG) | Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest (cleared) | 11.29 |
| MU15 (DNG) | Tableland Hollows Black Gum - Black Sally Open Forest (cleared) | 17.12 |
| MU33 (DNG) | Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest (cleared) | 29.17 |
| MU37 (DNG) | Coxs Permian Red Stringybark - Brittle Gum Woodland (cleared) | 30.01 |
| **Sub-total** | | **87.59** |
| **Total** | | **170.22** |

The project will also involve the removal of 238 individual *Eucalyptus aggregata* (Black Gum), 20 *Eucalyptus cannonii* (Cannon's Stringybark) and 61 *Thesium australe* (Austral Toadflax).

The Bathurst Copper Butterfly (*Paralucia spinifera*) was considered to be potentially impacted upon as result of indirect dust impacts from the mining activities.

No other fauna species were considered as being significantly impacted upon, however the removal of 200 ha of vegetation is suitable habitat for a number of threatened fauna species within the area.

### 3.3.2 Mitigation Measures

**Table 8 Mitigation measures for the Neubeck Coal Project**

| Impact | Mitigation Measures |
|---|---|
| **Direct Impacts** | |
| Impacts to flora (loss of species and habitat) | Rehabilitation of native vegetation communities that have been directly impacted by the mine footprint or ancillary infrastructure. This is to occur progressively over the life of the mine, with action commencing immediately after disturbance to the landscape (where possible). Actions include:<br>▪ Topsoil replacement containing original seed stock;<br>▪ Planting of native locally sourced seedlings and/or tubestock; and<br>▪ Ecological enhancement through revegetation of disturbed areas to represent native vegetation communities, ultimately providing an overall increase in the available habitat for fauna usage within the Project Application Area post mining. |
| | Collection of seed from threatened flora including *Eucalyptus aggregata* and *Eucalyptus cannonii* located within the Project Application Area for propagation at a later stage. |
| | Where suitable, rehabilitation of watercourses should include the establishment of *E. aggregata* and associated habitat. |
| | An ecological monitoring program should be developed to provide an indication on the environmental status of revegetation efforts within the Project Application Area. |
| Impacts to fauna (loss of species and habitat) | Where possible, clearing activities will be timed to avoid removal of hollow-bearing trees during breeding season of threatened species. |
| | A suitably qualified person is to be present to supervise vegetation clearing within the sites and that vegetation clearing is undertaken in the following manner;<br>▪ Hollow-bearing trees are to be clearly marked (spray paint or flagging tape) by a suitably qualified person prior to clearing of surrounding vegetation;<br>▪ Immediately prior to the felling of hollow-bearing trees, trees should be given two sharp taps with the machinery arm/bucket to encourage fauna to escape. After waiting 1 – 2 minutes after tapping the tree, the hollow-bearing tree should be felled as gently as possible ; and<br>▪ A suitably qualified person is to inspect each felled hollow-bearing tree |
| | Placement of hollow logs and felled hollow-bearing trees within adjacent |

| Impact | Mitigation Measures |
|---|---|
| | uncleared vegetation in the Project Application Area to provide additional habitat resources for terrestrial fauna. |
| | Establish a hollow replacement strategy using either/both a variety of different shaped and sized nest boxes and hollow standing trees that target any known or potentially occurring threatened fauna.<br>An annual monitoring program should be developed to determine the efficacy of the nest boxes within the Project Application Area with any required adaptive strategies being addressed in the process. All nest boxes are to be maintained for structural integrity and appropriately repaired where required during monitoring events. Timing of nest box monitoring will be outlined in the monitoring program. |
| | Ecological monitoring will be undertaken as required within a Biodiversity Management Plan to be developed |
| | Implementation of a biodiversity management plan including management actions for:<br>▪ Vegetation;<br>▪ Regeneration;<br>▪ Weed removal;<br>▪ Erosion control;<br>▪ Restoration and rehabilitation works;<br>▪ Pest fauna; and<br>▪ Fire. |
| **Indirect Impacts (reduction in quality of habitats)** | |
| Erosion and Sedimentation | Implementation of an Erosion and Sediment Control Plan. |
| | Installation of erosion and runoff control measures around cleared and operational areas with particular focus on Neubeck and Wangcol Creeks. |
| | Clearing of vegetation is not to be undertaken during extensive or heavy rain events. |
| | Rehabilitated vegetation will be monitored in accordance with an appropriate method to be included in the Rehabilitation Management Plan, and on site vegetation will be monitored in accordance with a method to be described in the Biodiversity Management Plan in accordance with current best practice methods. |

| Impact | | Mitigation Measures |
|---|---|---|
| Dust (Bathurst Copper Butterfly) | Dust from roads | Implementation of dust control measures to protect adjacent retained vegetation communities, with particular focus on Bathurst Copper Butterfly habitat (note that mitigation measures have largely been influenced by those recommended in Hochuli (2011) and SLR (2013)), include:<br>▪ Vehicle restrictions that limit the speed, weight or number of vehicles on the road;<br>▪ Surface improvement by measures such as adding gravel or slag to the dirt roads; and<br>▪ Surface treatment such as watering. |
| | Wind Erosion | ▪ Areas of surface disturbance exposed to wind erosion will be minimised by only clearing when immediate works from mining are to occur in that area;<br>▪ Revegetation – use of revegetation as an interim measure to minimise emissions of particulate matter from areas that may be exposed for an extended period of time;<br>▪ Dust management plan to be implemented; and<br>▪ Rehabilitation – use of vegetation and land contouring to produce the final post-mining land form. |
| | Coal Stockpiles | Water stockpiles as required by met conditions. |
| Weed Incursion | | Implementation of a weed management plan. |

## 3.4 Springvale Bore 8

The Project involved the construction and operation of additional surface mine dewatering facility, referred to as Bore 8, along with associated infrastructure an underground cable, water pipeline and access track. Bore 8, a fenced compound with a footprint of 0.32 ha houses four boreholes installed with submersible pumps, an associated switch room with power control equipment for the operation of pumps and a sump. The access track is 3.5km long and 10m wide. 11kV cables and water pipelines will be buried in the infrastructure corridor alongside the access track. Total area of disturbance for the borehole and associated infrastructure is approximately 4 ha.

Upon completion, the disturbance area will be partially rehabilitated, leaving a final footprint of 0.32 ha at Bore 8. An Asset Protection Zone of 20m around the perimeter has been established.

Bore 8 is required to facilitate the progress of coal extraction further to the east of existing workings at Springvale. Approval was granted on 8 March 2013.

### 3.4.1 Impact Assessment

The Project proposed to impact on native vegetation and one threatened flora species. The following table outlines the approved area of impact on native vegetation which equates to approximately 3.93 ha.

**Table 9 Springvale Bore 8 Vegetation Impacts**

| Map unit | Vegetation Community Name | Orig |
|---|---|---|
| MU07 | Newnes Plateau Narrow-leaved Peppermint - Mountain Gum - Brown Stringybark Layered Forest | 1.65 ha |
| MU28 | Sandstone Plateau And Ridge Scribbly Gum - Silver-top Ash Shrubby Woodland | 1.79 ha |
| MU30 | Exposed Blue Mountains Sydney Peppermint - Silver-top Ash Shrubby Woodland | 0.49 ha |
| **Total** | | **3.93 ha** |

Approximately 1,445 individual *Persoonia hindii* plants were recorded in the Study Area, with a total of 93 individual plants proposed to be removed. Following approval, but prior to construction, consideration was given to avoiding as many *P. hindii* as possible. The avoidance measures were successful in avoiding all *P. hindii* stems.

### 3.4.2 Compensatory Measures

Centennial Springvale have undertaken a number of measures to compensate for the loss of native vegetation and individual *P. hindii* as a result of the Project.

A Rehabilitation Management Plan has been prepared which specifically details the following (not limited to):

- A description of how the performance of the rehabilitation would be monitored and assessed;
- A description of measures for soil erosion and sediment control;
- Outline provisions for progressive rehabilitation of temporarily disturbed areas and final rehabilitation following decommissioning of the Bore 8 facilities; and
- Includes a timetable for the implementation of the components of the Plan.

A Persoonia hindii Management and Research program has been prepared detailing the following;

- Timetable to undertake surveys and mapping of *P. hindii* to establish its distribution and population across the Newnes Plateau;
- The measures for the translocation of all stems (ramets) of *P. hindii* found in the area of disturbance associated with the widening of access tracks for Bore 8, to nearby areas with similar physical and biological habitat features;
- Trails to assess whether such translocated *P. hindii* stems can be successfully returned to their original locations as a component of the rehabilitation of these areas;
- A study of the rhizomatous habit of *P. hindii* and how this may affect the success of the species in translocation and/or re-colonising disturbed areas;
- A monitoring program to study the *P. hindii* stems before and after translocation;
- A monitoring program to measure the ability of the residual P. hindii population along the disturbed areas of the Bore 8 access track and construction site to regenerate; and
- Include shots and long-term goals to measure the effectiveness of the Program.

In addition to the above listed compensatory measures, a condition of approval was to provide a direct offset to compensate for the area cleared:

provide an area that is suitable in its vegetation types and extent to satisfactorily offset the residual impacts of clearing 4 ha of native vegetation associated with the construction and use of Bore 8,including the residual impacts on Persoonia hindii; and make suitable arrangements to manage, protect and provide long-term security for this area.

In determining a suitable residual offset, the Director-General will have regard to the outcomes of the *Persoonia hindii* Management and Research Program, particularly the success of translocation and/or regeneration, and the Applicant's success in implementing the Rehabilitation Management Plan.

## 3.5 Angus Place Ventilation Facility

The following activities and infrastructure were proposed to enable the successful construction and implementation of the ventilation facility, known as Angus Place Colliery Ventilation Site, its supporting infrastructure and the Subsidence Assessment Area. The proposed infrastructure was in addition to the existing use of the Angus Place Colliery site.

- Development of underground access headings from Longwall 910 up to the proposed ventilation facility site;
- Continuation of underground roadways to develop gate roads from the ventilation shaft;
- Construction and operation of a ventilation facility, consisting of both upcast (exhaust) and downcast (intake) shafts;
- Implementation of ventilation facility backup generator and an above ground self bunded diesel storage tank (20,000L);
- Construction and operation of an air compressor station;
- Implementation of several surface to mine service boreholes;
- Personnel amenities such as a demountable first aid room and sanitary facilities;
- Permanent hardstand access arrangements and standing areas. Construction of adequate security fencing;
- Water management control ponds;
- Construction of fire tanks to protect assets from bushfire impacts;
- Shaft spoil emplacement area;
- New access track from Sunnyside Ridge Road to the proposed ventilation facility;
- Construction and operation of two electrical substations;
- Provision of electrical power supply from existing overhead power lines to the ventilation facility;
- Switchyard at the existing power line to link to the proposed extension of the electrical power supply;
- Buried cables; and
- Boreholes to supply services such as concrete, ballast, stone dust, emulsion, electricity, communications and compressed air.

Approval for Angus Place Colliery Modification 2 – Ventilation project was granted on the 22 April 2013.

### 3.5.1 Impact Assessment

The Project had a minor impact on native vegetation and one threatened flora species. The following table outlines the area of impact on native vegetation which totalled approximately 15 ha.

**Table 10 Angus Place Ventilation Facility Vegetation Impacts**

| Map unit | Vegetation Community Name | Area (ha) |
|---|---|---|
| MU07 | 7 Newnes Plateau Narrow-leaved Peppermint - Mountain Gum - Brown Stringybark Layered Forest | 9.34 |
| MU14 | 14 Tableland Mountain Gum - Snow Gum - Daviesia Montane Open Forest | 0.87 |

| | | |
|---|---|---|
| MU26a | 26a Newnes Plateau Gum Hollows varient: Brittle Gum - Mountain Gum, Scribbly Gum - Snow Gum Shrubby Open Forest | 4.64 |
| MU45 | 45 Newnes Plateau Tea Tree - Banksia - Mallee Heath | 0.16 |
| **Total** | | **15.01** |

Approximately 1,269 individuals of *Persoonia hindii* stems were proposed to be removed as a result of the Project. Following approval, but prior to construction, consideration was given to avoiding as many *P. hindii* as possible. Ultimately, 91 *P. hindii* stems were translocated as part of this project, with the remainder avoided.

### 3.5.2 Compensatory Measures

Centennial Angus Place have undertaken a number of measures to compensate for the loss of native vegetation and individual *P. hindii* as a result of the Project. Measures were also undertaken to prevent any indirect impacts that were considered a potential risk from the Project.

- A Rehabilitation Management Plan was prepared which specifically details the following (not limited to):
- A description of how the performance of the rehabilitation would be monitored and assessed;
- A description of measures for soil erosion and sediment control;
- Outline provisions for progressive rehabilitation of temporarily disturbed areas and final rehabilitation following decommissioning of the these facilities; and
- Includes a timetable for the implementation of the components of the Plan.

A *Persoonia hindii* Management and Research program was prepared detailing the following;

- Inclusion of a timetable to undertake surveys and mapping of *P. hindii* to establish its distribution and population across the Newnes Plateau;
- The measures for the translocation of all stems (ramets) of *P. hindii* found in the area of disturbance associated with the widening of access tracks to the Mod – 2 ventilation facilities, to nearby areas with similar physical and biological habitat features;
- Trails to assess whether such translocated *P. hindii* stems can be successfully returned to their original locations as a component of the rehabilitation of these areas;
- A study of the rhizomatous habit of *P. hindii* and how this may affect the success of the species in translocation and/or re-colonising disturbed areas;
- A monitoring program to study the *P. hindii* stems before and after translocation;
- A monitoring program to measure the ability of the residual *P. hindii* population along the disturbed areas of the ventilation facility’s access track and construction site to regenerate; and
- Include shots and long-term goals to measure the effectiveness of the Program.

A Construction Environmental Management Plan was prepared and implemented that included the following measures:

- Identification of environmental impacts and potential impacts of these activities and describe measures it mitigate and manage these impacts, including impacts associated with:
  - Noise emissions
  - Visual amenity
  - Night lighting
  - Air quality

- Traffic management
- Public safety
- Bushfire management
- Waste and hazardous materials management
- Vegetation removal (including identification of tree hollows, provision for the salvage (where feasible), and provision for their relocation and/or replacement in adjacent woodland); and
- Erosion and sediment control.

In addition to the above listed compensatory measures, a condition of approval was to provide a direct offset to compensate for the area cleared:

> *provide an area that is suitable in its vegetation types and extent to satisfactorily offset the residual impacts of clearing 15 ha of native vegetation associated with the construction and use of the Mod - 2 ventilation facilities and their supporting surface infrastructure and access track/roads, including the residual impacts on Persoonia hindii; and make suitable arrangements to manage, protect and provide long-term security for this area, consistent with the relevant NSW Offsets Policy.*

In determining a suitable residual offset, the Director-General will have regard to the outcomes of the *Persoonia hindii* Management and Research Program, particularly the success of translocation and/or regeneration, and the Applicant's success in implementing the Rehabilitation Management Plan.

## 3.6 Springvale Western Coal Services

The project aimed to improve existing facilities to meet future market demands, both export and domestic. Specifically, the Western Coal Services Project involved:

- Upgrades to the existing washery, workshops and infrastructure within the site by constructing a new washery adjacent to the existing facility that will remain operational to provide a total processing capacity of up to 7 Mtpa.
- Construction of processing infrastructure such as additional conveyors and transfer points and other coal handling requirements to cater for the upgraded washery facility within the existing disturbance footprint of the site.
- Extending and enlarging an existing reject emplacement area to enable sufficient reject disposal capacity for a 25 year life.
- Increasing the utilisation of the return side of the existing overland conveyor system to enable up to 6.3 Mtpa of coal to be delivered to Lidsdale Siding.
- Construction of a private haul road, approximately 1.3 km in length, linking the site with the existing private haul road from Angus Place Colliery to Mt Piper Power Station. This private road will cross a section of the existing Pine Dale Mine operation and over the Castlereagh Highway.
- Improvement of the current water management systems on the site by separating clean and dirty water streams prior to either reuse or discharge off site.
- Integration of the existing approved transport and processing of coal at Springvale Coal Mine and Angus Place Colliery into the one consent.
- Integration of the remaining rehabilitation, monitoring, water management and reporting requirements associated with the Lamberts Gully Mine which occupies the site.
- Continuation of the use of all existing approved infrastructure, facilities and activities associated with the

transport and processing of coal from each mine gate and the point of delivery to the site. This infrastructure includes the existing conveyors, private haul roads, Kerosene Vale Stockpile area, reject emplacement areas, services, access roads, car parks and buildings.

### 3.6.1 Impact Assessment

The Project had a minor impact on native vegetation. The following table outlines the area of impact on native (and regenerating) vegetation which totalled approximately 41.34 ha. Of this, approximately 0.05 ha of MU 11 Tableland Gully Snow Gum – Ribbon Gum Montane Grassy Forest, which is commensurate with the EEC *Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes Bioregions* was removed to allow for the Project.

**Table 11 Springvale Western Coal Services Vegetation Impacts**

| Native Vegetation Community | Area (ha) |
|---|---|
| MU 11 Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest | 0.05 |
| MU15 Tableland Hollows Black Gum – Black Sally Open Forest | 0 |
| MU 37 Coxs Permian Red Stringybark - Brittle Gum Woodland | 10.62 |
| **Total** | **10.68** |

### 3.6.2 Compensatory Measures

As a result of direct impacts upon native vegetation and fauna habitat, and potential indirect impacts, a number of compensatory measures have been undertaken to ameliorate these impacts.

A Biodiversity Management Plan was prepared for the development that included (but was not limited to) the following measures:

- Short, medium and long-term management of remnant vegetation and habitat on site;
- A detailed performance criteria for evaluating the performance of the Biodiversity Offset Strategy, and triggering any necessary remedial action;
- A description of the measures that would be implemented over the next 3 years for:
- Enhancing the quality of existing vegetation and fauna habitat;
- Establishing native vegetation and fauna habitat in the Additional Rehabilitation Initiatives area through focusing on assisted natural regeneration, targeted vegetation establishment and the introduction of naturally scarce fauna habitat features;
- Enhancing the landscaping of the site and along public roads to minimise visual and lighting impacts, particularly along Castlereagh highway;
- The protection of vegetation and soil outside the approved disturbance area;
- Maximise the salvage of resources within the approved disturbance area-including tree hollows and vegetative and soil resources;
- Collecting and propagating seed;
- Minimising impacts on fauna;
- Controlling, salinity, weeds, feral pests, erosion, access and bushfire risk.
- Monitoring program to report on the effectiveness of these measures.

A Biodiversity Management Plan was prepared for the development that included (but was not limited to) the following measures:

- Short, medium and long-term management of remnant vegetation and habitat on site;
- A detailed performance criteria for evaluating the performance of the Biodiversity Offset Strategy, and triggering any necessary remedial action;
- A description of the measures that would be implemented over the next 3 years for:
    - Enhancing the quality of existing vegetation and fauna habitat;
    - Establishing native vegetation and fauna habitat in the Additional Rehabilitation Initiatives area through focusing on assisted natural regeneration, targeted vegetation establishment and the introduction of naturally scarce fauna habitat features;
    - Enhancing the landscaping of the site and along public roads to minimise visual and lighting impacts, particularly along Castlereagh highway;
    - The protection of vegetation and soil outside the approved disturbance area;
    - Maximise the salvage of resources within the approved disturbance area-including tree hollows and vegetative and soil resources;
    - Collecting and propagating seed;
    - Minimising impacts on fauna;
    - Controlling, salinity, weeds, feral pests, erosion, access and bushfire risk.
- Monitoring program to report on the effectiveness of these measures.

Additional rehabilitation initiatives have been taken including the establishment and enhancement of locally endemic native vegetation species on Lamberts Gully Creek catchment, as well as improving fauna habitat values. Improvements to the riparian habitat of Wangcol Creek for at least 100m downstream of the Link haul road bridge crossing of the creek are also proposed.

In addition to the above listed compensatory measures, a condition of approval was to provide a direct offset to compensate for the area cleared:

> *provide an area that is suitable in its vegetation types and extent to satisfactorily offset the residual impacts of clearing 10.62 ha of native vegetation (Coxs Permian Red Stringybark - brittle Gum Woodland); and make suitable arrangements to manage, protect and provide long-term security for this area, consistent with the relevant NSW Offsets Policy.*

## 3.7 Clarence Reject Emplacement Area

The development within the site was for an additional reject emplacement area (REA), referred to as REA 6, to be used by Clarence Colliery to store waste rock as a result of ongoing mining operations. This required the removal of the majority of vegetation situated within the site boundary.

### 3.7.1 Impact Assessment

The project resulted in the removal of 4.1 ha of native vegetation defined as Newnes Plateau Narrow-leaved Peppermint – Silvertop Ash Layered Open Forest (MU26). This vegetation community is not commensurate with any TSC Act and/or EPBC Act listed ecological community.

A total of 16 hollow bearing trees were removed, reducing the available amount of roosting habitat for a number of threatened fauna species. The removed vegetation was also considered foraging habitat for a range of native fauna within the local area.

No threatened flora were removed as a result of the project.

No significant impacts to threatened flora, fauna and/or ecological communities were expected to occur as a result of the REA 6 operation.

### 3.7.2 Compensatory Measures

To compensate for the removal of 4.1 ha of native vegetation to accommodate for the REA, a number of measures have been undertaken. This includes future rehabilitation objectives defined within a Mining Operations Plan to ensure the REA site will be appropriately rehabilitated at the completion of the sites use.

In addition to the above listed compensatory measures, a condition of approval was to provide a direct offset to compensate for the area cleared:

By the end of December 2016, the Applicant shall, in consultation with the Office of Environment and Heritage (OEH), and to the satisfaction of the Secretary:

> *provide a suitable offset to satisfactorily offset clearing 4.1 hectares of Newnes Plateau Narrow-leaved Peppermint – Silver-top Ash Layered Open Forest and the loss of related biodiversity values, including for threatened species; and make suitable arrangements to manage, protect and provide long-term security in perpetuity for this area, consistent with the relevant NSW Offsets policy.*

## 3.8 The Conservation Values of the Newnes Plateau and Ben Bullen State Forest

Centennial Coal has recognised, through the final land use proposed for the Projects, the conservation values that the Newnes Plateau and Ben Bullen State Forest currently holds and will hold in the future following cessation of forestry and mining activities. These conservation values have been identified through consultation with a number of stakeholders and a literature review of stakeholder documentation, including:

- The Greater Blue Mountains World Heritage Area Strategic Plan (2009 to 2019)
- ‘Save our Swamps’ documentation (2010);
- Review of Piezometer Monitoring Data in Newnes Plateau Shrub Swamps and their Relationship with Underground Mining in the Western Coalfield, DECCW (2010);
- Coalpac Consolidation Project Planning Assessment Commission Report, (2013);
- The Geoheritage and Geomorphology of the Sandstone Pagodas of the North-western Blue Mountains region (NSW), Washington et al, (2011);
- The Gardens of Stone Park Proposal: Stage 2, the Western Escarpment, Airly-Genowlan Mesa, Newnes Plateau and related Crown lands, (2005)[1];
- The Impact of Coal Mining on the Gardens of Stone, Colong Foundation for Wilderness, (2010); and
- Alteration of Habitat Following Subsidence due to Longwall Mining – Key Threatening Process Listing, Office of Environment and Heritage, (2005).

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[1] Including *The Gardens of Stone Park Proposal Stage Two Illustrated: A proposal to extend the Gardens of Stone and Blue Mountains National Parks and create a Gardens of Stone Conservation Area and a Western Escarpment State Conservation Area*, Blue Mountains Conservation Society and the Colong Foundation for Wilderness, 2005.
*Seeing the Gardens...the other Blue Mountains: Nature based tourism and recreation in the Gardens of Stone Stage Two Park Proposal*, Blue Mountains Conservation Society and the Colong Foundation for Wilderness, 2009

This review identified the common theme and desire to protect, conserve, present and rehabilitate the environmental values of the Newnes Plateau for recreation and tourism purposes. This includes consideration of:

- Threats to conservation values that include (but are not limited to) fire, pests and weeds
- Methods to establish the health status of swamp communities to guide management decisions, as discussed in Chapter 10.3 of the EIS
- Impacts of mine water discharge on swamp communities, as discussed in Chapter 2 and Chapter 8 of the EIS
- Value of pagoda systems that occur within the Banks Wall and Burra Moko Head Sandstones, as discussed in Chapter 2 and Chapter 10.1 of the EIS[2]
- Impacts of mining related activities to areas with potential conservation value, including construction of access roads and utility corridors, historical cliff collapses, potential changes to hydrology; as discussed in Chapter 2 and Chapter 10.1, 10.2 and 10.3 of the EIS
- Support by Centennial Coal Company Ltd for the reservation of Mugii Murum-ban State Conservation Area in a State Conservation Area in 2011
- A heritage assessment for the Mount Airly Oil Shale Ruins, completed by Centennial Airly Pty Ltd in 2013
- Discharge of water away from the World Heritage Area and reuse of water for industrial purposes, as discussed in Chapter 10.2 of the EIS
- Subsidence protection zones whilst maintaining economically viable operations, as discussed in Chapter 8 of the EIS
- Collection of real time and relevant data to inform understanding of the biodiversity and geo-diversity values, as discussed in Chapter 2 and Chapter 10 and 10 of the EIS
- Management and monitoring of underground mining operations to achieve predicted height of fracturing, thereby minimising to the greatest extent possible surface related impacts, as discussed in Chapter 2 and Chapter 8 of the Springvale Mine Extension Project EIS and the Angus Place Mine Extension Project EIS
- Recognition of the geo-diversity of pagoda systems and avoidance of impacts to these systems within the Neubeck Coal Project EIS (Chapter 8)
- A minimum 300m set back of the mine footprint to pagoda systems, as discussed in Chapter 8 of the Neubeck Project EIS
- Minimising the footprint of the Neubeck Project to 201 hectares, of which 110 hectares are cleared or severely disturbed
- Avoidance of *Bursaria spinosa*, the known host plant for the Copperwing Butterfly, as discussed in Chapter 10 of the Neubeck Project EIS.

By taking into consideration the measures identified above, the conservation values of the Newnes Plateau, and to a lesser extent the Ben Bullen State Forest, and the management strategies to avoid and mitigate impacts, the mining operations at Angus Place and Springvale can be managed to achieve a future conservation outcome. Whilst the direct impacts of the Neubeck Project will result in a loss of threatened

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[2] The EIS refers to the Environmental Impact Statement of the Neubeck Coal Project, the Springvale Mine Extension Project and the Angus Place Colliery Extension Project, unless specified otherwise.

species and their habitats, by restricting the mine footprint as far as practicable these impacts have been minimised such that the offsets and supporting supplementary measures can compensate for this loss.

Centennial Coal has developed this biodiversity strategy to meet this broader conservation outcome.

## 3.9 Cumulative Impact Upon the Coxs River Catchment

A number of surrounding projects within the Coxs River Catchment contribute to cumulative impacts towards the Coxs River, resulting primarily from direct impacts.

The following projects are considered to have existing or future potential impacts upon the Coxs River:

- Western Coal Services Project;
- Angus Place Colliery Extension;
- Springvale Coal Mine Extension;
- Pine Dale Coal Mine Extension;
- Yarraboldy Extension;
- Mount Piper Power Station;
- Neubeck Open Cut Mine Project;
- Wallerawang Power Station;
- Lidsdale Siding project; and
- Blackmans Flat Waste facility.

A summation of direct impacts as a result of the above-mentioned projects includes mine water discharge from surface and underground workings, vegetation clearing including endangered ecological communities and direct removal of threatened flora species and threatened flora and fauna habitat.

The information available for the above projects indicates that impacts of the Projects specific to ecology will be mitigated through selective clearing, increased and selective monitoring of species, offsetting select species and vegetation, development rehabilitation plans and ongoing management and monitoring. Aquatic impacts are, however, considered to be placed upon the Coxs River as a consequence of multiple projects. Consultation with GHD (2014) and RPS (2014) reports, provided information on aquatic impacts to specific projects as discussed below.

In relation to stream ecology, GHD (2014) identified two expansion projects which have the potential to add to a cumulative impact on the current instream ecology of Coxs River. These include: Pine Dale Coal Mine Stage 2 Extension Project and Yarraboldy Extension (Stage 1) Project.

Of these two projects the most significant is the Pine Dale Coal Mine Stage 2 Extension Project. Dewatering of historical underground workings to Wangcol Creek will increase the potential for water quality degradation. The dewatering rate is expected to average 10 ML/day. Currently the water management strategy is not known though mitigation of this potential impact could be through the direct reuse of this water by Mount Piper Power Station via a pipeline connection between the two sites.

Groundwater drawdown as a result of the Stage 2 project would be expected to extend the predicted mining related drawdown extent further to the east. Typically the Stage 2 project will have an increased project specific drawdown due to the depth of excavation required to extract the Lithgow however it is not expected that a compounding effect would occur from the drawdown of both the Project and the Stage 2 project occurring.

The other recent Project is the Yarraboldy Extension (Stage 1) Project. Discharges from the mine will be avoided through the transfer of water underground into historical workings. This project will result in a minimal change to current water management practices though the potential for water impact still remains for years where discharges are required.

Springvale Coal Services has avoided discharge of mine water through site water management and the use of water storage on the surface, however during significant rain events it is expected that discharges will still occur to Wangcol Creek, which could have flow-on effects to Coxs River.

The primary impacts from the Angus Place and Springvale Coal projects, specific to instream ecology, are changes to surface hydrology and hydrogeology. With respect to instream ecology, both projects rely on discharges to the Coxs River catchment. Discharges predicted from these projects into the Coxs River have been identified as likely to increase over time. This is likely to modify water quality loads being transferred to the Coxs River and hence may influence the abundance and health of instream ecology.

At Blackmans Flat Waste Management Facility potential groundwater impacts have been identified in the review of the proposal from leachate though all attempts have been made within the design of the landfill such that migration to groundwater is limited though it has been identified as a potential pathway through to Wangcol Creek. Leachates from landfill areas have been known to degrade water quality and migration through to Wangcol Creek would most likely cause potential degradation to instream ecology and GDEs as it passes through the groundwater environment. A downstream surcharge dam has been proposed as a final capture point in the event of significant rainfall events which has a stated capacity equal to a peak 500 year ARI storm event.

Mitigation measures implemented by the Neubeck Coal, Lidsdale Siding and Wallerawang Power Station Projects have avoided potential aquatic impacts and are not considered to contribute to the cumulative impacts upon the Coxs River.

## 3.10 Temperate Highland Peat Swamps on Sandstone

This section has been prepared to address the predicted impacts to Temperate Highland Peat Swamps on Sandstone (THPSS) and the impactions these predictions may have on this Strategy. For the purpose of this Strategy, the community name Temperate Highland Peat Swamps on Sandstone (THPSS) is used to collectively discuss the vegetation communities MU50 Newnes Plateau Shrub Swamp, MU51 Newnes Plateau Hanging Swamp and MU52 Newnes Plateau Rush - Sedge Snow Gum Hollow Wooded Heath, as described in DECC (2006). All three of these vegetation communities are commensurate with the EPBC Act listed EEC THPSS. Newnes Plateau Shrub Swamp is individually listed as an EEC under the TSC Act.

### 3.10.1 Past Assessments

In 2011, Springvale Mine and Angus Place Colliery referred (separately) longwall extraction actions to the then Department of Sustainability, Environment, Water, Population and Communities (SEWPaC, now Department of the Environment, DotE) (referred to as EPBC 2011/5949 and EPBC 2011/5952 respectively). To support these applications, a significant body of work, referred to as the Preliminary Documentation, was submitted in 2011 to SEWPaC and placed on public exhibition during the assessment process.

In 2012, based on the information provided to the Department, these actions were conditionally approved by the Minister. The key conditions of approval for the Springvale Mine, relevant to this response to submissions, were:

(1) Unless otherwise agreed by the minister in writing, longwall mining is not to be undertaken in areas directly below known high quality sites of temperate highland peat swamps on sandstone or within approved buffer zones (as per condition 2) If at anytime the person taking the action seeks the minister’s agreement to vary this condition the person taking the action must demonstrate in writing that a proven technology or engineering methodology will be used for the proposed longwall mining that prevents severe impacts of subsidence on temperate highland peat swamps on sandstone, or that would allow any severe impacts on temperate highland peat swamps on sandstone to be remediated

(2) Within three months of the date of this approval, the person taking the action must submit details of proposed buffer zones around high quality temperate highland peat swamps on sandstone for the minister's approval. The buffer zones must be approved by the minister before mining of longwalls 416 and 417 can commence.

Throughout 2012 and 2013, Centennial undertook investigations to satisfy these conditions and in 2013 and 2014, Centennial submitted a substantial body of work to the Department of the Environment, including:

- Justification for the selection of a 26.5 degree angle of draw buffer, including background information on the buffer zone selection
- Application to Mine within Buffer Zones, supported by three volumes of supplementary information, including nine (9) swamp case studies, and various reports on swamp geology, results of ground penetrating radar (GPR) and resistivity studies on East Wolgan Swamp, critical analysis on the different mine geometries between longwall 411 (East Wolgan Swamp impacts) and longwalls 415 to 417, geotechnical investigation into East Wolgan Swamp, and others.
- Various case studies on remediation measures taken to remediate impacts to swamp communities.
- Springvale Mine Temperate Highland Peat Swamps on Sandstone Monitoring and Management Plan
- Angus Place Colliery Temperate Highland Peat Swamps on Sandstone Monitoring and Management Plan

This body of work is extensive, comprehensive and supported by various levels of peer review. For example, both the Springvale Mine Temperate Highland Peat Swamp on Sandstone Monitoring and Management Plan and the Angus Place Colliery Temperate Highland Peat Swamps on Sandstone Monitoring and Management Plan were peer reviewed by Dr David Goldney and Dr Grant Hose. Dr Hose was an expert who had previously been approved by the Department of the Environment to peer review previous swamp reports. Dr David Goldney was the expert who had undertaken an independent investigation into the impacts of mining on swamps at Angus Place Colliery for the then Department of Environment, Water, Heritage and Arts (DEWHA).

As a result of investigations into THPSS hydrogeology and interactions with mine subsidence, changes to the mine design were made, based on reduced mining void widths and increased chain pillar widths. The changes have been made in the context of cover depths in proposed future mining areas in the vicinity of THPSS and are designed to a criterion of sub-critical panel geometry. Subsidence modelling indicates that the design changes will result is very significant reductions to total subsidence and differential subsidence movements. These changes were made specifically to reduce the environmental impacts of longwall mining under the Newnes Plateau, and demonstrate Centennial's commitment to sustainable mining practices.

Based on the reports provided to it, on 21 October 2013, the Department of the Environment approved mining beneath THPSS under the terms of EPBC 2011/5949 Condition 1. The mine design approach for all future longwall mining described in the SVMEP EIS and the APMEP EIS in the vicinity of THPSS is consistent with that approved for longwall mining beneath THPSS by DotE under EPBC2011/5949.

### 3.10.2 Investigating Impacts to THPSS

As noted above, Centennial Coal has invested substantial time and resources into meeting, and exceeding, its compliance obligations under existing approvals, and will continue to do so in the future. Centennial Coal has done this in five broad areas:

(1) Investigation of impacts to THPSS, namely East Wolgan Swamp and the consequent Enforceable Undertaking entered into in 2011;

(2) Development of an adaptive management framework and response, following the conclusion of investigations;

(3) Comprehensive analysis and review of the mine design at both the Springvale and Angus Place operations;

(4) Further analysis and review of the potential for impacts to THPSS; and

(5) Investigation into the potential impacts of water discharged from the underground mining operations on the receiving environment.

Centennial acknowledged in Chapter 2 and Chapter 8 of the Springvale Mine Extension Project Environmental Impact Statement (SVMEP EIS) and the Angus Place Colliery Mine Extension Project Environmental Impact Statement (APMEP EIS) that longwall mining has caused impacts to certain THPSS, however, as identified in these documents, this has not been the case in all instances.

Chapter 2 of both the SVMEP EIS and the APMEP EIS acknowledged that subsidence impacts to swamp hydrology have been noted at two swamps (Kangaroo Creek Swamp and East Wolgan Swamp). Where impacts to certain THPSS on the Newnes Plateau have occurred, Centennial has conducted extensive research to understand the causes of the impacts. Centennial has used the findings of the research to avoid and mitigate both past and future impacts of longwall mining and related activities to THPSS on the Newnes Plateau.

- Extensive research and investigation, lead primarily by work commissioned by the then DEWHA (the Goldney 2010 Report), has shown that impacts to THPSS on the Newnes Plateau have been caused primarily by:
- Licenced discharge of mine water through THPSS
- Changes to swamp hydrology caused by cracking of rock substrate beneath THPSS as a result of mine subsidence

A high level of concern exists within the community and amongst decision makers in relation to the potential impacts to THPSS. This concern is driven to some extent by subsidence related impacts occurring within other coal fields, as well as the noted impacts to East Wolgan Swamp. A detailed investigation, spanning several years, was undertaken to identify the causal factors that lead to these effects. The results of studies are provided in **Table 12**.

**Table 12 Causal Factors Leading to Impacts to East Wolgan Swamp**

| Causal Factors | Springvale Coal Management Response |
|---|---|
| Mine water discharge | Cease mine water discharge to Newnes Plateau (including proposed underground water storage for future emergency mine water discharges).<br>(There have been no Newnes Plateau discharges since April 2010) |
| Intersection of major geological fault structures | Major geological structure zones identified through detailed topographic, geological and geophysical analysis, The relationship between mine subsidence, geological faulting and groundwater response is well understood from historical monitoring data (based on piezometers, extensometers, subsidence monitoring (terrestrial and LiDAR), exploration borehole data). This understanding is used in the mine planning and design process to ensure that combinations of risk factors do not occur in future mining areas in the Project Application Area. |
| Orientation of longwall panels sub-parallel to major structures | Angle of orientation increased for future swamps e.g increase to 24° for Carne West and 51° for Sunnyside East. |
| Steepness and depth valley containing swamps | Surface topography is well understood from Digital Terrain Model. Analysis of topographic and subsidence data identified no measured impacts at slope angles <18 degrees (see Section 8.2.1 of this EIS). |

| | |
|---|---|
| In situ stress direction and magnitude | Horizontal stress orientation mapped through exploration borehole geophysical testing / analysis. Horizontal stress magnitude measured through installation of instrumentation in surface to seam boreholes and in the roof at seam level. |
| Critical width longwall panel design | Future longwalls in the vicinity of swamps are based on Subcritical panel design |
| Location and orientation of geological structure adjacent to the permanent barrier pillar | Future Mine workings designed to avoid alignment of major geological structure zones sub-parallel with edge of permanent barrier pillar subject to multiple panel subsidence effects |
| Subsidence interaction of adjacent Angus Place and Springvale workings | Springvale Mine and Angus Place Colliery future mining areas are not adjacent to each other (separated by over 500 m) thus interaction will be avoided. |

As a result of the findings that lead to the impacts to East Wolgan Swamp, Centennial has not discharged mine water through THPSS on the Newnes Plateau since 2010 and is committed to managing mine water through the Water Transfer Scheme (WTS), which transfers mine water off the Newnes Plateau.

### 3.10.3 Additional Research and Monitoring

Centennial Coal has acknowledged the importance of the THPSS in the landscape. Research conducted over the last 5 years (2009 to 2014) by the University of Queensland has worked towards quantifying the nature and extent of the community across the Newnes Plateau. Further work undertaken through the Enforceable Undertaking has been targeted towards:

- The nature and extent of THPSS
- THPSS water balances
- Functionality of swamps
- Environmental history and origins
- Ecology/biodiversity of major structural species
- Contribution to the landscape
- Condition status/mapping
- Monitoring of selected reference sites
- Thresholds for recovery

The University of Queensland is currently conducting research on communities identified as temperate treeless palustrine swamps in a 268 square kilometre area which includes the Newnes Plateau. Based on publicly available combined mapping from the temperate zone of New South Wales and manual interpretation of the numerous vegetation classifications used, a region containing more than 1000 shrub swamp communities per degree of latitude/longitude was identified which contained the communities mapped as Newnes Plateau shrub swamps. A report based on the research will be published and finalised in 2014.

In 2010, the University of Queensland, via funding from the Australian Coal Association Research Program (ACARP) commenced an investigation into the potential of small unmanned aerial vehicle (UAV) platforms to capture imagery of THPSS. The purpose of the research was to establish whether this technology could be used to develop monitoring tools for detecting change in condition and composition of THPSS communities that may then be correlated to potential impacts from underground mining. The project was successful in generating multi-spectral orthophoto mosaics with resolutions of less than 10 centimetres, resulting in greater coverage of THPSS communities in remote and difficult to access locations. The ACARP report was published in September 2014.

Ultimately, it is the swamp condition and health that will determine whether there has been a significant impact. To assist in understanding how to establish impacts, the University of Queensland have developed a Monitoring Handbook, titled Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps (2014) (see **Appendix 1**). This Monitoring Handbook identifies that there are three environmental factors which affect floristics (1) geology, through subsidence responses, (2) hydrology (including water quality, groundwater level, flow and infiltration) and (3) flora composition and condition. The Monitoring Handbook identifies performance indicators for vegetation monitoring that take into consideration these factors and their effects on swamp health. Three trigger levels have been established and will be used to determine impacts, when measured against a baseline:

- Reduction in live vegetation cover of more than 20% within the community, compared with baseline data;
- A single patch of non-vegetative cover greater than 400m$^2$ doubles in size compared with baseline data; and
- A significant increase in exotic species cover compared with the baseline data
- The Monitoring Handbook includes a statistically valid sampling design capable of recording change as a result of exceedance of these triggers.

### 3.10.4 Offsetting Requirements for Temperate Highland Peat Swamp on Sandstone

Centennial has invested considerable time and money in monitoring and undertaking specialist studies in relation to their mining activities. From specialist studies, major geological structural zones can be confidently identified within the Springvale and Angus Place mining and exploration leases. Monitoring of swamp water levels and surface water gauging has shown that no impacts to the swamps or surface Regular seasonal ecological monitoring since 2005 has also revealed no observable impacts on the flora and fauna recorded within undermined areas, including THPSS. These Projects are not expected to have a significant impact upon any shrub swamps or hanging swamps. This prediction is supported by a high level of confidence in subsidence predictions as shown by post-mining subsidence monitoring data.

As discussed in the Angus Place Mine Extension Project EIS, the Springvale Mine Extension Project EIS, predicted subsidence is not expected to result in a significant impact to THPSS. Significant is defined as not negligible. As a result, no direct offset is required. In order to ensure impacts are within those predicted in the EISs, Centennial will:

- Monitor annually for ecosystem health using the UQ handbook (see **Appendix 1**);
- Where this monitoring shows mining related impacts (as per fig 4.1 in that handbook), mitigation measures will be implemented (Soft or hard engineering); and
- Reconcile annual monitoring and mitigation every 5 years against Handbook triggers. Where impacts are above triggers, additional mitigation. Where impacts are attributable to mining and cannot be mitigate or mitigation is not successful, offsets will be provided.

In the unlikely event that monitoring does show an impact has occurred to an area of THPSS and where mitigation is not successful, one of three measures are proposed:

(a) Conservation bond for the value of swamps (based on values identified in economic assessment);

(b) Direct offset with the size of the offset calculated using the larger of the results of a BBAM assessment or EPBC Act Offsets Assessment Guide; or

(c) A combination of both A and B.

## 3.11 Residual Impacts Summary

### 3.11.1 Vegetation

The combined clearing footprint of all projects is provided in **Table 13** below. The projects covered by this Regional Strategy propose a total clearing area of 151.02 ha of wooded vegetation and an additional 87.59 ha of cleared lands.

Whilst being in a cleared, low condition, the cleared lands are recognised by this Regional Strategy as having some remaining biodiversity value. Cleared lands have therefore been described as 'derived grasslands' of the parent vegetation communities with impacts assessed accordingly.

The combined impacts to listed EECs include the removal of 0.19 ha of Montane Peatlands and Swamps (MU53) and 17.14 ha of Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (MU11 and MU15). Impacts to 28.41 ha of derived grasslands of the Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland are also covered in this Strategy.

Both of these EECs are listed under the TSC Act. No EECs listed under the EPBC Act are proposed to be cleared.

The largest impacts are to dry sclerophylly woodland communities, predominately MU07 Newnes Plateau Narrow-leaved Peppermint - Mountain Gum - Brown Stringybark Layered Forest, MU26 Newnes Plateau Narrow-leaved Peppermint - Silver-top Ash Layered Open Forest, MU33 Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest and MU37 Coxs Permian Red Stringybark - Brittle Gum Woodland. Combined, these communities make up 95.81 ha (63%).

None of these communities are listed EECs under the TSC Act or EPBC Act.

**Table 13 Centennial Western Projects - Vegetation Impacts Summary**

| Map Unit | Community Name | EEC Equivalent | Angus Place | Springvale | Neubeck | Springvale Bore 8 | Angus Place MOD 2 - Ventilation Facility | Western Coal Services | Clarence Colliery REA 6 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| MU07 | Newnes Plateau Narrow-leaved Peppermint - Mountain Gum - Brown Stringybark Layered Forest | | 1.09 | 1.5 | | 1.65 | 9.34 | | | **13.58** |
| MU11 | Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | | 0.22 | 12.64 | | | 0.05 | | **12.91** |
| MU14 | Tableland Mountain Gum - Snow Gum - Daviesia Montane Open Forest | | 0.16 | | | | 0.87 | | | **1.03** |
| MU15 | Tableland Hollows Black Gum - Black Sally Open Forest | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | | | 4.23 | | | | | **4.23** |
| MU26 | Newnes Plateau Narrow-leaved Peppermint - Silver-top Ash Layered Open Forest | | 8.2 | 5.44 | | | | | 4.1 | **17.74** |
| MU26a | Newnes Plateau Gum Hollows varient: Brittle Gum - Mountain Gum, Scribbly Gum - Snow Gum Shrubby Open Forest | | 0.11 | 1.09 | | | 4.64 | | | **5.84** |
| MU28 | Sandstone Plateau And Ridge Scribbly Gum - Silver-top Ash Shrubby Woodland | | 5.46 | 2.29 | | 1.79 | | | | **9.54** |
| MU29 | Sandstone Slopes Sydney Peppermint Shrubby Forest | | 1.83 | 0.1 | | | | | | **1.93** |
| MU30 | Exposed Blue Mountains Sydney Peppermint - Silver-top Ash Shrubby Woodland | | 6.39 | | | 0.49 | | | | **6.88** |
| MU32 | Tableland Hills Scribbly Gum - Narrow-leaved Stringybark Shrubby Open Forest | | | | 2.59 | | | | | **2.59** |
| MU33 | Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest | | | | 15 | | | | | **15** |

| Map Unit | Community Name | EEC Equivalent | Angus Place | Springvale | Neubeck | Springvale Bore 8 | Angus Place MOD 2 - Ventilation Facility | Western Coal Services | Clarence Colliery REA 6 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| MU35 | Tableland Gully Mountain Gum - Broad-leaved Peppermint Grassy Forest | | | | 9.11 | | | | | **9.11** |
| MU37 | Coxs Permian Red Stringybark - Brittle Gum Woodland | | | | 38.87 | | | 10.62 | | **49.49** |
| MU44 | Sandstone Plateaux Tea Tree - Dwarf Sheoak - Banksia Rocky Heath | | | 0.07 | | | | | | **0.07** |
| MU45 | Newnes Plateau Tea Tree - Banksia - Mallee Heath | | | | | | 0.16 | | | **0.16** |
| MU53 | Mountain Hollow Grassy Fen | Montane Peatlands and Swamps (TSC Act) | | | 0.19 | | | | | **0.19** |
| MU8 | Newnes Sheltered Peppermint - Brown Barrel Shrubby Forest | | | 0.73 | | | | | | **0.73** |
| **Sub-total** | | | **23.24** | **11.44** | **82.63** | **3.93** | **15.01** | **10.67** | **4.1** | **151.02** |
| **Cleared Land** | | | | | | | | | | |
| MU11 (DNG) | Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest (cleared) | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | | | 11.29 | | | | | **11.29** |
| MU15 (DNG) | Tableland Hollows Black Gum - Black Sally Open Forest (cleared) | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | | | 17.12 | | | | | **17.12** |
| MU33 (DNG) | Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest (cleared) | | | | 29.17 | | | | | **29.17** |
| MU37 (DNG) | Coxs Permian Red Stringybark - Brittle Gum Woodland (cleared) | | | | 30.01 | | | | | **30.01** |
| **Total** | | | **23.24** | **11.44** | **170.22** | **3.93** | **15.01** | **10.67** | **4.1** | **238.61** |

### 3.11.2 Threatened Flora

In order to retain consistency with the offset methodologies of the NSW Biodiversity Offsets Policy for Major Projects and EPBC Act Environmental Offsets Policy, impacts to threatened flora have been assessed as the number of recorded individuals. These are displayed in **Table 14** below.

**Table 14 Centennial Western projects - Threatened Flora Impacts Summary**

| Species | Angus Place | Springvale | Neubeck | Springvale Bore 8 | Angus Place MOD 2 - Ventilation Facility | Western Coal Services | Clarence Colliery REA 6 | Total |
|---|---|---|---|---|---|---|---|---|
| *Eucalyptus aggregata* (Black Gum) (V) | | | 238 | | | | | **238** |
| *Eucalyptus cannonii* (Cannon's Stringybark) (V) | | | 20 | | | | | **20** |
| *Thesium australe* (Austral Toadflax) (V, V*) | | | 61 | | | | | **61** |
| *Persoonia hindii* (E) | | | | | 91 | | | **91** |

**Key:**

| | | | |
|---|---|---|---|
| V | Vulnerable Species under the TSC Act | V* | Vulnerable Species under the EPBC Act |
| E | Endangered Species under the TSC Act | | |

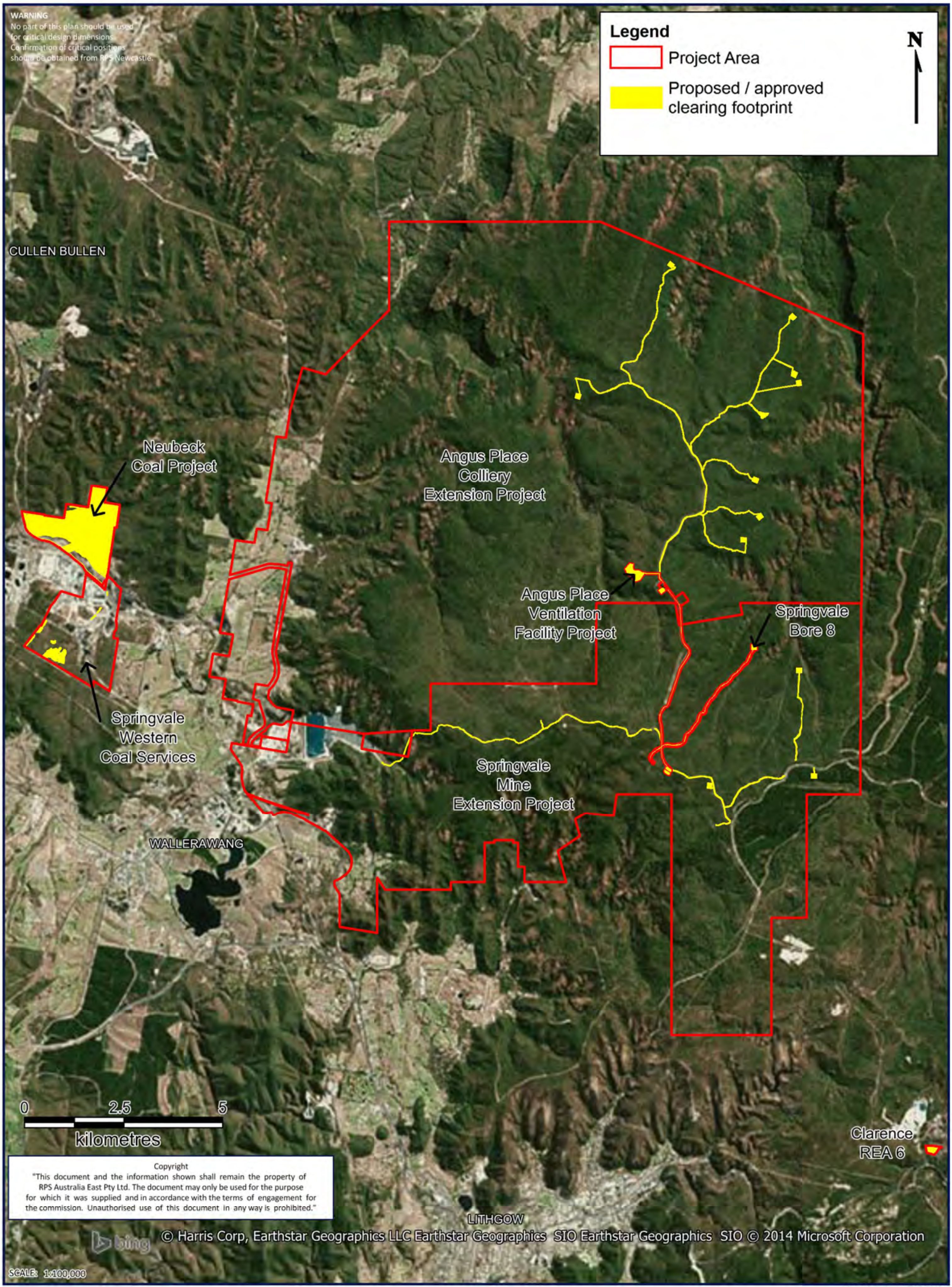
### 3.11.3 Threatened Fauna

In order to retain consistency with the offset methodologies of the NSW Biodiversity Offsets Policy for Major Projects and EPBC Act Environmental Offsets Policy, impacts to threatened fauna has been assessed as the area of habitat in hectares to be lost.

Suitable habitats for fauna species often cross several of the vegetation communities that are displayed in **Table 13**. As later detailed in this report, these vegetation communities have been classified based on the 'best fit' vegetation type listed in the BioBanking Vegetation Types Database (OEH 2009). Parameters used to choose the 'best fit' Vegetation Type included overstorey and understorey floristics, soil landscape, location and topographic position. The BioBanking Vegetation Types, and by extension the vegetation communities, can be broadly categorised by 'Vegetation Formation'. This broader formation class category has been used in **Table 15** to assess the potential losses to threatened fauna habitat.

**Table 15 Centennial Western Projects - Fauna Impacts Summary**

| Formation | Equivalent Map Unit | Fauna Habitat Suitability | Area (ha) |
|---|---|---|---|
| Dry Sclerophyll Forests (Shrubby subformation) | MU2, MU8, MU21, MU26, MU26a, MU28, MU29, MU30, MU32, MU37, MU38, MU42 | Woodland Birds, Arboreal Mammals, Forest Owls, microchiropteran bats, Giant Burrowing Frog and Stuttering Frog (in proximity to water courses). | 94.74 |
| Freshwater Wetlands | MU53 | Amphibians | 0.19 |
| Grassy Woodlands | MU11, MU13, MU15, MU20, MU33 | Woodland Birds, Arboreal Mammals, Forest Owls, microchiropteran bats. | 32.14 |
| Heathlands | MU43, MU44, MU45 | Eastern Pygmy Possum, Burrowing Frog and Stuttering Frog (in proximity to water courses). | 0.23 |
| Wet Sclerophyll Forests (Grassy subformation) | MU3, MU14, MU35 | Woodland Birds, Arboreal Mammals, Forest Owls, microchiropteran bats, Giant Burrowing Frog and Stuttering Frog (in proximity to water courses). | 10.14 |
| Wet Sclerophyll Forests (Shrubby subformation) | MU7 | Woodland Birds, Arboreal Mammals, Forest Owls, microchiropteran bats, Giant Burrowing Frog and Stuttering Frog (in proximity to water courses). | 13.58 |
| Derived Grasslands (combined) | MU11, MU15, MU20, MU33, MU37 and MU38 | Marginal habitat for a range of fauna species. | 87.59 |



TITLE: FIGURE 1 PROPOSED AND EXISTING DEVELOPMENT SITES
LOCATION: LITHGOW, NSW
DATUM: DATUM
PROJECTION: MGA ZONE56
DATE: 19/09/2014
PURPOSE: REGIONAL BIODIVERSITY STRATEGY
LAYOUT REF: J:\JOBS\Centennial\All Jobs\123063 OEH Submissions - Fassifern\10 - Drafting\MapInfo Workspaces\Eco Biobanking Report
VERSION (PLAN BY): PH (A-A4)

CLIENT: CENTENNIAL
JOB REF: 123063

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# 4.0 The Regional Biodiversity Strategy

This Regional Strategy aims to provide appropriate and targeted compensatory measures for the unavoidable residual impacts detailed in **Section 3**. To achieve this goal, three core initiatives have been developed, namely direct offsets, supplementary measures and a Coxs River Catchment Restoration Program. These are summarised below and detailed within the following sections.

## 4.1 Development Sites

The areas of vegetation clearing impacts and impacts to specific notable species have been analysed for seven proposed and existing projects:

- Angus Place Colliery Extension Project;
- Springvale Mine Extension Project;
- Neubeck Development Site;
- Springvale Bore 8;
- Angus Place Ventilation Facility Project;
- Springvale Western Coal Services; and
- Clarence REA 6.

## 4.2 Conservation Sites

The areas being considered for the potential value as offsets, management or rehabilitation (collectively referred to as conservation sites in this report) are listed below:

- Airly Offset Site;
- Wolgan Road Northern Offset Site;
- Wolgan Road Southern Management Site;
- Commonwealth Colliery Rehabilitation Site;
- Brays lane, Lidsdale Management Site;
- Wangcol Creek Rehabilitation Site; and
- Lamberts Gully Rehabilitation Site.

## 4.3 Variables

The variables that have been analysed are:

- area of vegetation types (as described in the Vegetation of the Western Blue Mountains (DEC 2006));
- area of BioMetric vegetation type as described in the BioBanking Assessment Methodology(BBAM);
- area of vegetation formation as described in the BBAM - this can be used to analyse general habitat associations for a range of fauna species;
- BBAM Ecosystem Credits; and
- BBAM Species Credits.

## 4.4 Supplementary Measures

Throughout the development of the Biodiversity Strategy, Centennial has undertaken a review of the Priority Actions for species and communities of concern to the Office of Environment and Heritage and the Department of the Environment. This review has identified a number of threatened species where actions for recovery can be supported by additional investment in research. These supplementary measures are detailed in **Section 6**.

## 4.5 Coxs River Catchment Restoration Program

As detailed in **Section 3.9** many cumulative impacts affect the nature and quality of the Coxs River catchments. Impacts include mine water discharge from both underground mine operations and from open cut mine operations. Impacts to water quality and quantity are also experienced from power generation and from the surrounding human settlements. The Coxs River and its tributaries contain numerous biodiversity values, including EECs and threatened species.

This Regional Strategy provide an opportunity to implement the Coxs River Catchment Restoration Program, which is aimed to further enhance the biodiversity values, water quality and amenity that exist within the Coxs River Catchment and ameliorate the cumulative impacts associated with Centennial projects and the many other projects that influences the physical and chemical nature of the Coxs River. The details of this program are discussed in detail in **Section 7**.

# 5.0 Offset, Management and Rehabilitation Areas

A combination of direct offsets, management sites, and rehabilitation areas (collecitvely referred to in this report as conservation areas) has been proposed as part of the Regional Strategy in order to provide adequate compensation for the habitats and vegetation losses. The requirements of the OEH and Department of the Environment Director General's Requirements for the respective State Significant Developments included guidance for what information should be provided in describing an offset. A summary of the information requirements and where it is presented within this report is provided in **Table 16** and **Table 17** for OEH and DotE respectively.

**Table 16 Office of Environment and Heritage Requirements**

| Office of Environment and Heritage Requirements | Where Addressed in this Report |
|---|---|
| clear quantification of each vegetation community that will be directly and indirectly impacted, | Table 13 |
| clear maps showing the vegetation communities to be impacted, | Detailed within the respective Ecological Report for each project |
| clear quantification of each vegetation community on the proposed offset sites | Table 27 |
| a clear map showing the location of the proposed offset site and the vegetation communities on the site, including the size of the offset site, the landscape context and the cadastre boundaries, | Section 5.3 |
| demonstration of the metric used to show that the impacts are fully offset, | Section 5.5 and Section 5.6 |
| details of the proposed mechanism for securing the offset site in perpetuity, | Section 5.9 |
| objectives for management of the proposed offset site, and | Section 5.10 |
| demonstration that the proposed offset proposal is consistent with relevant Government policies and principles | Section 2 of this Report and Table 1 |

**Table 17 Department of the Environment Requirements**

| Department of the Environment Requirements | Where Addressed in this Report |
|---|---|
| Location and size of the offset land | Figure 3 and Table 27. |
| Maps showing the relevant ecological features, the landscape context and the cadastre boundary | Figure 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 |
| The current tenure arrangements (including zoning and land ownership) of the offset land | Figure 3 |
| Confirmed records of presence (or otherwise) of relevant protected matters on the offset land | Figure 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 |
| Detailed information of the presence and quality of habitat for relevant protected matters on the offset land. The quality of habitat should be assessed in a manner consistent with *How to use the offset assessment guide* | Section 5.8 |
| Management actions that will be undertaken that improve or maintain the quality of the proposed offset land | Section 5.3 |
| Time over which management actions will deliver proposed improvements or maintenance of habitat quality | Section 8 and 9 of this Report |
| Risk of damage, degradation or destruction to any offset land in the absence of formal protection and/or management over a foreseeable period of time (20 years) | Section 5.3 |
| Presence of pending development applications, mining leases or other activities on or near the offset land that indicate development intent | None recognised |
| Average risk of loss for similar sites | Section 5.3 |
| Presence and strength of formal protection mechanisms currently in place | Section 5.9 |

| Department of the Environment Requirements | Where Addressed in this Report |
|---|---|
| The proposed strategy is additional to any existing requirement, determined by law or planning regulations, agreed to under other schemes or programs or required under an existing duty of care | Section 2 |
| Overall cost of the strategy, including acquisition/land transfer costs; implementation of related management actions; and monitoring, reporting and auditing of the strategy | Section 9 |

The Biodiversity Strategy will be included in the Statement of Commitments for each EIS.

## 5.2 Strategic Lands Assessment (Site Selection)

In 2012 Centennial undertook a Strategic Land Assessment of the Centennial off-tenement land holdings. The Project was targeted at assessing the options / opportunities for more actively managing Centennial's entire land bank. The Project aimed to strategically assess the current off-tenement land holdings to identify future land use potential within the following key areas:

- Identification of land which has a high value for biodiversity, conservation and/or restoration;
- Identification of land which is of Aboriginal or European heritage significance;
- Identification of land which has potential for current or future alternative land uses;
- Identification of prime agricultural land; and
- Identification of land which has potential for soil carbon farming and land productivity initiatives.

The Biodiversity component of the Project aimed to assess land which has a high value for biodiversity and conservation. Such land may have potential environmental and economic value associated with the Biodiversity Banking and Offsets Scheme (BioBanking) in NSW. The BioBanking Scheme is operated under Part 7A of the Threatened Species Conservation Act 1995 by OEH. Other lands that also have the potential to be restored to increase areas of endangered ecological communities or provide additional threatened species habitat also may have potential under the BioBanking Scheme to generate additional BioBanking Credits.

### 5.2.1.1 Traffic Light Approach

A traffic light approach was established to identify land holdings which have Biodiversity/Conservation value. The following approach was used to classify each land holding:

**Green Land – High Biodiversity Value**

- Over 5 ha with low edge to area ratio;
- Mostly intact native vegetation (including native grasslands);
- High condition (biobanking);
- Likely to contain numerous threatened species and/or threatened ecological communities;
- High landscape/strategic value;
- High connectivity value;
- Likely to contain riparian zones; and
- High management or restoration potential.

**Amber - Moderate Biodiversity Value**

- Over 5 ha with medium edge to area ratio;

- Partly intact native vegetation (including native grasslands);
- Moderate - High condition (biobanking);
- Likely to contain some threatened species and/or threatened ecological communities;
- Moderate landscape/strategic value;
- Moderate connectivity value;
- Likely to contain riparian zones; and
- Moderate - High management or restoration potential.

**Red - Low Biodiversity Value**

- Generally less than 5 ha with medium – high edge to area ratio;
- Mostly cleared or non-native vegetation;
- Low condition (biobanking);
- Likely to contain few threatened species and/or threatened ecological communities;
- Low landscape/strategic value;
- Low connectivity value;
- May still contain riparian zones; and
- Low management or restoration potential.

These key parameters are shown in **Table 18**. The above classifications were used to prepare a map layer of the lands assessed to inform future decisions of the suitability of lands for biodiversity conservation and restoration. An example of the result of the traffic light mapping is presented in **Figure 2**.

**Table 18 The Key Parameters and Associated Categories used to Provide an Overall Biodiversity Value**

| Parameter | Low | Medium | High |
|---|---|---|---|
| Size | <5 ha | 5-50 ha | >50 ha |
| Edge(m):Area (m$^2$) Ratio | >0.04 | 0.01-0.04 | <0.01 |
| Native Vegetation (%) | <30% | 30% - 70% | >70% |
| BioBanking Condition | Low | Moderate | High |
| Threatened Species / Endangered Ecological Communities Potential | ▪ No TS or EECs likely; or<br>▪ Vulnerable species highly mobile. | ▪ Highly mobile Endangered or Critically Endangered species;<br>▪ Vulnerable species solely reliant on habitats present; or<br>▪ EECs occupy <50% of the site. | ▪ Endangered or Critically Endangered species solely reliant on habitats present; or<br>▪ EECs occupy >50% of the site. |
| Landscape Connectivity/Strategic Value | ▪ Isolated from areas of native vegetation and conservation reserves; and<br>▪ Not included in DECC 25yr investment map (Hunter). | ▪ Tentative connectivity to offsite areas of native vegetation and/or;<br>▪ Within 1km of conservation reserve or DECC 25yr investment site (Hunter). | ▪ Strong connectivity to offsite areas of native vegetation; or<br>▪ Adjacent to existing conservation reserve; or<br>▪ Included in DECC 25yr investment map (Hunter). |

| Parameter | Low | Medium | High |
|---|---|---|---|
| Riparian/Aquatic Values | Farm dams and ephemeral drainage lines only. | Permanent streams; or small wetlands. | ▪ Rivers and wetlands; or<br>▪ Groundwater dependent ecosystems. |
| Restoration/Management Potential | Existing cultivated or developed lands | Partially disturbed or remnant native vegetation | Existing bushland in moderate to high condition |
| **Overall Biodiversity Value** | Red | Amber | Green |
| | ▪ Native Vegetation (%) = Low; and<br>▪ Threatened Species / Endangered Ecological Communities Potential = Low; and<br>▪ Landscape/Strategic Value = Low | Doesn't fit into Red or Green categories, adaptable land-use depending on priorities. | ▪ Native Vegetation (%) = High; and<br>▪ Threatened Species / Endangered Ecological Communities Potential = Medium or High; and<br>▪ Landscape Connectivity/Strategic Value = High |

A total of approximately 5,821 ha of off-tenement land holdings within the western region were reviewed for this assessment. The assessment resulted in the following outcomes:

- 1,762 ha (30%) Green;
- 413 ha (7%) Amber/Green;
- 1,432 ha (25%) Amber;
- 1,035 ha (18%) Red/Amber; and
- 1,179 ha (20%) Red.

This Regional Strategy has included 557 ha of lands that were part of the strategic assessment, as well as an additional 281 ha of land that has since been considered as part of this Regional Strategy.

It is important to consider the overall strategic value of land and its appropriateness for conservation. The biodiversity and conservation value classification of Centennial off-tenement land holdings was therefore weighted against the other competing uses of the lands, such as future infrastructure or agriculture. As a result, the off-tenement lands considered were short listed for more detailed consideration as suitable offsets, taking into account:

- residual competing possible future uses, such as agriculture;
- location in relation to suitability for management;
- feedback from the Office of Environment and Heritage, Department of Planning and Environment and Department of the Environment in relation to preferred land parcels; and
- the financial loss resultant in dedicating the land to conservation (land value) in addition to cost of managing the land for biodiversity.

The chosen conservation areas proposed as part of this Strategy are resultant from an investigation of all of the above competing factors.

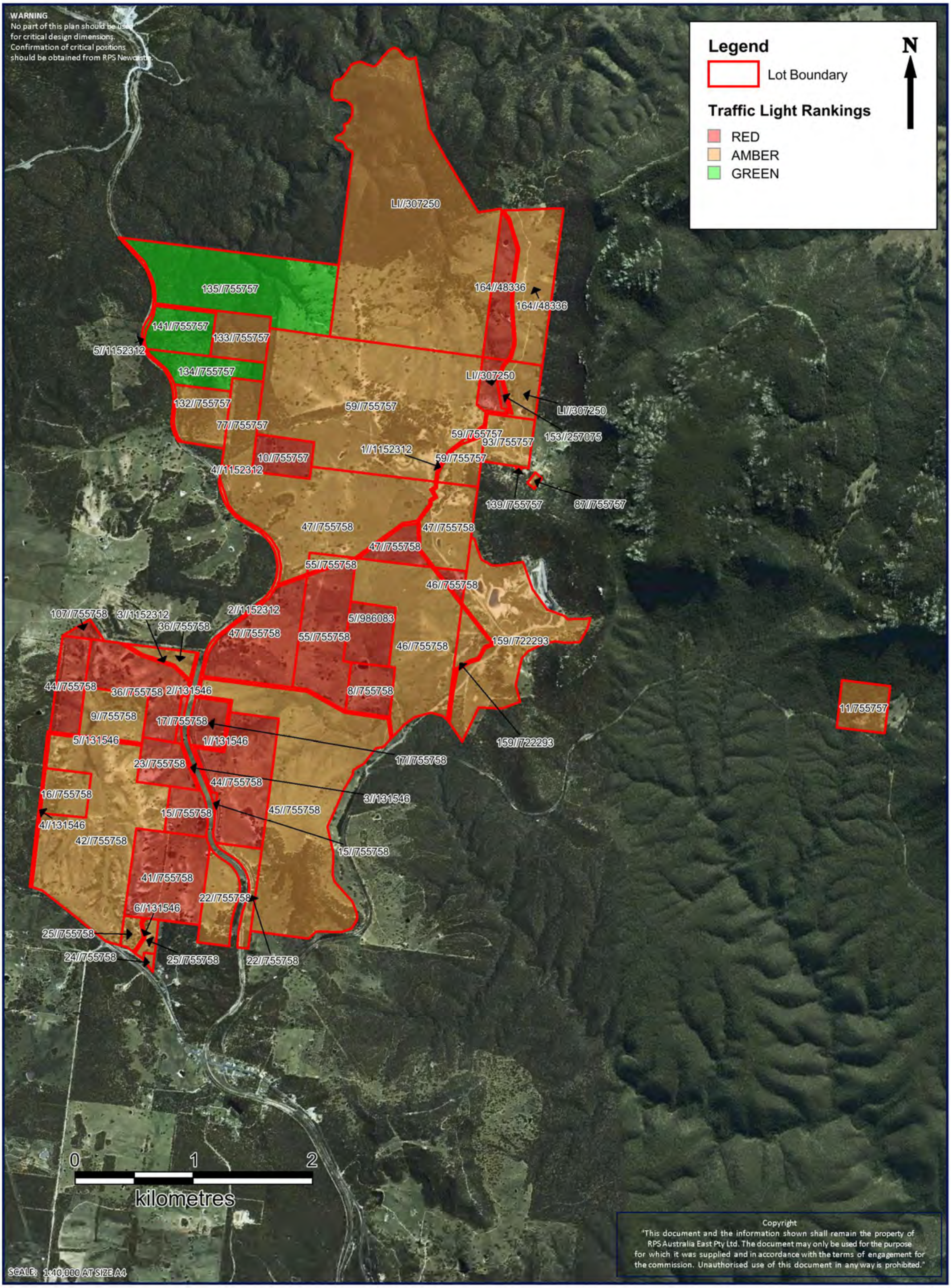


FIGURE 2 EXAMPLE OF THE TRAFFIC LIGHT APPROACH FOR SITES AT AIRLY

LOCATION: AIRLY

DATUM: GDA 94
PROJECTION: MGA ZONE 56

DATE: 19/09/2014
PURPOSE: REPORT FIGURE

LAYOUT REF: J:\JOBS\Centennial\All Jobs\123063 OEH Submissions - Fassifern\10 - Drafting\MapInfo Workspaces\Eco Biobanking Report
VERSION (PLAN BY): PH (A-A4)

CLIENT: CENTENNIAL
JOB REF: 123063

## 5.3 Offset and Land Management Provisions

Conservation sites have been proposed that consider several factors, including providing greater areas of commensurate habitat to that being lost, wherever possible. Additionally, sites that have strategic value due to their position in relation to other large tracts of forested habitats or the existing or potential high biodiversity values have been investigated.

The offsets package has been divided into three forms:

(1) Offsets land to be secured in perpetuity (Section 5.7) with an Offsets Management Plan.

- Airly Offset Site; and
- Wolgan Road Northern Offset Site.

(2) Rehabilitation Land in accordance with a defined Rehabilitation Plan

- Wangcol Creek Rehabilitation;
- Lamberts Gully Rehabilitation; and
- Commonwealth Colliery Rehabilitation Site.

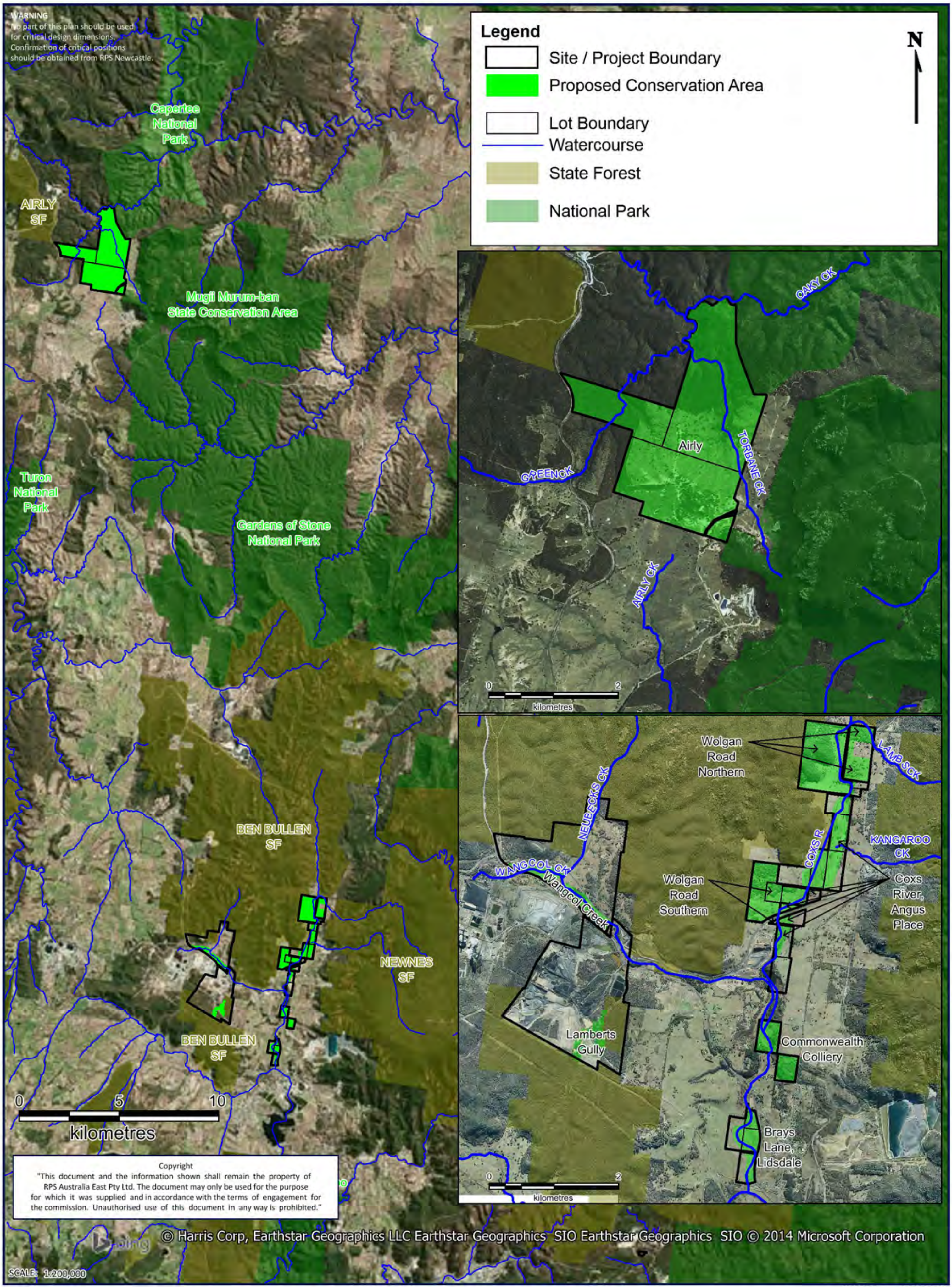
(3) Land Management to be rehabilitated and restored as per a Land Management Plan.

- Wolgan Road Southern Management Site;
- Brays lane, Lidsdale Management Site; and
- Coxs River, Angus Place Management Site.

All plans will be under a Regional Biodiversity Management Plan.

**Figure 3** depicts the regional context of the proposed offsets and demonstrates the connectivity value of these offsets.

Several conservation sites overlap with another key initiate of this Regional Strategy, namely the Coxs River Catchment Restoration Program. This is further detailed in **Section 7**. The following sections provide an overview of each conservation site, including the strategic and biodiversity values.



| | | | | | | | |
|---|---|---|---|---|---|---|---|
| TITLE: | FIGURE 3 CONSERVATION SITE LOCATIONS - REGIONAL CONTEXT | LOCATION: | LITHGOW, NSW | DATUM: | DATUM | DATE: | 19/09/2014 |
| | | | | PROJECTION: | MGA ZONE56 | PURPOSE: | REGIONAL BIODIVERSITY STRATEGY |

LAYOUT REF: J:\JOBS\Centennial\All Jobs\123063 OEH Submissions - Fassifern\10 - Drafting\MapInfo Workspaces\Eco

VERSION (PLAN BY): PH (B-A4)

CLIENT: CENTENNIAL

JOB REF: 123063

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### 5.3.2 Airly Offset Site

This site comprises three separate lots, namely Lot59 DP755757, Lot135 DP755757 and Lot163 DP48336. It sits within the Capertee Valley in The City of Lithgow Shire of Central Western NSW. These proposed offset site is located between the Airly State Forest, Capertee National Park and Mugii Murum-ban State Conservation Area and will make a significant contribution to the conservation of the connectivity between these estates.

#### 5.3.2.1 Biodiversity Values

This site is comprised of a variety of vegetation communities. The site provides habitat for a number of threatened flora and fauna species and endangered ecological communities listed under both the state TSC Act and the Federal EPBC Act.

Ecological investigations have confirmed the presence of seven threatened fauna species listed as Vulnerable under the TSC Act 1995 including Brown Treecreeper (*Climacteris picumnus victoriae*), Grey-crowned Babbler (*Pomatostomus temporalis temporalis*), Diamond Firetail (*Stagonopleura guttata*), Speckled Warbler (*Chthonicola sagittata*), Little Lorikeet (*Glossopsitta pusilla*), Sooty Owl (*Tyto tenebricosa*) and Large-eared Pied Bat (*Chalinolobus dwyeri*). Large-eared Pied Bat is also listed as Vulnerable under the EPBC Act.

A combination of desktop reviews of The Vegetation of the Western Blue Mountains (DEC 2006) and ground-truthing has found that the site contains 38.58 ha of Capertee Rough-Barked Apple – Redgum – Yellow Box Grassy Woodland (MU20) which is commensurate with White Box – Yellow Box – Blakely’s Red Gum Woodland Endangered Ecological Community (EEC) (TSC Act) and White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland, a Critically Endangered Ecological Community (CEEC) under the EPBC Act. An additional 67.53 ha of the derived grasslands component of this community has also been mapped across this site. This EEC/CEEC is collectively referred to as Box-Gum Woodland throughout this report.

**Plate 1 Box-Gum Woodland within the Airly Offset Site**

The site includes riparian vegetation of Torbane Creek and much of its upper catchment. The creek contains MU54 Capertee - Wolgan Riparian Rough-barked Apple - River Oak Open Forest in good condition.

**Plate 2 Riparian vegetation along Torbane Creek**

The contiguous remnant vegetation within the northern portion of these lots are in good condition and, where vegetated, can be assumed to be in the same condition as the neighbouring Airly State Forest, Mugii Murumban State Conservation Area and Capertee National Park. The patches of remnant vegetation in the eastern portion of the offset area would be affected to a degree by edge effects due to surrounding derived grassland vegetation but most is still in good condition and retains connectivity with the more extensive areas of vegetation within and surrounding the site.

**Plate 3 Dry woodland vegetation within Airly Offset connected to the Capertee National Park and Airly State Forest**

This vegetation is very likely to provide habitat in the form of foraging resource and breeding sites for many of the threatened species known from the adjacent Airly Mine Project Area. This includes a total of 167 fauna species, comprising 29 mammal, 108 bird, 20 reptile and 10 amphibian species. Of the 167 fauna species detected, 15 were listed as Vulnerable under the TSC Act 1995. MU20 and MU21 is habitat for *Eucalyptus cannonii* (Capertee Stringybark) with multiple records for this species collected from within these vegetation communities in the locality. To date, six *E. cannonii* trees have been recorded from within the offset site. However, this number does not account for all individuals of this species within this site.

**Plate 4 *Eucalyptus cannonii* fruit within the Airly Offsets site**

The offset value of this site in the threatened species that it provides habitat for, the Endangered Ecological Community that occurs within the site and the considerable connectivity between Airly State Forest, Capertee National Park and Mugii Murum-ban State Conservation Area that the conservation of this and other proposed lots will ensure. In addition, through management of the cleared areas there will potentially be a considerable gain in the area of the majority of the vegetation communities, and associated flora and fauna habitat, that occurs within the site including the Box-Gum Woodland EEC/CEEC.

A substantial proportion of the site is currently used as grazing land and is predominately cleared of a canopy, mid storey and shrub layer. A dominant native groundcover however persists across the site. As can be seen in **Figure 4**, paddock trees and remnant vegetation are scattered throughout the cleared land. A great deal of natural regeneration was noted during site inspections and the site is likely to respond well to assisted regeneration.

**Plate 5 Cleared land within Airly Offset showing natural regeneration of the canopy and shrub layer.**

The vegetation recorded within the site is provided in **Table 19**. The vegetation has been mapped in **Figure 4**.

**Table 19 Vegetation within the Airly Offset Site**

| Vegetation | Area (ha) |
|---|---|
| MU13 Tableland Gully Ribbon Gum - Blackwood - Apple Box Forest | **6.91** |
| MU20 Capertee Rough-barked Apple - Redgum - Yellow Box Grassy Woodlands (EEC/CEEC) | **38.58** |
| Derived grasslands of MU20 Capertee Rough-barked Apple - Redgum - Yellow Box Grassy Woodlands (EEC/CEEC) | **67.53** |
| MU21 Capertee - Wolgan Slopes Red Box - Grey Gum - Stringybark Grassy Open Forest | **22.61** |
| MU38 Capertee Grey Gum - Narrow-leaved Stringybark - Scribbly Gum - Callitris - Ironbark Shrubby Open Forest | **178.56** |
| Derived grasslands of MU38 Capertee Grey Gum - Narrow-leaved Stringybark - Scribbly Gum - Callitris - Ironbark Shrubby Open Forest | **176.61** |
| MU42 Capertee Hills White Box - Tumbledown Redgum - Ironbark - Callitris Shrubby Woodland | **32.69** |
| MU54 Capertee - Wolgan Riparian Rough-barked Apple - River Oak Open Forest | **8.36** |
| **Total** | **532.01** |

#### 5.3.2.2 Proposed Protection and Management

This conservation area is proposed to be protected under Section 88B of the Conveyancing Act 1919, the terms of the Section 88B instrument will make reference to a dedicated Biodiversity Offsets Management Plan (BOMP). Key enhancement and management objectives of the site are:

- removal of grazing pressures;
- riparian areas restoration within cleared lands;
- native species planting within derived native grasslands, including *Eucalyptus cannonii* and species commensurate with Box-Gum Woodland;
- weed removal / control; and
- Rabbit control.

**Legend**

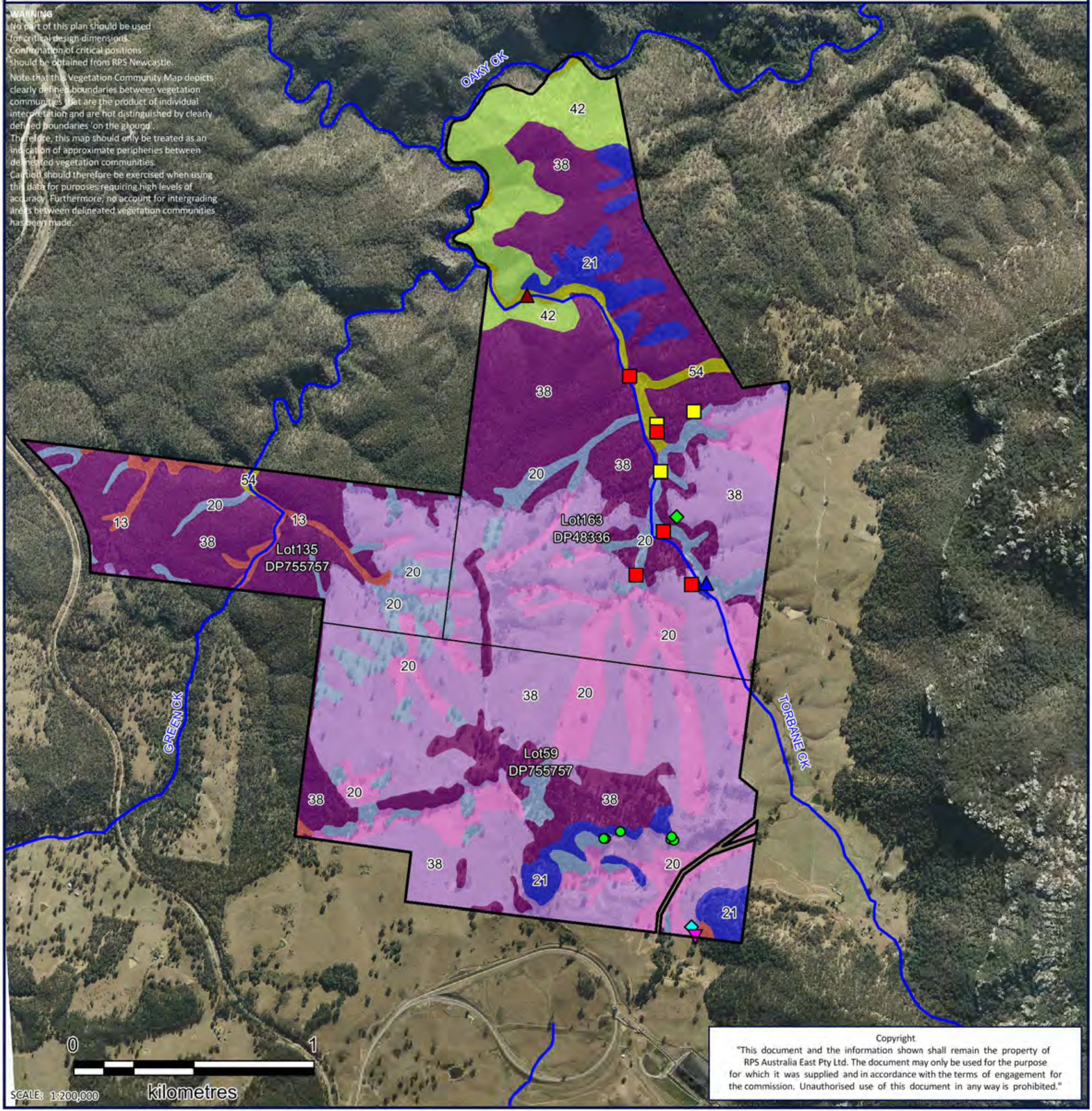
▭ Lot Boundary
— Watercourse

*Threatened Species*

● *Eucalyptus cannonii*
■ Brown Treecreeper
◆ Diamond Firetail
▲ Grey-crowned Babbler
▼ Large-eared Pied Bat
■ Little Lorikeet
◆ Sooty Owl
▲ Speckled Warbler

*Vegetation Communities*

| | |
|---|---|
| 🟥 | 13 Tableland Gully Ribbon Gum - Blackwood - Apple Box Forest |
| 🟦 | 20 Capertee Rough-barked Apple - Redgum - Yellow Box Grassy Woodlands (EEC / CEEC) |
| 🟦 | 21 Capertee - Wolgan Slopes Red Box - Grey Gum - Stringybark Grassy Open Forest |
| 🟪 | 38 Capertee Grey Gum - Narrow-leaved Stringybark - Scribbly Gum - Callitris - Ironbark Shrubby Open Forest |
| 🟩 | 42 Capertee Hills White Box - Tumbledown Redgum - Ironbark - Callitris Shrubby Woodland |
| 🟨 | 54 Capertee - Wolgan Riparian Rough-barked Apple - River Oak Open Forest |
| 🟪 | Derived grasslands of 20 Capertee Rough-barked Apple - Redgum - Yellow Box Grassy Woodlands (EEC / CEEC) |
| 🟪 | Derived grasslands of 38 Capertee Grey Gum - Narrow-leaved Stringybark - Scribbly Gum - Callitris - Ironbark Shrubby Open Forest |



WARNING
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TITLE: FIGURE 4: AIRLY OFFSET SITE BIODIVERSITY VALUES
LOCATION: LITHGOW, NSW
DATUM: DATUM
PROJECTION: MGA ZONE56
DATE: 29/09/2014
PURPOSE: REGIONAL BIODIVERSITY STRATEGY
LAYOUT REF: J:\JOBS\Centennial\All Jobs\123063 OEH Submissions - Fassifern\10 - Drafting\MapInfo Workspaces\Eco
VERSION (PLAN BY): PH (B-A4)

CLIENT: CENTENNIAL
JOB REF: 123063

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### 5.3.3 Wolgan Road Northern Offset Site

This site consists of two lots, namely Lot56 DP751636 and Lot100 DP1033592. It is bounded on its western and north-eastern boundary by Ben Bullen State Forest. The eastern boundary of the site is bounded by Wolgan Road, with some remnant woodland vegetation along Lambs Creek connecting the site to the Newnes Stare Forest, approximately 500m to the east.

A mix of woodlands and farm lands occur to the south. The Gardens of Stone National Park occurs approximately 5.5km to the north east and is connected by contiguous forested vegetation via Ben Bullen State Forest.

This site contains a length of the Coxs River and Lambs Creek. The low lying areas surrounding the river have been mapped as dominated by MU15 Tableland Hollows Black Gum - Black Sally Open Forest. This vegetation community is commensurate with the TSC Act listed EEC Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland. Approximately 20.08 ha of this EEC has been mapped, with an additional 39.53 ha occurring as derived native grasslands of the EEC.

MU15 also contains *Eucalyptus aggregata* (Black Gum), which is listed as Vulnerable under the TSC Act. To date, 266 trees have been recorded. However, this number does not account for all individuals of this species within this site.

**Plate 6 Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland and derived grasslands EEC containing *Eucalyptus aggregata* within the Wolgan Road North Offset Site.**

This site also contains 1.46 ha of MU53 Mountain Hollow Grassy Fen along Lambs Creek. This community is commensurate with Montane Peatlands and Swamps, which is listed as an EEC under the TSC Act.

**Plate 7 Montane Peatlands and Swamps EEC within the Wolgan Road North Offset Site.**

The western half of this site contains predominately dry sclerophyll woodlands on relatively steep slopes. The ridge tops offer areas of dry woodland and rocky habitats, including some pagodas.

**Plate 8 Typical Dry Woodland Habitat within the Wolgan Road North Offset Site.**

**Plate 9 Pagoda within the Wolgan Road North Offset Site.**

Some of the sheltered slopes provide damper habitats that were found to be suitable to support *Derwentia blakelyi*. This species is listed as Vulnerable under the TSC Act. To date 94 individual plants have been recorded. However, this number does not account for all individuals of this species within this site.

**Plate 10 *Derwentia blakelyi* within the Wolgan Road North Offset Site.**

**Table 20 Vegetation within the Wolgan Road North Offset Site.**

| Vegetation Community | Area (ha) |
|---|---|
| MU8 Newnes Sheltered Peppermint - Brown Barrel Shrubby Forest | 2.68 |
| MU 11 Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest | 1.14 |
| MU 15 Tableland Hollows Black Gum - Black Sally Open Forest | 18.94 |
| MU 28 Sandstone Plateau And Ridge Scribbly Gum - Silver-top Ash Shrubby Woodland | 1.57 |
| MU 29 Sandstone Slopes Sydney Peppermint Shrubby Forest | 2.51 |
| MU 30 Exposed Blue Mountains Sydney Peppermint - Silver-top Ash Shrubby Woodland | 3.74 |
| MU 35 Tableland Gully Mountain Gum - Broad-leaved Peppermint Grassy Forest | 0.21 |
| MU 37 Coxs Permian Red Stringybark - Brittle Gum Woodland | 24.24 |
| MU 43 Pagoda Rock Sparse Shrubland | 0.24 |
| Derived Grasslands of MU 11 Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest | 12.08 |
| Derived Grasslands of MU 15 Tableland Hollows Black Gum - Black Sally Open Forest | 27.45 |
| Derived Grasslands of MU 37 Coxs Permian Red Stringybark - Brittle Gum Woodland | 2.86 |
| MU 53 Mountain Hollow Grassy Fen | 1.46 |
| **Total** | **99.12** |

#### 5.3.3.2 Proposed Protection and Management

This conservation area is proposed to be protected under Section 88B of the Conveyancing Act 1919, the terms of the Section 88B instrument will make reference to a dedicated Biodiversity Offsets Management Plan (BOMP).

Key enhancement and management objectives of the site are:

- removal of grazing pressures;
- riparian restoration along Coxs River and drainage lines;
- native species planting within derived native grasslands, including:
    - species associated with Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland EEC,
    - *Eucalyptus aggregata;*
    - *Eucalyptus cannonii*;
    - *Themeda triandra* (habitat for *Thesium australe*); and
    - *Bursaria spinosa* subsp. *lasiophylla* (habitat for the Bathurst Copper Butterfly)
- weed removal / control; and
- Rabbit control.

**Legend**

▭ Lot Boundary

— Watercourse

*Threatened Species*
(locations represent several individuals)

▲ *Derwentia blakelyi*

◆ *Eucalyptus aggregata*

■ Gang gang Cockatoo

*Vegetation*

🟥 11 Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest (EEC)

🟩 15 Tableland Hollows Black Gum - Black Sally Open Forest (EEC)

🟪 28 Sandstone Plateau and Ridge Scribbly Gum - Silvertop Ash Shrubby Woodland

🟩 29 Sandstone Slopes Sydney Peppermint Shrubby Forest

🟦 30 Exposed Blue Mountains Sydney Peppermint - Silvertop Ash Shrubby Woodland

🟩 35 Tableland Gully Mountain Gum - Broad-leaved Peppermint Grassy Forest

🟧 37 Coxs Permian Red Stringybark - Brittle Gum Woodland

🟫 43 Pagoda Rock Sparse Shrubland

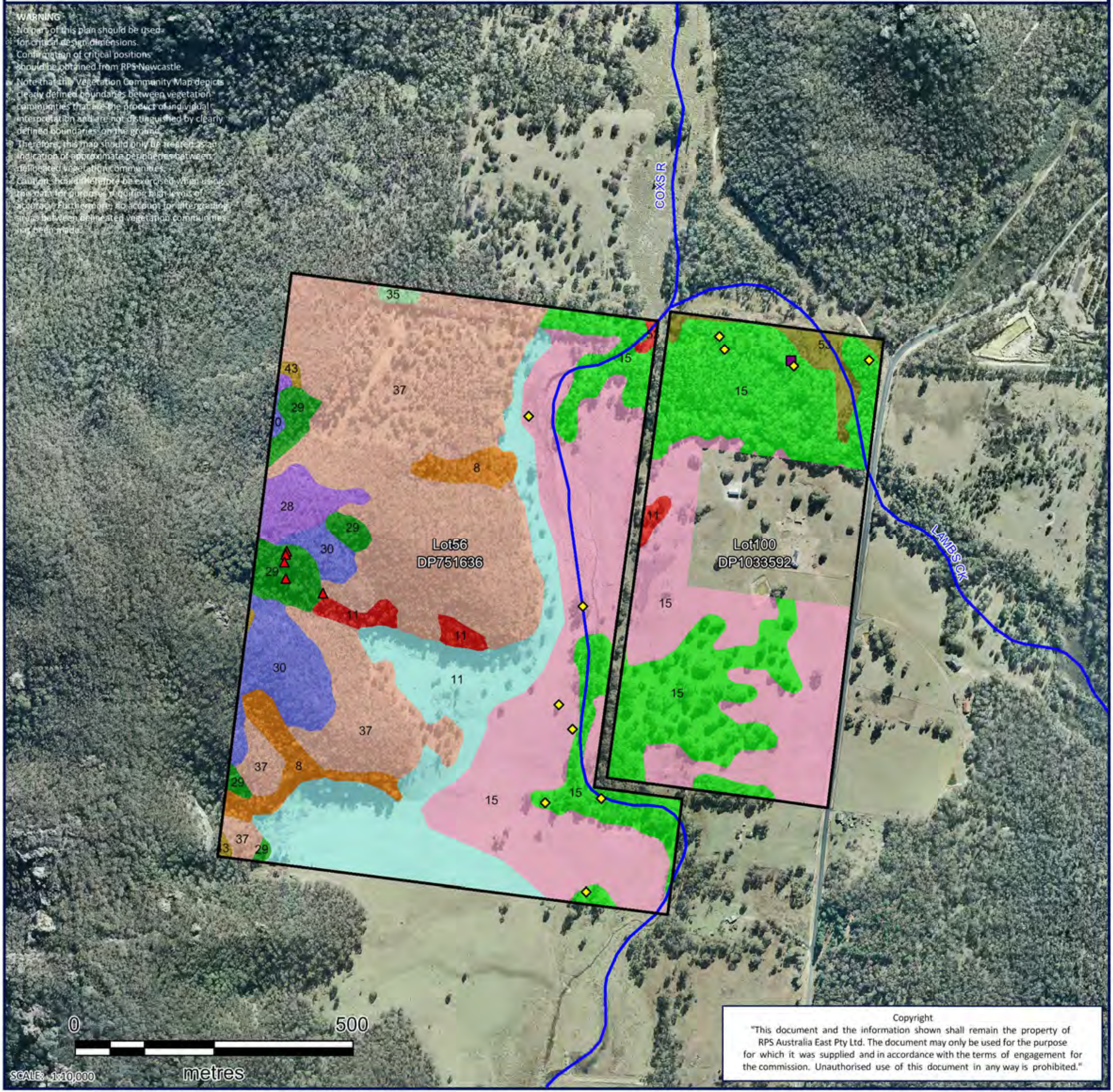
🟫 53 Mountain Hollow Grassy Fen (EEC)

🟧 8 Newnes Sheltered Peppermint - Brown Barrel Shrubby Forest

🟦 Derived grasslands of 11 Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest (EEC)

🟪 Derived grasslands of 15 Tableland Hollows Black Gum - Black Sally Open Forest (EEC)

🟧 Derived grasslands of 37 Coxs Permian Red Stringybark - Brittle Gum Woodland



WARNING
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TITLE: FIGURE 5 WOLGAN ROAD NORTHERN OFFSET SITE BIODIVERSITY VALUES
LOCATION: LITHGOW, NSW
DATUM: DATUM
PROJECTION: MGA ZONE56
DATE: 29/09/2014
PURPOSE: REGIONAL BIODIVERSITY STRATEGY
LAYOUT REF: J:\JOBS\Centennial\All Jobs\123063 OEH Submissions - Fassifern\10 - Drafting\MapInfo Workspaces\Eco
VERSION (PLAN BY): PH (B-A4)

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### 5.3.4 Wolgan Road Southern Management Site

This site comprises of three lots, Lot1, DP597541, Lot25, DP827626 and Lot27 DP827626. It is bounded on its eastern boundary by Ben Bullen State Forest. The northeast corner of this lot also meets the state forest. A mix of woodlands and farm lands occur to the north, south and east. The Angus Place Haul Road separates a small portion of the southeast corner of lot 27.

The Gardens of Stone Nation Park occurs approximately 8km to the north east and is connected by contiguous forested vegetation via Ben Bullen State Forest.

The site contains a length of the Coxs River. The low lying areas surrounding the river have been mapped as dominated by MU15 Tableland Hollows Black Gum - Black Sally Open Forest. This vegetation community is commensurate with the TSC Act listed EEC Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland. Approximately 6.35 ha of this EEC has been mapped, with an additional 25.17 ha occurring as derived native grasslands of the EEC. Western parts of the site are dominated by dry sclerophyll woodlands on undulating slopes.

MU15 also contains *Eucalyptus aggregata* (Black Gum), which is listed as Vulnerable under the TSC Act. To date, 108 trees have been recorded. However, this number does not account for all individuals of this species within this site.

**Table 21 Vegetation within the Wolgan Road Southern Management Site.**

| Vegetation Community | Area (ha) |
|---|---|
| MU11 Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest | **2.95** |
| MU15 Tableland Hollows Black Gum - Black Sally Open Forest | **3.4** |
| MU37 Coxs Permian Red Stringybark - Brittle Gum Woodland | **16.11** |
| Derived grasslands of MU 15 Tableland Hollows Black Gum - Black Sally Open Forest | **25.17** |
| Derived grasslands of MU 37 Coxs Permian Red Stringybark - Brittle Gum Woodland | **4.39** |
| **Total** | **52.02** |

#### 5.3.4.2 Proposed Protection and Management

This conservation area is proposed to be protected and managed through the requirements of the conditions of approval for the Projects covered by this Regional Strategy. Key enhancement and management objectives of the site are:

- removal of grazing pressures;
- riparian areas restoration along Coxs River and drainage lines;
- native species planting within derived native grasslands, including:
  - species associated with Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland EEC,
  - *Eucalyptus aggregata;*
  - *Eucalyptus cannonii*;
  - *Themeda triandra* (habitat for *Thesium australe*); and
  - *Bursaria spinosa* subsp. *lasiophylla* (habitat for the Bathurst Copper Butterfly)
- weed removal / control; and
- Rabbit control.

**Legend**

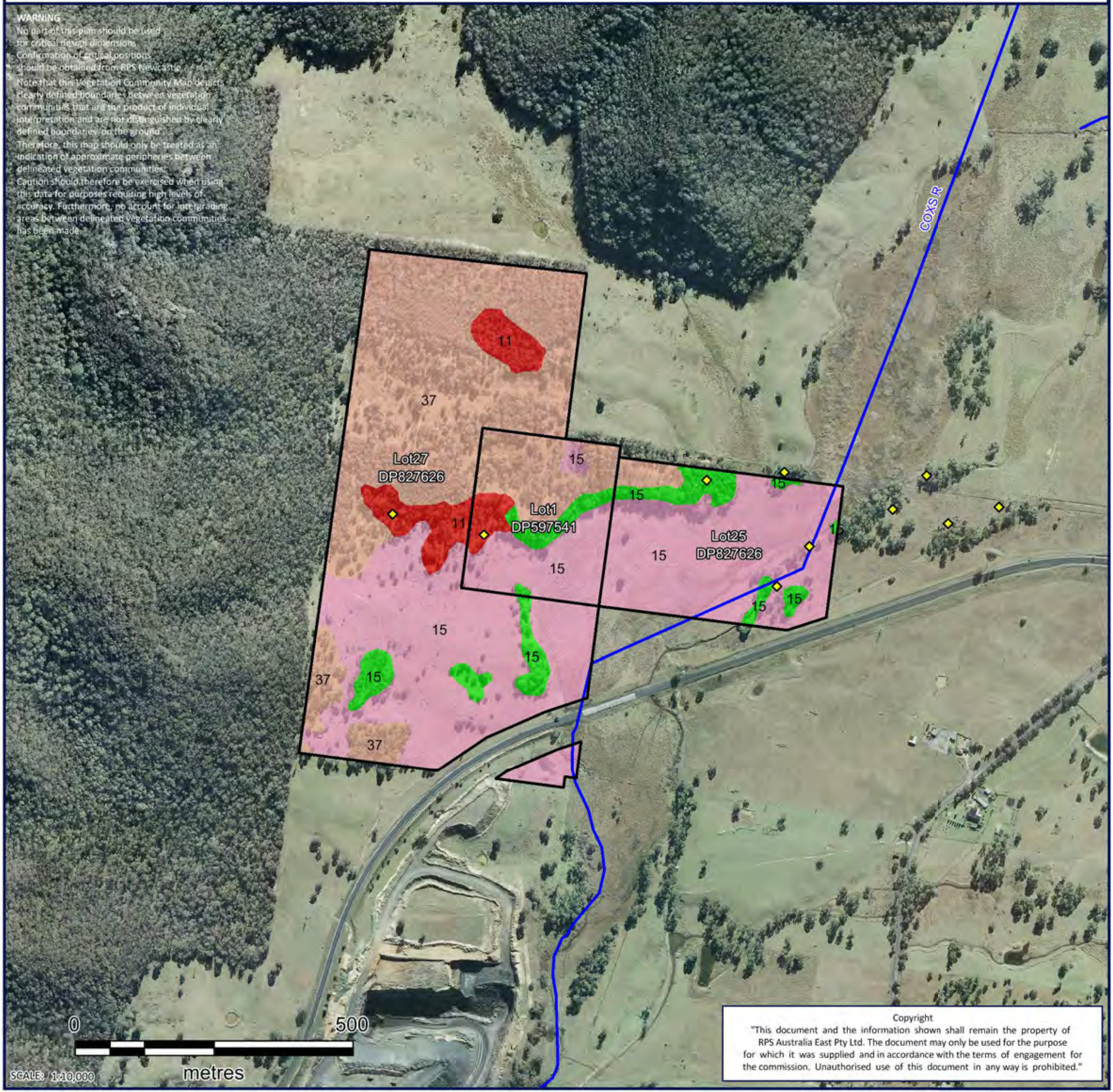
▭ Lot Boundary

— Watercourse

*Threatened Species*
(locations represent several individuals)
◆ *Eucalyptus aggregata*

*Vegetation Communities*

- 🟥 11 Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest (EEC)
- 🟩 15 Tableland Hollows Black Gum - Black Sally Open Forest (EEC)
- 🟧 37 Coxs Permian Red Stringybark - Brittle Gum Woodland
- 🟪 Derived grasslands of 15 Tableland Hollows Black Gum - Black Sally Open Forest (EEC)
- 🟧 Derived grasslands of 37 Coxs Permian Red Stringybark - Brittle Gum Woodland



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TITLE: FIGURE 6 WOLGAN ROAD SOUTHERN MANAGEMENT SITE BIODIVERSITY VALUES
LOCATION: LITHGOW, NSW
DATUM: DATUM
PROJECTION: MGA ZONE56
DATE: 29/09/2014
PURPOSE: REGIONAL BIODIVERSITY STRATEGY
LAYOUT REF: J:\JOBS\Centennial\All Jobs\123063 OEH Submissions - Fassifern\10 - Drafting\MapInfo Workspaces\Eco
VERSION (PLAN BY): PH (B-A4)
CLIENT: CENTENNIAL
JOB REF: 123063

### 5.3.5 Commonwealth Colliery Rehabilitation Site

This site comprises of two lots, Lot1 DP65810 and Lot1 DP52865.This site has been included in the offset strategy due to their strategic position along the Coxs River, and the opportunity to rehabilitate the site.

Lot1 DP65810 currently exists as predominately cleared lands with patchy remnant native vegetation.

**Plate 11 Coxs River at Commonwealth Colliery.**

**Plate 12 Creek bed stabilisation at Coxs River, Commonwealth Colliery.**

Whilst both lots contain some non-native Pine, Lot1 DP52865 contains a plantation which dominates this site. The site is therefore proposed to be rehabilitated to a native vegetation type.

**Table 22 Vegetation within the Commonwealth Colliery Rehabilitation Site**

| Vegetation Community | Total |
|---|---|
| MU 11 Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest | **1.05** |
| MU 15 Tableland Hollows Black Gum - Black Sally Open Forest | **1.64** |
| MU 33 Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest | **1.82** |
| MU 59 Non-native Vegetation - Pine plantation / woodlot / shelter | **13.72** |
| Derived grasslands of MU 15 Tableland Hollows Black Gum - Black Sally Open Forest | **11.5** |
| **Total** | **29.73** |

### 5.3.5.2 Proposed Protection and Management

This conservation area is proposed to be protected and managed through the requirements of the conditions of approval for the Projects covered by this Regional Strategy. Key enhancement and management objectives of the site are:

- riparian areas restoration along Coxs River;
- native species planting within derived native grasslands, including:
    - species associated with Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland EEC, and
    - *Eucalyptus aggregata*.
- weed removal / control; and
- Rabbit control.

**Legend**

▭ Lot Boundary

— Watercourse

*Vegetation Communities*

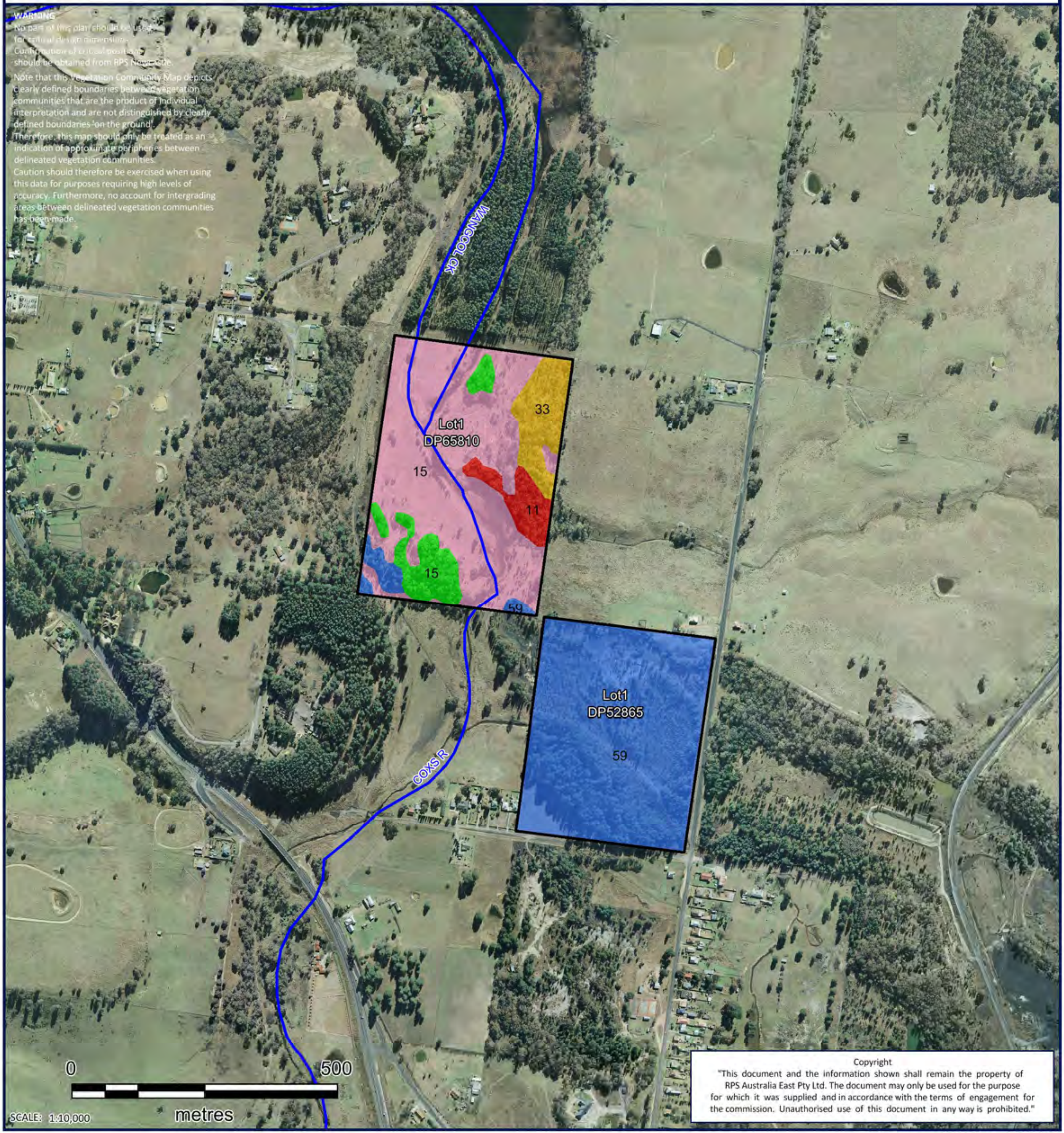
🟥 11 Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest (EEC)

🟩 15 Tableland Hollows Black Gum - Black Sally Open Forest (EEC)

🟨 33 Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest

🟦 59 Non-native Vegetation - Pine plantation / woodlot / shelter

▨ Derived grasslands of 15 Tableland Hollows Black Gum - Black Sally Open Forest (EEC)



WARNING

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TITLE: FIGURE 7 COMMONWEALTH COLLIERY REHABILITATION SITE BIODIVERSITY VALUES

LOCATION: LITHGOW, NSW

DATUM: DATUM
PROJECTION: MGA ZONE56

DATE: 29/09/2014
PURPOSE: REGIONAL BIODIVERSITY STRATEGY

LAYOUT REF: J:\JOBS\Centennial\All Jobs\123063 OEH Submissions - Fassifern\10 - Drafting\MapInfo Workspaces\Eco

VERSION (PLAN BY): PH (B-A4)

CLIENT: CENTENNIAL
JOB REF: 123063

### 5.3.6 Brays Lane, Lidsdale Management Site

This site comprises four lots, Lot164 DP751651, Lot4 DP1088207 and two lots of Lot101 DP1137972. This site has been considered due to its position along the Coxs River.

This site is almost entirely cleared of a canopy, mid storey and shrub layer. however, the ground cover is dominated by native grasses and is likely be commensurate with the Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (derived native grasslands) EEC.

**Plate 13 Coxs River at Brays Lane, Lidsdale Management Site**

**Plate 14 Diverted channel of the Coxs River at Brays Lane, Lidsdale Management Site**

**Table 23 Vegetation within the Brays Lane, Lidsdale Management Site**

| Vegetation Community | Total |
|---|---|
| Derived Native Grassland of MU15 Tableland Hollows Black Gum - Black Sally Open Forest | **25.71** |
| **Total** | **25.71** |

#### 5.3.6.2 Proposed Protection and Management

This conservation area is proposed to be protected and managed through the requirements of the conditions of approval for the Projects covered by this Regional Strategy. Key enhancement and management objectives of the site are:

- removal of grazing pressures;
- riparian areas restoration along Coxs River;
- native species planting within derived native grasslands, including:
    - species associated with Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland EEC,
    - *Eucalyptus aggregata;*
    - *Themeda triandra* (habitat for *Thesium australe*); and
    - *Bursaria spinosa* subsp. *lasiophylla* (habitat for the Bathurst Copper Butterfly)
- weed removal / control; and
- Rabbit control.

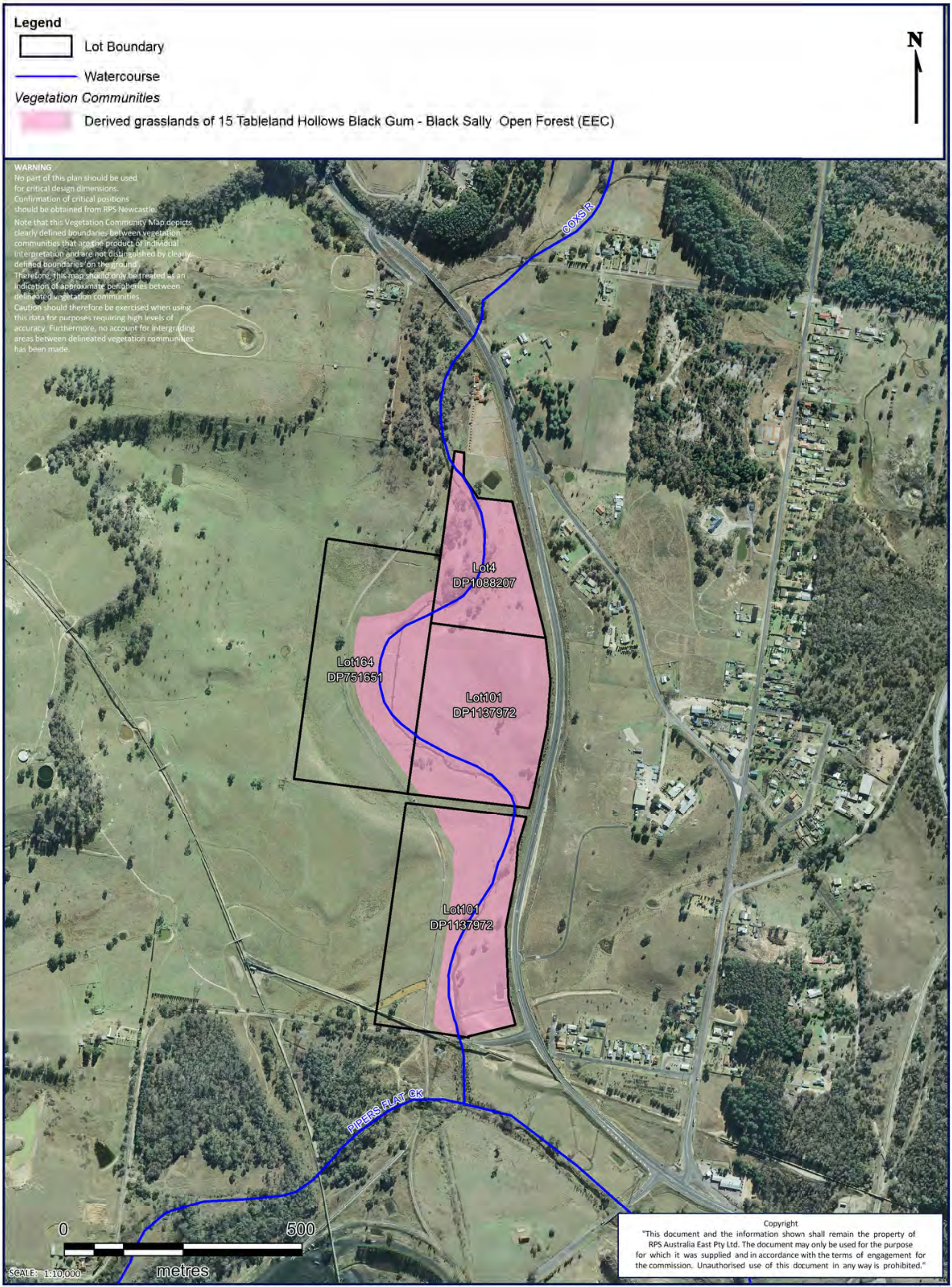
**Legend**

▭ Lot Boundary

— Watercourse

*Vegetation Communities*

▨ Derived grasslands of 15 Tableland Hollows Black Gum - Black Sally Open Forest (EEC)



WARNING
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TITLE: FIGURE 8 BRAYS LANE, LIDSDALE MANAGEMENT SITE BIODIVERSITY VALUES
LOCATION: LITHGOW, NSW
DATUM: DATUM
PROJECTION: MGA ZONE56
DATE: 29/09/2014
PURPOSE: REGIONAL BIODIVERSITY STRATEGY
LAYOUT REF: J:\JOBS\Centennial\All Jobs\123063 OEH Submissions - Fassifern\10 - Drafting\MapInfo Workspaces\Eco
VERSION (PLAN BY): PH (B-A4)

CLIENT: CENTENNIAL
JOB REF: 123063

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### 5.3.7 Wangcol Creek Rehabilitation Site

This site is part of the Neubeck Project and has been considered as a result of its environmental importance and position in relation to the development footprint. Rehabilitation associated with the Wangcol creek site is a result of the Neubeck Project.

Ecological condition varies throughout the Wangcol Creek Rehabilitation site. Some portions of the site have been entirely cleared, resulting in a low biodiversity value and a lack of natural resources such as native vegetation at all strata levels, as well as native riparian vegetation. Other areas demonstrate a better ecological condition, with the presence of native sedges and grasses aiding in bank stability. Non native Willows and Pine trees have been recorded throughout the rehabilitation site.

The threatened flora species *Eucalyptus aggregata* (Black Gum) has been recorded 37 times throughout the site. Vegetation communities commensurate with the EEC Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland have also been delineated on site.

**Plate 15 Vegetated area of Wangcol Creek rehabilitation site**

**Plate 16 Highly disturbed area of Wangcol creek rehabilitation site**

The following table provides a deconstruction of the vegetation communities present within the Wangcol Creek Rehabilitation Site.

**Table 24 Vegetation within the Wangcol Creek Rehabilitation Area**

| Vegetation Community | Area (ha) |
|---|---|
| MU 11 Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest | 0.99 |
| MU 15 Tableland Hollows Black Gum - Black Sally Open Forest | 0.26 |
| MU 33 Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest | 0.78 |
| MU 37 Coxs Permian Red Stringybark - Brittle Gum Woodland | 2.44 |
| MU 53 Mountain Hollow Grassy Fen | 2.20 |
| Derived native grasslands of MU 15 Tableland Hollows Black Gum - Black Sally Open Forest (cleared) | 12.76 |
| Derived native grasslands of MU 33 Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest (cleared) | 3.91 |
| **Total** | **23.34** |

### 5.3.7.2 Proposed Protection and Management

These conservation areas are proposed to be protected in accordance with the Nuebeck development project. Key enhancement and management objectives of the site are:

- riparian areas restoration along Wangcol Creek;
- native species planting within derived native grasslands, including:
  - species associated with Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland EEC,
  - *Eucalyptus aggregata;*
  - *Themeda triandra* (habitat for *Thesium australe*); and
  - *Bursaria spinosa* subsp. *lasiophylla* (habitat for the Bathurst Copper Butterfly)
- weed removal / control; and
- Rabbit control.

**Legend**

▭ Management Boundary

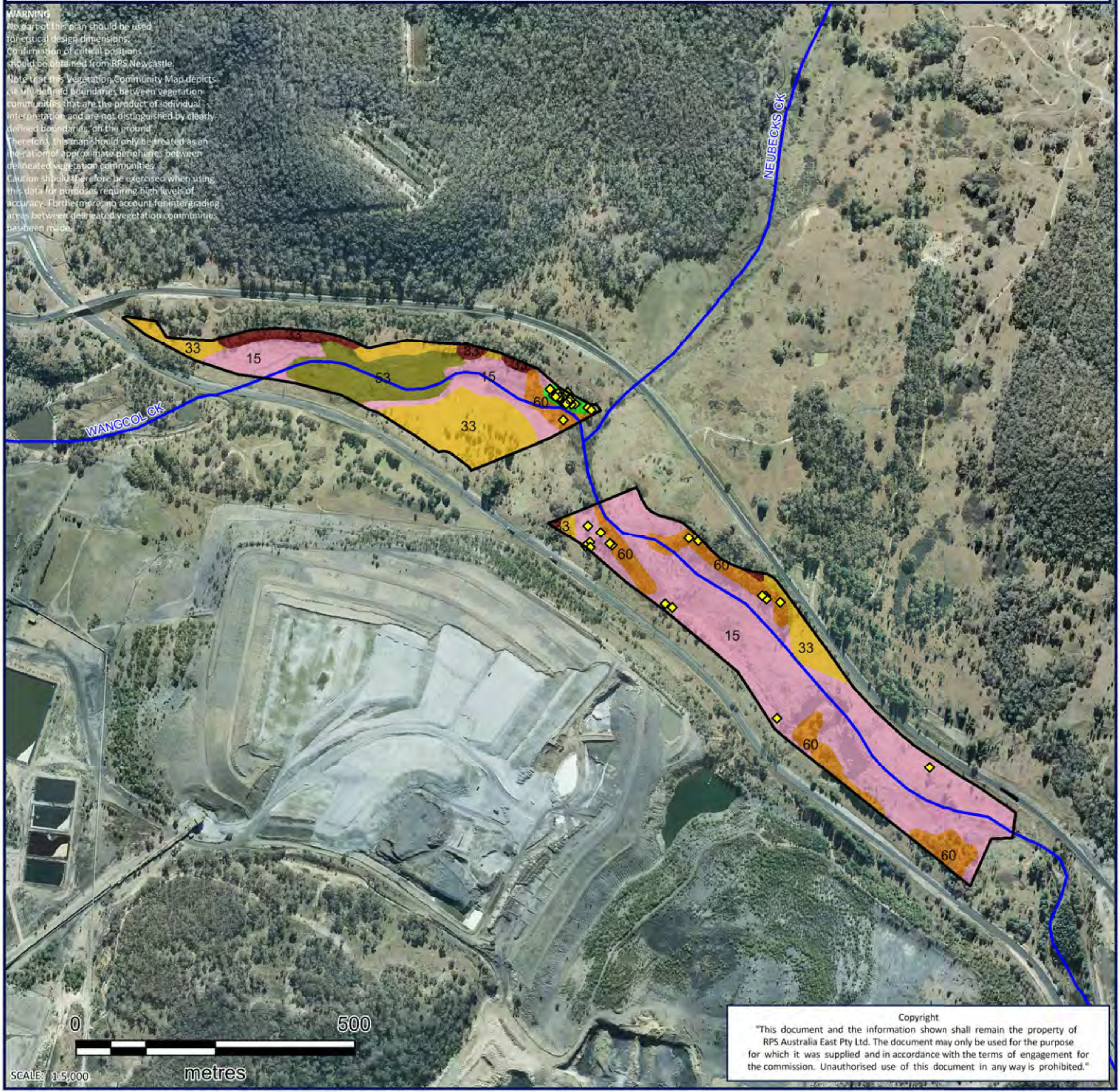
— Watercourse

*Threatened Species*
(locations represent several individuals)

◆ *Eucalyptus aggregata*

*Vegetation Communities*

🟩 15 Tableland Hollows Black Gum - Black Sally Open Forest (EEC)
🟥 33 Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest
🟫 53 Mountain Hollow Grassy Fen (EEC)
🟧 60 Non-native Vegetation - Other exotics (willow etc)
🟪 Derived grasslands of 15 Tableland Hollows Black Gum - Black Sally Open Forest (EEC)
🟨 Derived grasslands of 33 Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest



WARNING
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Therefore, this map should only be treated as an indication of approximate peripheries between delineated vegetation communities.
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TITLE: FIGURE 9 WANGCOL CREEK REHABILITATION AREA BIODIVERSITY VALUES
LOCATION: LITHGOW, NSW
DATUM: DATUM
PROJECTION: MGA ZONE56
DATE: 29/09/2014
PURPOSE: REGIONAL BIODIVERSITY STRATEGY
LAYOUT REF: J:\JOBS\Centennial\All Jobs\123063 OEH Submissions - Fassifern\10 - Drafting\MapInfo Workspaces\Eco
VERSION (PLAN BY): PH (B-A4)

CLIENT: CENTENNIAL
JOB REF: 123063

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### 5.3.8 Lamberts Gully Rehabilitation Site

Lamberts Gully Rehabilitation Site forms part of the Springvale Western Coal Services site. The gully was selected as it provides an opportunity to increase habitat connectivity between existing land parcels, as well as enhancing the condition of an ecologically sensitive feature (the creek line).

The vegetation on site is considered to be in moderate condition, with the canopy and ground layers containing primarily native species. The shrub layer was sparse, however this is a natural state of the specific vegetation communities on site.

The threatened flora species *Eucalyptus aggregata* (Black Gum) has been recorded 22 times throughout the site. Two vegetation communities occur within the Lamberts Gully Rehabilitation Site, both of which are commensurate with the Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland EEC.

**Plate 17 Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (EEC) containing *Eucalyptus aggregata* at Lamberts Gully**

**Plate 18 Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (EEC) at Lamberts Gully**

The following table provides a deconstruction of the vegetation communities present within the Lamberts Gully Rehabilitation Site.

**Table 25 Vegetation within the Lamberts Gully Rehabilitation Area**

| Vegetation Community | Area (ha) |
|---|---|
| MU 11 Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest | 8.29 |
| MU 15 Tableland Hollows Black Gum - Black Sally Open Forest | 0.44 |
| **Total** | **8.73** |

### 5.3.8.2 Proposed Protection and Management

These conservation areas are proposed to be protected in accordance with the Springvale Western Coal Services operations. Key enhancement and management objectives of the site are:

- removal of grazing pressures;
- riparian areas restoration along Lamberts Gully;
- native species planting within derived native grasslands, including:
  - species associated with Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland EEC,
  - *Eucalyptus aggregata;*
  - *Eucalyptus cannonii*;
  - *Themeda triandra* (habitat for *Thesium australe*); and
  - *Bursaria spinosa* subsp. *lasiophylla* (habitat for the Bathurst Copper Butterfly)
- weed removal / control; and
- Rabbit control.

**Legend**

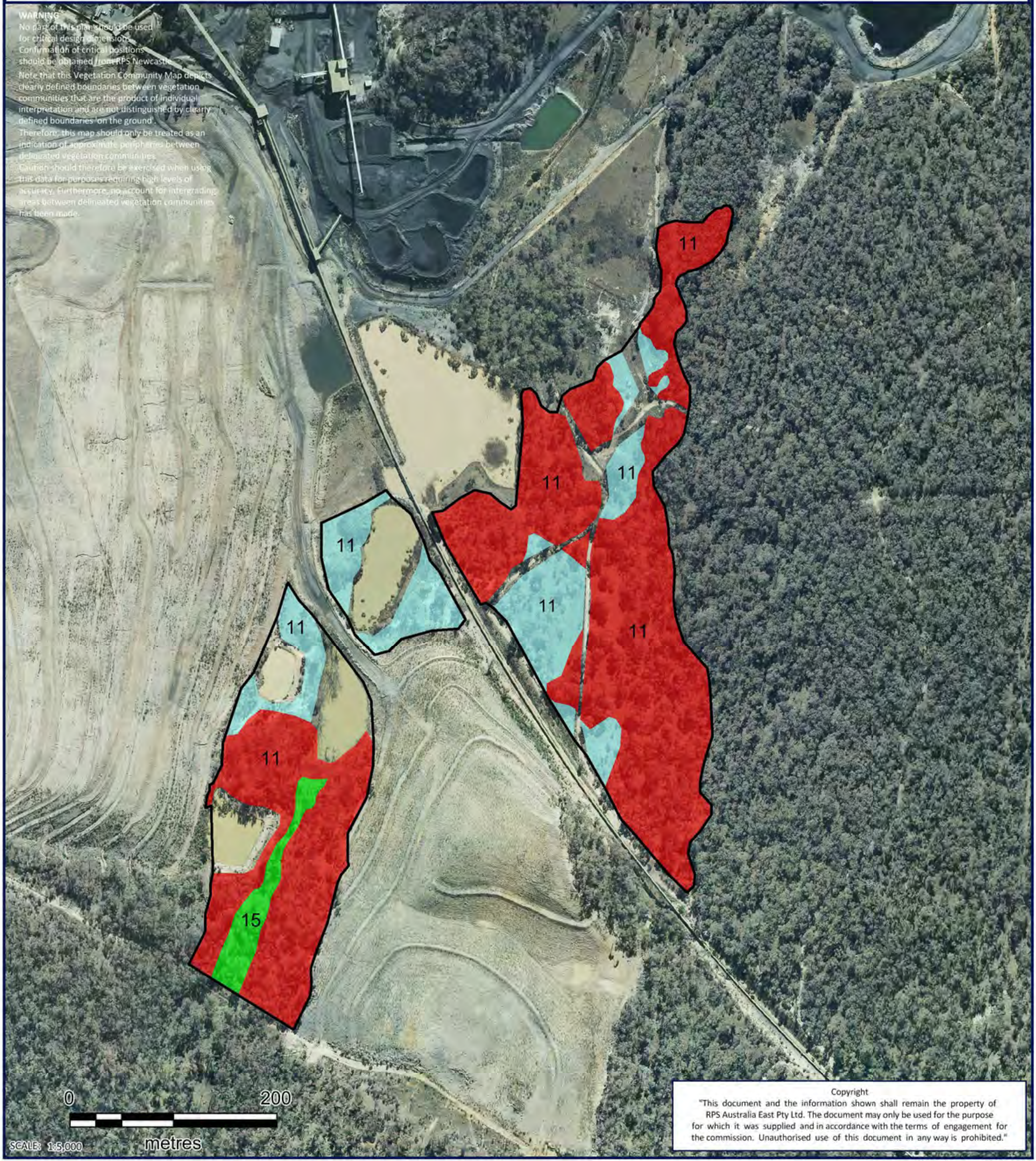
☐ Management Boundary

*Vegetation Communities*

🟥 11 Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest (EEC)

🟩 15 Tableland Hollows Black Gum - Black Sally Open Forest (EEC) (contains Eucalyptus aggregata)

🟦 Derived grasslands of 11 Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest (EEC)



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TITLE: FIGURE 10 LAMBERTS GULLY REHABILITATION BIODIVERSITY VALUES

LOCATION: LITHGOW, NSW

DATUM: DATUM
PROJECTION: MGA ZONE56

DATE: 29/09/2014
PURPOSE: REGIONAL BIODIVERSITY STRATEGY

LAYOUT REF: J:\JOBS\Centennial\All Jobs\123063 OEH Submissions - Fassifern\10 - Drafting\MapInfo Workspaces\Eco

VERSION (PLAN BY): PH (B-A4)

CLIENT: CENTENNIAL
JOB REF: 123063

### 5.3.9 Coxs River, Angus Place Management Site

This site comprises eleven lots, Lot1 DP751636, Lot15 DP751636, Lot2 DP751636, Lot24 DP751636, Lot28 DP751636, Lot4 DP751636, Lot6 DP751636, Lot23 DP827626, Lot26 DP827626, Lot358 DP44086 and Lot700 DP1067040. This site has been considered due to its position along the Coxs River. These lots are part of the Angus Place major Extension Project Application Area. Their inclusion is primarily focused on enhancement on the Coxs River catchment as part of the Coxs River Catchment Restoration Program.

These sites are almost entirely cleared of a canopy, mid storey and shrub layer. however, the ground cover is dominated by native grasses and is likely be commensurate with the Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (derived native grasslands) EEC.

**Table 26 Vegetation within the Coxs River, Angus Place Management Site**

| Vegetation Community | Total |
|---|---|
| MU15 Tableland Hollows Black Gum - Black Sally Open Forest | **5.98** |
| Derived grasslands of MU 15 Tableland Hollows Black Gum - Black Sally Open Forest | **56.29** |
| **Total** | **62.27** |

#### 5.3.9.2 Proposed Protection and Management

This area is proposed to be protected and managed Angus Place Colliery. It is to be recognised by Angus Place Colliery as an area of biodiversity significance and managed as such in their operations. Key enhancement and management objectives of the site are:

- removal of grazing pressures;
- riparian areas restoration along Coxs River;
- native species planting within derived native grasslands, including:
  - species associated with Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland EEC,
  - *Eucalyptus aggregata;*
  - *Themeda triandra* (habitat for *Thesium australe*); and
  - *Bursaria spinosa* subsp. *lasiophylla* (habitat for the Bathurst Copper Butterfly)
- weed removal / control; and
- Rabbit control.

**Legend**

▭ Lot Boundary

— Watercourse

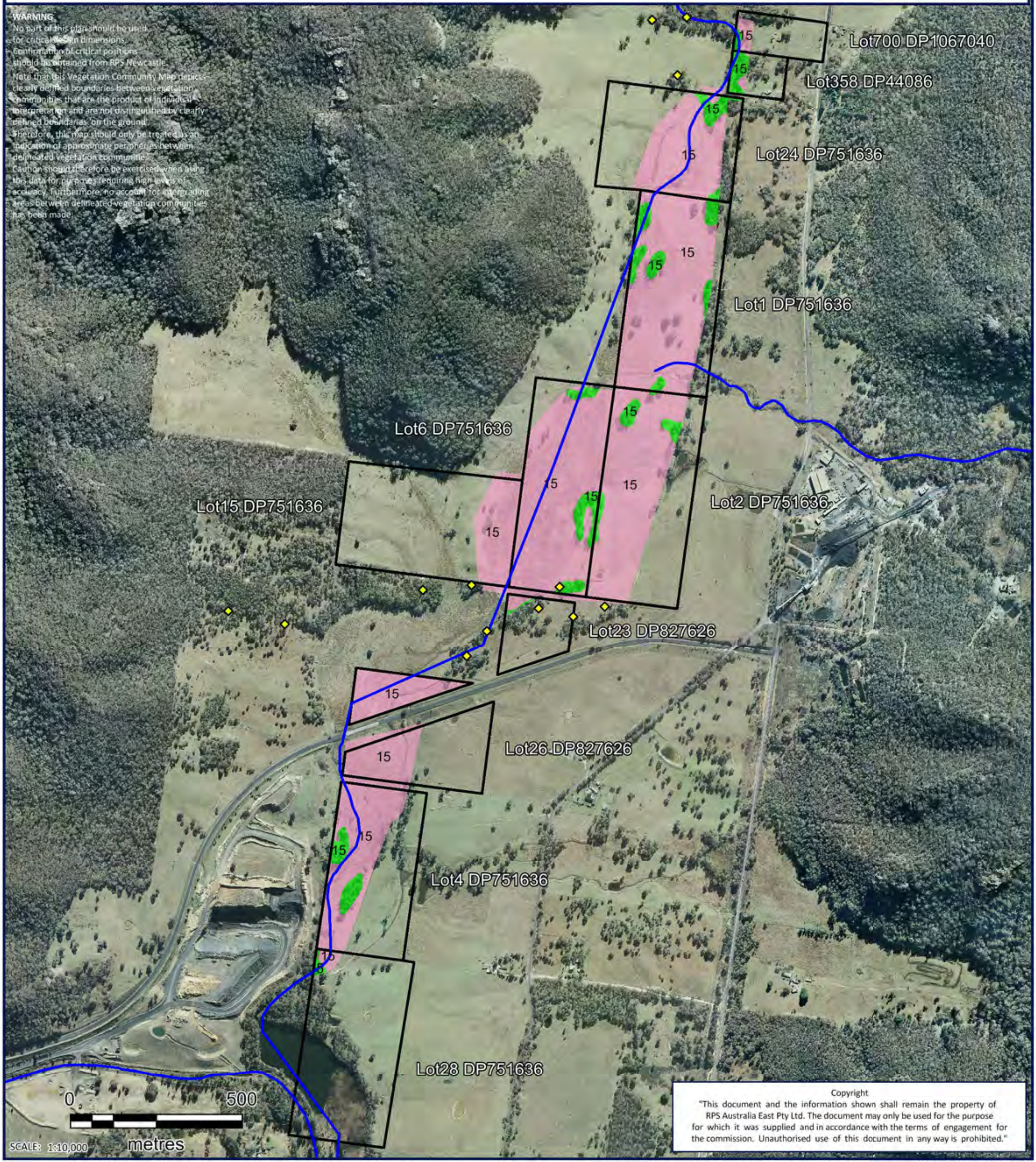
*Threatened Species*
(locations represent several individuals)

◆ *Eucalyptus aggregata*

*Vegetation Communities*

🟩 15 Tableland Hollows Black Gum - Black Sally Open Forest (EEC)

🟪 Derived grasslands of 15 Tableland Hollows Black Gum - Black Sally Open Forest (EEC)



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TITLE: FIGURE 11 COXS RIVER, ANGUS PLACE REHABILITATION SITE BIODIVERSITY VALUES
LOCATION: LITHGOW, NSW
DATUM: DATUM
PROJECTION: MGA ZONE56
DATE: 29/09/2014
PURPOSE: REGIONAL BIODIVERSITY STRATEGY
LAYOUT REF: J:\JOBS\Centennial\All Jobs\123063 OEH Submissions - Fassifern\10 - Drafting\MapInfo Workspaces\Eco
VERSION (PLAN BY): PH (B-A4)
CLIENT: CENTENNIAL
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## 5.4 Conservation Outcomes Summary

### 5.4.1 Vegetation

The combined offsets area of all sites is provided in **Table 27** below. The sites covered by this Regional Strategy propose a total conservation area of 418.66 ha of woodland or naturally swampy vegetation and an additional 400.55 ha of cleared lands. Whilst being in a cleared, low condition, the cleared lands are recognised by this Regional Strategy as having some remaining biodiversity value. Cleared lands have therefore been described as 'derived grasslands' of the parent vegetation communities with their biodiversity value assessed accordingly. The conservation sites achieve key biodiversity outcomes, including strategically linking landscapes and improvements of water quality within the Coxs River catchment.

The conservation outcomes for listed EECs include the preservation of 3.66 ha of Montane Peatlands and Swamps and 70.79 ha Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland. Preservation of 145.25 ha of derived grasslands of the Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland is also covered in this Strategy. Both of these EECs are listed under the TSC Act.

The proposed provision of the Airly offset site will also provide biodiversity gains for Box-Gum Woodland, which is listed as an EEC under the TSC Act and a CEEC under the EPBC Act. A total of 38.58 ha wooded Box-Gum Woodland and 67.53 ha of derived grasslands will be protected and enhanced as a result of the Airly offset site.

Substantial conservation is also proposed for dry sclerophylly woodland communities, predominately MU21 Capertee - Wolgan Slopes Red Box - Grey Gum - Stringybark Grassy Open Forest, MU37 Coxs Permian Red Stringybark - Brittle Gum Woodland. Combined MU38 Capertee Grey Gum - Narrow-leaved Stringybark - Scribbly Gum - Callitris - Ironbark Shrubby Open Forest and MU42 Capertee Hills White Box - Tumbledown Redgum - Ironbark - Callitris Shrubby Woodland. These communities make up 276.81 ha (66%) of the total proposed offset of existing wooded habitats.

**Table 27 Centennial Western Offsets Sites - Vegetation Conservation Summary**

| Map Unit | Community Name | EEC Equivalent | Airly | Lidsdale Northern | Lidsdale Southern | Brays lane | Lamberts Gully | Wangcol Creek Neubeck | Coxs River Angus Place | Commonwealth Colliery | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MU8 | Newnes Sheltered Peppermint - Brown Barrel Shrubby Forest | | | 2.68 | | | | | | | 2.68 |
| MU11 | Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | | 1.14 | 2.95 | | 8.29 | 0.99 | | 1.05 | 14.42 |
| MU11 (DNG) | Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest (cleared) | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | | 12.08 | | | | | | | 12.08 |
| MU13 | Tableland Gully Ribbon Gum - Blackwood - Apple Box Forest | | 6.91 | | | | | | | | 6.91 |
| MU15 | Tableland Hollows Black Gum - Black Sally Open Forest | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | | 18.94 | 3.4 | 25.71 | 0.44 | 0.26 | 5.98 | 1.64 | 56.37 |
| MU15 (DNG) | Tableland Hollows Black Gum - Black Sally Open Forest (cleared) | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | | 27.45 | 25.17 | | | 12.76 | 56.29 | 11.5 | 133.17 |
| MU20 | Capertee Rough-barked Apple - Redgum - Yellow Box Grassy Woodlands (cleared) | Box-Gum Woodland (TSC Act and EPBC Act) | 38.58 | | | | | | | | 38.58 |
| MU20 (DNG) | Capertee Rough-barked Apple - Redgum - Yellow Box Grassy Woodlands (cleared) | Box-Gum Woodland (TSC Act and EPBC Act) | 67.53 | | | | | | | | 67.53 |
| MU21 | Capertee - Wolgan Slopes Red Box - Grey Gum - Stringybark Grassy Open Forest | | 22.61 | | | | | | | | 22.61 |
| MU28 | Sandstone Plateau And Ridge Scribbly Gum - Silver-top Ash Shrubby Woodland | | | 1.57 | | | | | | | 1.57 |
| MU29 | Sandstone Slopes Sydney Peppermint Shrubby Forest | | | 2.51 | | | | | | | 2.51 |
| MU30 | Exposed Blue Mountains Sydney Peppermint - Silver-top Ash Shrubby Woodland | | | 3.74 | | | | | | | 3.74 |
| MU33 | Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest | | | | | | | 0.78 | | 1.82 | 2.60 |
| MU33 (DNG) | Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest (cleared) | | | | | | | 3.91 | | | 3.91 |
| MU35 | Tableland Gully Mountain Gum - Broad-leaved Peppermint Grassy Forest | | | 0.21 | | | | 0 | | | 0.21 |
| MU37 | Coxs Permian Red Stringybark - Brittle Gum Woodland | | | 24.24 | 16.11 | | | 2.44 | | | 42.79 |
| MU37 (DNG) | Coxs Permian Red Stringybark - Brittle Gum Woodland (cleared) | | | 2.86 | 4.39 | | | | | | 7.25 |
| MU38 | Capertee Grey Gum - Narrow-leaved Stringybark - Scribbly Gum - Callitris - Ironbark Shrubby Open Forest | | 178.72 | | | | | | | | 178.72 |
| MU38 (DNG) | Capertee Grey Gum - Narrow-leaved Stringybark - Scribbly Gum - Callitris - Ironbark Shrubby Open Forest | | 176.61 | | | | | | | | 176.61 |
| MU42 | Capertee Hills White Box - Tumbledown Redgum - Ironbark - Callitris Shrubby Woodland | | 32.69 | | | | | | | | 32.69 |
| MU43 | Pagoda Rock Sparse Shrubland | | | 0.24 | | | | | | | 0.24 |
| MU53 | Mountain Hollow Grassy Fen | Montane Peatlands and Swamps (TSC Act) | | 1.46 | | | | 2.2 | | | 3.66 |
| MU54 | Capertee - Wolgan Riparian Rough-barked Apple - River Oak Open Forest | | 8.36 | | | | | | | | 8.36 |
| Total | | | 532.01 | 99.12 | 52.02 | 25.71 | 8.73 | 23.34 | 62.27 | 16.01 | 819.21 |

### 5.4.2 Threatened Flora

In order to retain consistency with the offset methodologies of the NSW Biodiversity Offsets Policy for Major Projects and EPBC Act Environmental Offsets Policy, conservation to threatened flora has been assessed as the number of recorded individuals. A summary of the recorded threatened flora within proposed conservation areas is provided in **Table 28**. It is noted that surveys for threatened flora are far less comprehensive than that undertaken within the individual Project areas.

**Table 28 Centennial Western projects - Threatened Flora Conservation Summary**

| Species | Airly | Wolgan Road North | Wolgan Road South | Brays lane | Lamberts Gully | Wangcol Creek | Coxs River, Angus Place | Commonwealth Colliery | Total |
|---|---|---|---|---|---|---|---|---|---|
| Eucalyptus aggregata (Black Gum) (V) | | 266 | 108 | 10 | 22 | 37 | | | 443 |
| *Eucalyptus cannonii* (Cannon's Stringybark) (V) | 6 | | | | | | | | 6 |
| *Thesium australe* (Austral Toadflax) (V, V*) | | | | | | | | | 0 |
| *Persoonia hindii* (E) | | | | | | | | | 0 |
| *Derwentia blakelyi* (V) | | 94 | | | | | | | 94 |

**Key:**

| | | | |
|---|---|---|---|
| V | Vulnerable Species under the TSC Act | V* | Vulnerable Species under the EPBC Act |
| E | Endangered Species under the TSC Act | | |

### 5.4.3 Threatened Fauna

In order to retain consistency with the offset methodologies of the NSW Biodiversity Offsets Policy for Major Projects and EPBC Act Environmental Offsets Policy, impacts to threatened fauna has been assessed as the area of habitat in hectares to be preserved.

Suitable habitats for fauna species often cross several of the vegetation communities that. As later detailed in **Section 5.6**, these vegetation communities have been classified based on the 'best fit' vegetation type listed in the BioBanking Vegetation Types Database (OEH 2009). Parameters used to choose the 'best fit' Vegetation Type included overstorey and understorey floristics, soil landscape, location and topographic position. The BioBanking Vegetation Types, and by extension the vegetation communities, can be broadly categorised by 'Vegetation Formation'. This broader formation class category has been used in **Table 29** to assess the potential gains to threatened fauna habitat.

**Table 29 Centennial Western projects - Fauna Habitat Preservation Summary**

| Formation | Equivalent Map Unit | Fauna Habitat Suitability | Area (ha) |
|---|---|---|---|
| Dry Sclerophyll Forests (Shrubby subformation) | MU2, MU8, MU21, MU26, MU26a, MU28, MU29, MU30, MU32, MU37, MU38, MU42 | Woodland Birds, Arboreal Mammals, Forest Owls, microchiropteran bats, Giant Burrowing Frog and Stuttering Frog (in proximity to water courses). | 287.32 |
| Forested Wetlands | MU54 | Woodland Birds, Arboreal Mammals, Forest Owls, microchiropteran bats, Giant Burrowing Frog and Stuttering Frog (in proximity to water courses). | 8.36 |
| Freshwater Wetlands | MU53 | Amphibians | 3.66 |
| Grassy Woodlands | MU11, MU13, MU15, MU20, MU33 | Woodland Birds, Arboreal Mammals, Forest Owls, microchiropteran bats. | 118.88 |
| Heathlands | MU43, MU44, MU45 | Eastern Pygmy Possum, Burrowing Frog and Stuttering Frog (in proximity to water courses). | 0.24 |

| Formation | Equivalent Map Unit | Fauna Habitat Suitability | Area (ha) |
|---|---|---|---|
| Wet Sclerophyll Forests (Grassy subformation) | MU3, MU14, MU35 | Woodland Birds, Arboreal Mammals, Forest Owls, microchiropteran bats, Giant Burrowing Frog and Stuttering Frog (in proximity to water courses). | 0.21 |
| Derived Grasslands (combined) | MU11, MU15, MU20, MU33, MU37 and MU38 | Marginal habitat for a range of fauna species. | 418.66 |

## 5.5 Conservation Balance Calculations

This Regional Strategy has investigated several different variables to assess the suitability of the compensatory habitat initiatives being proposed. This includes standard area comparisons of vegetation, habitats and number of species lost and gained. The Strategy has also reviewed the adequacy of compensatory measures against the BioBank Assessment Methodology (BBAM) (TSC Act) and the Offsets Assessment Guide (EPBC Act).

### 5.5.1 Vegetation Communities

A comparative analysis of the vegetation losses in **Table 13** and gains in **Table 27** has been undertaken to assess the appropriateness of the conservation sites in terms of area. **Table 30** shows that an overall 3.4:1 conservation outcome is proposed by this strategy. Notably, positive gains in offsets are proposed for all EECs .

**Table 30 Development and Offsets Balance Analysis for Vegetation Communities**

| Map Unit | Community Name | EEC Equivalent | Total-devt (ha) | Total-cons (ha) | Balance | Ratio |
|---|---|---|---|---|---|---|
| MU07 | Newnes Plateau Narrow-leaved Peppermint - Mountain Gum - Brown Stringybark Layered Forest | | 13.58 | 0 | -13.58 | Not within offset area |
| MU8 | Newnes Sheltered Peppermint - Brown Barrel Shrubby Forest | | 0.73 | 2.68 | 1.95 | 3.7:1 |
| MU11 | Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | 12.91 | 14.42 | 1.51 | 1.1:1 |
| MU13 | Tableland Gully Ribbon Gum - Blackwood - Apple Box Forest | | 0 | 6.91 | 6.91 | Not within development area |
| MU14 | Tableland Mountain Gum - Snow Gum - Daviesia Montane Open Forest | | 1.03 | 0 | -1.03 | Not within offset area |
| MU15 | Tableland Hollows Black Gum - Black Sally Open Forest | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | 4.23 | 56.37 | 52.14 | 13:3:1 |
| MU20 | Capertee Rough-barked Apple - Redgum - Yellow Box Grassy Woodlands (cleared) | Box-Gum Woodland (TSC Act and EPBC Act) | 0 | 38.58 | 38.58 | Not within development area |
| MU21 | Capertee - Wolgan Slopes Red Box - Grey Gum - Stringybark Grassy Open Forest | | 0 | 22.61 | 22.61 | Not within development area |
| MU26 | Newnes Plateau Narrow-leaved Peppermint - Silver-top Ash Layered Open Forest | | 17.74 | 0 | -17.74 | Not within offset area |
| MU26a | Newnes Plateau Gum Hollows varient: Brittle Gum - Mountain Gum, Scribbly Gum - Snow Gum Shrubby Open Forest | | 5.84 | 0 | -5.84 | Not within offset area |
| MU28 | Sandstone Plateau And Ridge Scribbly Gum - Silver-top Ash Shrubby Woodland | | 9.54 | 1.57 | -7.97 | 0.2:1 |
| MU29 | Sandstone Slopes Sydney Peppermint Shrubby Forest | | 1.93 | 2.51 | 0.58 | 1.3:1 |
| MU30 | Exposed Blue Mountains Sydney Peppermint - Silver-top Ash Shrubby Woodland | | 6.88 | 3.74 | -3.14 | 0.5:1 |

| Map Unit | Community Name | EEC Equivalent | Total-devt (ha) | Total-cons (ha) | Balance | Ratio |
|---|---|---|---|---|---|---|
| MU32 | Tableland Hills Scribbly Gum - Narrow-leaved Stringybark Shrubby Open Forest | | 2.59 | 0 | -2.59 | Not within offset area |
| MU33 | Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest | | 15 | 2.60 | -12.40 | 0.2:1 |
| MU35 | Tableland Gully Mountain Gum - Broad-leaved Peppermint Grassy Forest | | 9.11 | 0.21 | -8.90 | 0:1 |
| MU37 | Coxs Permian Red Stringybark - Brittle Gum Woodland | | 49.49 | 12.79 | -6.70 | 0.9:1 |
| MU38 | Capertee Grey Gum - Narrow-leaved Stringybark - Scribbly Gum - Callitris - Ironbark Shrubby Open Forest (clea | | 0 | 178.72 | 178.72 | Not within development area |
| MU42 | Capertee Hills White Box - Tumbledown Redgum - Ironbark - Callitris Shrubby Woodland | | 0 | 32.69 | 32.69 | Not within development area |
| MU43 | Pagoda Rock Sparse Shrubland | | 0 | 0.24 | 0.24 | Not within development area |
| MU44 | Sandstone Plateaux Tea Tree - Dwarf Sheoak - Banksia Rocky Heath | | 0.07 | 0 | -0.07 | Not within offset area |
| MU45 | Newnes Plateau Tea Tree - Banksia - Mallee Heath | | 0.16 | 0 | -0.16 | Not within offset area |
| MU53 | Mountain Hollow Grassy Fen | Montane Peatlands and Swamps (TSC Act) | 0.19 | 3.66 | 3.47 | 19:3:1 |
| MU54 | Capertee - Wolgan Riparian Rough-barked Apple - River Oak Open Forest | | 0 | 8.36 | 8.36 | Not within development area |
| MU11 (DNG) | Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest (cleared) | | 11.29 | 12.08 | 0.79 | 1.1:1 |
| MU37 (DNG) | Coxs Permian Red Stringybark - Brittle Gum Woodland (cleared) | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | 30.01 | 7.25 | -22.76 | 0.2:1 |
| MU15 (DNG) | Tableland Hollows Black Gum - Black Sally Open Forest (cleared) | | 17.12 | 133.17 | 116.05 | 7.8:1 |
| MU33 (DNG) | Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest (cleared) | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | 29.17 | 3.91 | -25.26 | 0.1:1 |
| MU20 (DNG) | Capertee Rough-barked Apple - Redgum - Yellow Box Grassy Woodlands (cleared) | | 0 | 67.53 | 67.53 | Not within development area |
| MU38 (DNG) | Capertee Grey Gum - Narrow-leaved Stringybark - Scribbly Gum - Callitris - Ironbark Shrubby Open Forest | Box-Gum Woodland (TSC Act and EPBC Act) | 0 | 176.61 | 176.61 | Not within development area |
| **Total** | | | **238.61** | **819.21** | **580.60** | **3.4:1** |

## 5.5.2 Habitats and Species

The broader formation class category has been used in **Table 31** to assess the potential gains to threatened fauna habitat. This shows that most broad vegetation formations are being compensated for by this Strategy. The exception to this is the Wet Sclerophyll Forests (Shrubby subformation). However, the habitat this formation provides to locally occurring fauna species crosses other habitats that are being offset at a ratio greater than the impact.

**Table 31 Centennial Western projects - Fauna Habitat Preservation Summary**

| Formation | Equivalent Map Unit | Fauna Habitat Suitability | Area-Devt (ha) | Area-Cons (ha) | Balance (ha) | Ratio |
|---|---|---|---|---|---|---|
| Dry Sclerophyll Forests (Shrubby subformation) | MU2, MU8, MU21, MU26, MU26a, MU28, MU29, MU30, MU32, MU37, MU38, MU42 | Woodland Birds, Arboreal Mammals, Forest Owls, microchiropteran bats, Giant Burrowing Frog and Stuttering Frog (in proximity to water courses). | 94.74 | 287.32 | 192.57 | 3.03:1 |
| Forested Wetlands | MU54 | Woodland Birds, Arboreal Mammals, Forest Owls, microchiropteran bats, Giant Burrowing Frog and Stuttering Frog (in proximity to water courses). | | 8.36 | 8.36 | No habitat within devt area |

| Formation | Equivalent Map Unit | Fauna Habitat Suitability | Area-Devt (ha) | Area-Cons (ha) | Balance (ha) | Ratio |
|---|---|---|---|---|---|---|
| Freshwater Wetlands | MU53 | Amphibians | 0.19 | 3.66 | 3.47 | 19.26:1 |
| Grassy Woodlands | MU11, MU13, MU15, MU20, MU33 | Woodland Birds, Arboreal Mammals, Forest Owls, microchiropteran bats. | 32.14 | 118.88 | 86.74 | 3.7:1 |
| Heathlands | MU43, MU44, MU45 | Eastern Pygmy Possum, Burrowing Frog and Stuttering Frog (in proximity to water courses). | 0.23 | 0.24 | 0.01 | 1.04:1 |
| Wet Sclerophyll Forests (Grassy subformation) | MU3, MU14, MU35 | Woodland Birds, Arboreal Mammals, Forest Owls, microchiropteran bats, Giant Burrowing Frog and Stuttering Frog (in proximity to water courses). | 10.14 | 0.21 | -9.39 | 0.02:1 |
| Wet Sclerophyll Forests (Shrubby subformation) | MU7 | Woodland Birds, Arboreal Mammals, Forest Owls, microchiropteran bats, Giant Burrowing Frog and Stuttering Frog (in proximity to water courses). | 13.58 | | -13.58 | No habitat within cons area |
| Derived Grasslands (combined) | MU11, MU15, MU20, MU33, MU37 and MU38 | Marginal habitat for a range of fauna species. | 87.59 | 400.55 | 312.96 | 4.57:1 |

## 5.6 Credit Calculations

The BioBank Assessment Methodology (BBAM) was applied to assess the offset requirements resulting from the proposal and the offset value of the proposed conservation sites. The online BioBank Credit Calculator (BBCC) was run for all sites.

A desktop assessment was utilised with the lowest baseline values used for the vegetation communities mapped within the development areas to estimate the likely Ecosystem and Species Credits that would be sought by the Office of Environment and Heritage. This same methodology was applied to the offset areas to determine the Ecosystem and Species Credits generated by the Offset for the Neubeck Coal Project the assessment complied with the BBAM. Fieldwork and calculations were conducted by a certified BioBank Accredited Assessor with all field data used for the BBCC calculations.

For vegetation figures within the conservation area there were some areas of field validated vegetation mapping, where this was not available the extents of the communities relied on mapping by DEC (2006). For species credits, only known records were used in the calculator and where reliable field data was not available the precautionary approach for presence of habitat and likelihood of species occurrence was applied.

In calculating the ecosystem credits for each vegetation community, vegetation communities were classified based on the ‘best fit’ vegetation type listed in the BioBanking Vegetation Types Database (OEH 2009). Parameters used to choose the ‘best fit’ Vegetation Type included overstorey and understorey floristics, soil landscape, location and topographic position. The conversion of vegetation communities to Biometric vegetation Types is provided in **Table 32**.

**Table 32 Western Blue Mountains to BioBank Vegetation Mapping Unit Conversion**

| Western Blue Mountains Vegetation Mapping Units | WBM Vegetation Community Description | Formation | BioBank Vegetation Units | BioBank Vegetation Units Description |
|---|---|---|---|---|
| MU 7 | Newnes Plateau Narrow-Leaved Peppermint – Mountain Gum – Brown Stringybark Layered Forest | Wet Sclerophyll Forests (Shrubby subformation) | HN558 | Narrow-leaved Peppermint - Mountain Gum - Brown Barrel moist open forest on high altitude ranges, northern South Eastern Highlands |
| MU 8 | Newnes Sheltered Peppermint – Brown Barrel Shrubby Forest | Dry Sclerophyll Forests (Shrubby subformation) | HN599 (originally HN558) | Sydney Peppermint - Narrow-leaved Peppermint shrubby open forest on sheltered slopes of the Newnes Plateau, Sydney Basin (Narrow-leaved Peppermint - Mountain Gum - |

| Western Blue Mountains Vegetation Mapping Units | WBM Vegetation Community Description | Formation | BioBank Vegetation Units | BioBank Vegetation Units Description |
|---|---|---|---|---|
| | | | | Brown Barrel moist open forest on high altitude ranges, northern South Eastern Highlands) |
| MU11 | Tableland Gully Snow Gum - Ribbon Gum Montane Grassy Forest | Grassy Woodlands | HN572 | Ribbon Gum - Snow Gum grassy forest on damp flats, eastern South Eastern Highlands |
| MU13 | Tableland Gully Ribbon Gum - Blackwood - Apple Box Forest | Grassy Woodlands | HN501 | Apple Box - Broad-leaved Peppermint dry open forest of the Abercrombie-Tarlo area, South Eastern Highlands |
| MU14 | Tableland Mountain Gum - Snow Gum - Daviesia Montane Open Forest | Wet Sclerophyll Forests (Grassy subformation) | HN590 | Snow Gum - Mountain Gum tussock grass-herb forest of the South Eastern Highlands |
| MU15 | Tableland Hollows Black Gum - Black Sally Open Forest | Grassy Woodlands | HN504 | Black Gum grassy woodland of damp flats and drainage lines of the eastern Southern Tablelands, South Eastern Highlands |
| MU20 | Capertee Rough-barked Apple - Redgum - Yellow Box Grassy Woodlands (EEC) | Grassy Woodlands | HN614 | Yellow Box - Blakely's Red Gum grassy woodland on the tablelands, South Eastern Highlands |
| MU21 | Capertee - Wolgan Slopes Red Box - Grey Gum - Stringybark Grassy Open Forest | Dry Sclerophyll Forests (Shrubby subformation) | HN534 | Grey Gum - Narrow-leaved Stringybark - Inland Scribbly Gum shrubby open forest of the western Capertee Valley, Sydney Basin |
| MU 26 | Newnes Plateau Narrow-Leaved Peppermint – Silvertop Ash Layered Open Forest | Dry Sclerophyll Forests (Shrubby subformation) | HN600 | Sydney Peppermint - Silvertop Ash heathy open forest on sandstone ridges of the upper Blue Mountains, Sydney Basin |
| MU 26a | Newnes Plateau Narrow-Leaved Peppermint – Silvertop Ash Layered Open Forest (Gentle Depressions) | Dry Sclerophyll Forests (Shrubby subformation) | HN600 | Sydney Peppermint - Silvertop Ash heathy open forest on sandstone ridges of the upper Blue Mountains, Sydney Basin |
| MU 28 | Sandstone Plateau and Ridge Scribbly Gum – Silvertop Ash Shrubby Woodland | Dry Sclerophyll Forests (Shrubby subformation) | HN600 (originally HN599) | Sydney Peppermint - Silvertop Ash heathy open forest on sandstone ridges of the upper Blue Mountains, Sydney Basin (Sydney Peppermint - Narrow-leaved Peppermint shrubby open forest on sheltered slopes of the Newnes Plateau, Sydney Basin) |
| MU 29 | Sandstone Slopes Sydney Peppermint Shrubby Forest | Dry Sclerophyll Forests (Shrubby subformation) | HN600 (originally HN599) | Sydney Peppermint - Silvertop Ash heathy open forest on sandstone ridges of the upper Blue Mountains, Sydney Basin (Sydney Peppermint - Narrow-leaved Peppermint shrubby open forest on sheltered slopes of the Newnes Plateau, Sydney Basin) |
| MU 30 | Exposed Blue Mountains Sydney Peppermint - Silver-top Ash Shrubby Woodland | Dry Sclerophyll Forests (Shrubby subformation) | HN600 | Sydney Peppermint - Silvertop Ash heathy open forest on sandstone ridges of the upper Blue Mountains, Sydney Basin |
| MU32 | Tableland Hills Scribbly Gum - Narrow-leaved Stringybark | Dry Sclerophyll Forests | HN570 | Red Stringybark - Brittle Gum - Inland Scribbly Gum dry open |

| Western Blue Mountains Vegetation Mapping Units | WBM Vegetation Community Description | Formation | BioBank Vegetation Units | BioBank Vegetation Units Description |
|---|---|---|---|---|
| | Shrubby Open Forest | (Shrubby subformation) | | forest of the tablelands, South Eastern Highlands |
| MU33 | Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Open Forest | Grassy Woodlands | HN514 | Broad-leaved Peppermint - Red Stringybark grassy open forest on undulating hills, South Eastern Highlands |
| MU35 | Tableland Gully Mountain Gum - Broad-leaved Peppermint Grassy Forest | Wet Sclerophyll Forests (Grassy subformation) | HN590 | Snow Gum - Mountain Gum tussock grass-herb forest of the South Eastern Highlands |
| MU37 | Coxs Permian Red Stringybark - Brittle Gum Woodland | Dry Sclerophyll Forests (Shrubby subformation) | HN570 | Red Stringybark - Brittle Gum - Inland Scribbly Gum dry open forest of the tablelands, South Eastern Highland |
| MU38 | Capertee Grey Gum - Narrow-leaved Stringybark - Scribbly Gum - Callitris - Ironbark Shrubby Open Forest | Dry Sclerophyll Forests (Shrubby subformation) | HN534 | Grey Gum - Narrow-leaved Stringybark - Inland Scribbly Gum shrubby open forest of the western Capertee Valley, Sydney Basin |
| MU42 | Capertee Hills White Box - Tumbledown Redgum - Ironbark - Callitris Shrubby Woodland | Dry Sclerophyll Forests (Shrubby subformation) | HN544 | Inland Scribbly Gum - Grey Gum - Narrow-leaved Ironbark shrubby open forest on hills of western Capertee Valley, Sydney Basin |
| MU 43 | Pagoda Rock Sparse Shrubland | Heathlands | HN508 | |
| MU 44 | Sandstone Plateaux Tee Tree – Dwarf Sheoak – *Banksia* Rocky Heath | Heathlands | HN508 | Blue Mountains Mallee Ash - Dwarf Casuarina heath of the upper Blue Mountains, Sydney Basin |
| MU45 | Newnes Plateau Tea Tree - Banksia - Mallee Heath | Heathlands | HN508 | Blue Mountains Mallee Ash - Dwarf Casuarina heath of the upper Blue Mountains, Sydney Basin |
| MU53 | Mountain Hollow Grassy Fen | Freshwater Wetlands | HN602 | Tableland swamp meadow on impeded drainage sites of the western Sydney Basin and South Eastern Highlands |
| MU 54 | Capertee – Wolgan Riparian Rough-Barked Apple – River Oak Open Forest | Forested Wetlands | HN574 | River Oak open forest of major streams, Sydney Basin and South East Corner |

## 5.7 BioBanking Assessment Methodology Credit Calculations

### 5.7.1 Ecosystem Credit Balance

**Table 33** summarises the Ecosystem Credits required from the development sites. **Table 34** summarises the Ecosystem Credits generated by the conservation sites. **Table 35** calculated the balance of each Biometric vegetation type of this regional strategy.

With reference to the BBAM (2008) and BBAM (2014), an ecosystem credit created from a biobank site is a matching ecosystem credit to credits generated from a development site if it shares the same vegetation type and occurs within the same CMA subregion/IBRA subregion.

Not all development sites and conservation sites occur within the same CMA or IBRA subregions. However, as shown in **Table 35** below, several vegetation types have been matched. Additional overall gains occur across specific vegetation formations. Whilst the matching of credits does not strictly follow the BBAM methodology, this omission should be considered in line with the overall biodiversity gains of this strategy. It includes a substantially greater benefit to all EECs being impacted upon by the developments. An additional EEC/CEEC (Box-Gum Woodland) is being provided through the provision of the Airly offset site. Additionally, the offsets and conservation outcomes have been strategically chosen to provide conservation and biodiversity gains to areas that have been identified as important by relevant government agencies.

### 5.7.2 Species Credit Balance

**Table 36** summarises the Species Credits required from the development sites. **Table 37** summarises the Species Credits generated by the conservation sites. **Table 38** calculated the balance of each Species Credit required and generated. Species included are any Species Credit Species that were recorded by the Projects. Conservation outcomes for fauna species have assumed suitable habitat in accordance with **Table 31**. Conservation outcomes for flora species are based on recorded individuals only.

Whilst a credit deficit is shown in applying the BBAM, the following limitations are noted:

- The calculations have only incorporated the losses and gains resultant from removing and conserving existing wooded habitats. The inclusion of cleared areas proposed for replanting would further close the gap on the existing species credit deficits.
- The calculations have only incorporated the recorded individuals of *Eucalyptus aggregata*, *Eucalyptus cannonii* and *Derwentia blakelyi*. However, many additional individuals of these species are believed to occur within conservation sites, which, if recorded, would further close the gap on the existing species credit deficits.
- The calculations do not include additional future planting of *Eucalyptus aggregata* and *Eucalyptus cannonii*.

Whilst deficits in species credits have been produced by applying the BBAM, abundant potential habitat exists within the offset lands (with the exception of *P. hindii*) and habitat restoration will aim to create and/or increase the populations of these species within the sites. Additionally, this Regional Strategy proposes supplementary measures as part of the offsets package (see **Section 6**).

**Table 33 Cumulative Ecosystem Credits Required by the Developments**

| BioBank Vegetation Units | Formation | BioBank Vegetation Units Description | EEC Equivalent | Angus Place | Springvale | Neubeck | Springvale Bore 8 | Angus Place MOD 2 - Ventilation Facility | Western Coal Services | Clarence Colliery REA | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HN504 | Grassy Woodlands | Black Gum grassy woodland of damp flats and drainage lines of the eastern Southern Tablelands, South Eastern Highlands | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | | | 684 | | | | | 684 |
| HN514 | Grassy Woodlands | Broad-leaved Peppermint - Red Stringybark grassy open forest on undulating hills, South Eastern Highlands | | | | 896 | | | | | 896 |
| HN558 | Wet Sclerophyll Forests (Shrubby subformation) | Narrow-leaved Peppermint - Mountain Gum - Brown Barrel moist open forest on high altitude ranges, northern South Eastern Highlands | | 81 | 112 | | 123 | 695 | | | 1011 |
| HN570 | Dry Sclerophyll Forests (Shrubby subformation) | Red Stringybark - Brittle Gum - Inland Scribbly Gum dry open forest of the tablelands, South Eastern Highland | | | | 2199 | | | 496 | | 2695 |
| HN572 | Grassy Woodlands | Ribbon Gum - Snow Gum grassy forest on damp flats, eastern South Eastern Highlands | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | | | 509 | | | | | 509 |
| HN590 | Wet Sclerophyll Forests (Grassy subformation) | Snow Gum - Mountain Gum tussock grass-herb forest of the South Eastern Highlands | | | | 347 | | 77 | | | 424 |
| HN599 | Dry Sclerophyll Forests (Shrubby subformation) | Sydney Peppermint - Narrow-leaved Peppermint shrubby open forest on sheltered slopes of the Newnes Plateau, Sydney Basin (Narrow-leaved Peppermint - Mountain Gum - Brown Barrel moist open forest on high altitude ranges, northern South Eastern Highlands) | | | 54 | | | | | | 54 |
| HN600 | Dry Sclerophyll Forests (Shrubby subformation) | Sydney Peppermint - Silvertop Ash heathy open forest on sandstone ridges of the upper Blue Mountains, Sydney Basin | | 1210 | 502 | | 124 | 253 | | 126 | 2215 |
| Sub-Total | | | | 1291 | 668 | 4635 | 247 | 1025 | 496 | 126 | 8488 |
| HN563 | | Prickly Tea-tree - sedge wet heath on sandstone plateaux, central and southern Sydney Basin | Newnes Plateau Shrub Swamp (TSC Act) / Temperate Highland Peat Swamps on Sandstone (THPSS) | 810 | 3101 | | | | | | 3911 |
| Total | | | | 2101 | 3769 | 4635 | 247 | 1025 | 496 | 126 | 12399 |

**Table 34 Cumulative Ecosystem Credits Generated by the Conservation Sites**

| BioBank Vegetation Units | Formation | BioBank Vegetation Units Description | EEC Equivalent | Airly Biobank | Lidsdale Northern Lots | Lidsdale Southern Lots | Brays lane | Lamberts Gully | Wangcol Creek Neubeck | Coxs River Angus Place | Commonwealth Colliery | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HN501 | Grassy Woodlands | Apple Box - Broad-leaved Peppermint dry open forest of the Abercrombie-Tarlo area, South Eastern Highlands | | 56 | | | | | | | | 56 |
| HN504 | Grassy Woodlands | Black Gum grassy woodland of damp flats and drainage lines of the eastern Southern Tablelands, South Eastern Highlands | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | | 533 | 350 | 368 | 5 | 147 | 628 | 157 | 2188 |
| HN514 | Grassy Woodlands | Broad-leaved Peppermint - Red Stringybark grassy open forest on undulating hills, South Eastern Highlands | | | | | | | 54 | | 19 | 73 |
| HN534 | Dry Sclerophyll Forests (Shrubby subformation) | Grey Gum - Narrow-leaved Stringybark - Inland Scribbly Gum shrubby open forest of the western Capertee Valley, Sydney Basin | | 4237 | | | | | | | | 4237 |
| HN544 | Dry Sclerophyll Forests (Shrubby subformation) | Inland Scribbly Gum - Grey Gum - Narrow-leaved Ironbark shrubby open forest on hills of western Capertee Valley, Sydney Basin | | 285 | | | | | | | | 285 |
| HN570 | Dry Sclerophyll Forests (Shrubby subformation) | Red Stringybark - Brittle Gum - Inland Scribbly Gum dry open forest of the tablelands, South Eastern Highland | | | 215 | 197 | | | 20 | | | 432 |
| HN572 | Grassy Woodlands | Ribbon Gum - Snow Gum grassy forest on damp flats, eastern South Eastern Highlands | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | | 127 | 29 | | 71 | 9 | | 10 | 246 |
| HN574 | Forested Wetlands | River Oak open forest of major streams, Sydney Basin and South East Corner | | 96 | | | | | | | | 96 |
| HN599 | Dry Sclerophyll Forests (Shrubby subformation) | Sydney Peppermint - Narrow-leaved Peppermint shrubby open forest on sheltered slopes of the Newnes Plateau, Sydney Basin (Narrow-leaved Peppermint - Mountain Gum - Brown Barrel moist open forest on high altitude ranges, northern South Eastern Highlands) | | | 20 | | | | | | | 20 |
| HN600 | Dry Sclerophyll Forests (Shrubby subformation) | Sydney Peppermint - Silvertop Ash heathy open forest on sandstone ridges of the upper Blue Mountains, Sydney Basin | | | 78 | | | | | | | 78 |

| BioBank Vegetation Units | Formation | BioBank Vegetation Units Description | EEC Equivalent | Airly Biobank | Lidsdale Northern Lots | Lidsdale Southern Lots | Brays lane | Lamberts Gully | Wangcol Creek Neubeck | Coxs River Angus Place | Commonwealth Colliery | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HN602 | Freshwater Wetlands | Tableland swamp meadow on impeded drainage sites of the western Sydney Basin and South Eastern Highlands | Montane Peatlands and Swamps (TSC Act) | | 10 | | | | 24 | | | 34 |
| HN614 | Grassy Woodlands | Yellow Box - Blakely's Red Gum grassy woodland on the tablelands, South Eastern Highlands | Box-Gum Woodland (TSC Act and EPBC Act) | 1165 | | | | | | | | 1165 |
| Total | | | | 5839 | 983 | 576 | 368 | 76 | 254 | 628 | 186 | 8910 |

**Table 35 Regional Biodiversity Strategy Ecosystem Credit Balance**

| BioBank Vegetation Units | Formation | BioBank Vegetation Units Description | EEC Equivalent | Total Required (Development) | Total Generated (Conservation) | Balance |
|---|---|---|---|---|---|---|
| HN501 | Grassy Woodlands | Apple Box - Broad-leaved Peppermint dry open forest of the Abercrombie-Tarlo area, South Eastern Highlands | | 0 | 56 | 56 |
| HN504 | Grassy Woodlands | Black Gum grassy woodland of damp flats and drainage lines of the eastern Southern Tablelands, South Eastern Highlands | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | 684 | 2188 | 1504 |
| HN508 | Heathlands | Blue Mountains Mallee Ash - Dwarf Casuarina heath of the upper Blue Mountains, Sydney Basin | | 0 | 0 | 0 |
| HN514 | Grassy Woodlands | Broad-leaved Peppermint - Red Stringybark grassy open forest on undulating hills, South Eastern Highlands | | 896 | 73 | -823 |
| HN534 | Dry Sclerophyll Forests (Shrubby subformation) | Grey Gum - Narrow-leaved Stringybark - Inland Scribbly Gum shrubby open forest of the western Capertee Valley, Sydney Basin | | 0 | 4237 | 4237 |
| HN544 | Dry Sclerophyll Forests (Shrubby subformation) | Inland Scribbly Gum - Grey Gum - Narrow-leaved Ironbark shrubby open forest on hills of western Capertee Valley, Sydney Basin | | 0 | 285 | 285 |
| HN558 | Wet Sclerophyll Forests (Shrubby subformation) | Narrow-leaved Peppermint - Mountain Gum - Brown Barrel moist open forest on high altitude ranges, northern South Eastern Highlands | | 1011 | 0 | -1011 |
| HN570 | Dry Sclerophyll Forests (Shrubby subformation) | Red Stringybark - Brittle Gum - Inland Scribbly Gum dry open forest of the tablelands, South Eastern Highland | | 2695 | 432 | -2263 |
| HN572 | Grassy Woodlands | Ribbon Gum - Snow Gum grassy forest on damp flats, eastern South Eastern Highlands | Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland (TSC Act) | 509 | 246 | -263 |
| HN574 | Forested Wetlands | River Oak open forest of major streams, Sydney Basin and South East Corner | | 0 | 96 | 96 |
| HN590 | Wet Sclerophyll Forests (Grassy subformation) | Snow Gum - Mountain Gum tussock grass-herb forest of the South Eastern Highlands | | 424 | 0 | -424 |
| HN599 | Dry Sclerophyll Forests (Shrubby subformation) | Sydney Peppermint - Narrow-leaved Peppermint shrubby open forest on sheltered slopes of the Newnes Plateau, Sydney Basin (Narrow-leaved Peppermint - Mountain Gum - Brown Barrel moist open forest on high altitude ranges, northern South Eastern Highlands) | | 54 | 20 | -34 |
| HN600 | Dry Sclerophyll Forests (Shrubby subformation) | Sydney Peppermint - Silvertop Ash heathy open forest on sandstone ridges of the upper Blue Mountains, Sydney Basin | | 2215 | 78 | -2137 |
| HN602 | Freshwater Wetlands | Tableland swamp meadow on impeded drainage sites of the western Sydney Basin and South Eastern Highlands | Montane Peatlands and Swamps (TSC Act) | 0 | 34 | 34 |
| HN614 | Grassy Woodlands | Yellow Box - Blakely's Red Gum grassy woodland on the tablelands, South Eastern Highlands | Box-Gum Woodland (TSC Act and EPBC Act) | 0 | 1165 | 1165 |
| Total | | | | 8488 | 8910 | 442 |

**Table 36 Cumulative Species Credits Required by the Developments**

| Species Scientific Name | Common Name | Angus Place | Springvale | Neubeck | Springvale Bore 8 | Angus Place MOD 2 - Ventilation Facility | Western Coal Services | Clarence Colliery REA | Total |
|---|---|---|---|---|---|---|---|---|---|
| *Callocephalon fimbriatum* | Gang-gang Cockatoo | 465 | 229 | 1633 | 79 | 300 | 212 | 82 | 3000 |
| *Chalinolobus dwyeri* | Large-eared Pied Bat | 1788 | 880 | 6280 | 302 | | | 315 | 10720 |
| *Eucalyptus aggregata* | Black Gum | | | 18846 | | | | | 18846 |
| *Eucalyptus cannonii* | Capertee Stringybark | | | 413 | | | | | 413 |
| *Persoonia hindii* | | | | | 4769 | | | | 4769 |
| *Derwentia blakelyi* | | | | | | | | | 0 |
| *Thesium australe* | Austral toadflax | | | 1052 | | | | | 1052 |
| *Falsistrellus tasmaniensis* | Eastern False Pipistrelle | 516 | 254 | 1814 | 87 | 334 | 236 | 91 | 3332 |
| *Miniopterus schreibersii oceanensis* | Eastern Bentwing-bat | 310 | 153 | 1089 | 52 | 200 | 142 | 55 | 2001 |
| *Saccolaimus flaviventris* | Yellow-bellied Sheathtail-bat | 516 | 254 | 1814 | 87 | 334 | 236 | 91 | 3332 |
| *Scoteanax rueppellii* | Greater Broad-nosed Bat | 516 | 254 | 1814 | 87 | 334 | 236 | 91 | 3332 |
| *Mormopterus norfolkensis* | Eastern Freetail-bat | 516 | 254 | 1814 | 87 | 334 | 236 | 91 | 3332 |
| Total | | 4627 | 2278 | 36569 | 5550 | 2991 | 1298 | 816 | 54129 |

**Table 37 Cumulative Species Credits Generated by the Conservation Sites**

| Species Scientific Name | Common Name | Airly Biobank | Lidsdale Northern Lots | Lidsdale Southern Lots | Brays lane | Lamberts Gully | Wangcol Creek Neubeck | Coxs River Angus Place | Commonwealth Colliery | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| *Callocephalon fimbriatum* | Gang-gang Cockatoo | 1726 | 330 | 135 | | 52 | 140 | | 27 | 2410 |
| *Chalinolobus dwyeri* | Large-eared Pied Bat | 1726 | 330 | 135 | | 52 | 140 | | 27 | 2410 |
| *Eucalyptus aggregata* | Black Gum | | 1596 | 648 | 60 | 132 | 122 | | | 2658 |
| *Eucalyptus cannonii* | Capertee Stringybark | 36 | | | | | | | | 36 |
| *Persoonia hindii* | | | | | | | | | | 0 |
| *Derwentia blakelyi* | | | 564 | | | | | | | 564 |
| *Thesium australe* | Austral toadflax | | | | | | | | | 0 |
| *Falsistrellus tasmaniensis* | Eastern False Pipistrelle | 1726 | 330 | 135 | 154 | 52 | 140 | 374 | 27 | 2938 |
| *Miniopterus schreibersii oceanensis* | Eastern Bentwing-bat | 1726 | 330 | 135 | 154 | 52 | 140 | 374 | 27 | 2938 |
| *Saccolaimus flaviventris* | Yellow-bellied Sheathtail-bat | 1726 | 330 | 135 | 154 | 52 | 140 | 374 | 27 | 2938 |
| *Scoteanax rueppellii* | Greater Broad-nosed Bat | 1726 | 330 | 135 | 154 | 52 | 140 | 374 | 27 | 2938 |
| *Mormopterus norfolkensis* | Eastern Freetail-bat | 1726 | 330 | 135 | 154 | 52 | 140 | 374 | 27 | 2938 |
| Total | | 12118 | 4470 | 1593 | 830 | 496 | 1202 | 1870 | 189 | 22768 |

**Table 38 Regional Biodiversity Strategy Species Credit Balance**

| Species Scientific Name | Common Name | Total Required (Development) | Total Generated (Conservation) | Balance |
|---|---|---|---|---|
| *Callocephalon fimbriatum* | Gang-gang Cockatoo | 3000 | 2410 | -590 |
| *Chalinolobus dwyeri* | Large-eared Pied Bat | 10720 | 2410 | -8310 |
| *Eucalyptus aggregata* | Black Gum | 18846 | 2658 | -16188 |
| *Eucalyptus cannonii* | Capertee Stringybark | 413 | 36 | -377 |
| *Persoonia hindii* | | 4769 | 0 | -4769 |
| *Derwentia blakelyi* | | 0 | 564 | 564 |
| *Thesium australe* | Austral toadflax | 1052 | 0 | -1052 |
| *Falsistrellus tasmaniensis* | Eastern False Pipistrelle | 3332 | 2938 | -394 |

| Species Scientific Name | Common Name | Total Required (Development) | Total Generated (Conservation) | Balance |
|---|---|---|---|---|
| *Miniopterus schreibersii oceanensis* | Eastern Bentwing-bat | 2001 | 2938 | 937 |
| *Saccolaimus flaviventris* | Yellow-bellied Sheathtail-bat | 3332 | 2938 | -394 |
| *Scoteanax rueppellii* | Greater Broad-nosed Bat | 3332 | 2938 | -394 |
| *Mormopterus norfolkensis* | Eastern Freetail-bat | 3332 | 2938 | -394 |
| Total | | 54129 | 22768 | -31361 |

## 5.8 EPBC Act Offsets Assessment Guide

An assessment of the offset requirements of threatened species listed under the EPBC Act has been undertaken in accordance with the Offsets Assessments Guide. The species identified for this assessment *Thesium australe*, Regent Honeyeater, Spotted-tailed Quoll, Koala and Large-eared Pied Bat.

It is noted that the Bathurst Copper Butterfly was assessed within the Neubeck project as having potential to be indirectly impacted as a result of the project. As impact to this species cannot be determined without continued monitoring, this has not been included within this assessment. Management of this species is further discussed in **Section 5.12.1**.

### 5.8.1 Austral Toadflax (*Thesium australe*)

*Thesium australe* was recorded within the Neubeck project area with 61 plants proposed to be removed. Currently no direct offset of individuals has been established. Proposed land management of conservation sites, including habitat creation of this species is discussed in **Section 5.12.4**.

### 5.8.2 Fauna Habitat Offsets Under the EPBC Act

Those fauna species assessed (Regent Honeyeater, Spotted-tailed Quoll, Koala and Large-eared Pied Bat) were assessed as having similar habitat losses and gains as a result of the projects and this Strategy. For the purpose of this assessment, habitats of Dry Sclerophyll Forests (Shrubby subformation), Grassy Woodlands, Wet Sclerophyll Forests (Grassy subformation) and Wet Sclerophyll Forests (Shrubby subformation) have been regarded as habitat suitable for these species. Therefore, the total habitat loss is 105.60 ha and the total area of conservation is 406.40 ha. These numbers were entered into the EPBC Act Offsets Assessment calculator for each species. All areas were given a moderate habitat quality score of 6 out of 10. The attributes that were entered into the calculator for the conservation area is provided in **Table 39**.

**Table 39 EPBC Act Offsets Assessment Calculator Attributes for Assessed Fauna Species**

| Attribute | Score |
|---|---|
| Risk-related time horizon (max. 20 years) | 20 years |
| Time Until Ecological Benefit | 5 years |
| Risk of Loss (%) without offset | 50 |
| Risk of Loss (%) with offset | 20 |
| Confidence in results | 90% |
| Start quality | 6 |
| Future quality without offset | 6 |
| Future quality with offset | 6 |
| Confidence in results | 90% |

The results of the calculation varied due to the listing status of each fauna species. The percentage of impact that has been offset as a result of the development for the Vulnerable Koala and Large-eared Pied Bat is calculated at 119.81%. The percentage of impact that has been offset as a result of the development for the Endangered Regent Honeyeater and Spotted-tailed Quoll is calculated at 98.23%. A minimum of 90% direct offset is required by the Offsets Assessments Guide.

It is noted that this calculation has not included a predicted gain in site value in order to demonstrate that the proposed existing wooded conservation areas, in their existing condition, provide adequate conservation areas for these species. These areas are however proposed to be managed to improve their biodiversity values. The areas of cleared lands, whilst currently providing marginal habitats for these species, will also be improved over time.

### 5.8.3 Box-Gum Woodland

This strategy provides additional biodiversity gains of MNES through the conservation of 38.58 ha of White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland (Critically Endangered under the EPBC Act) within the Airly Offset Site. An additional 67.53 ha of the derived grasslands component of this community has also been mapped across this site. Conservation, improvements and management of this community will be a significant component of a future management plan of this site.

## 5.9 Securing the Offset Land

Conservation areas are proposed to be protected by two specific mechanisms, namely a positive (or restrictive) covenant, or approval conditions.

### 5.9.1 Protective Covenants

The conservation lands that will be protected through a positive (or restrictive) covenant is the Airly Offset Site and the Wolgan Road Northern Offset Site. Offset land will be secured using a positive (or restrictive) covenant, imposed under s88B of the Conveyancing Act. This security provides in-perpetuity conservation and achieves the requirements for security under both the Offsets Policy and EPBC Policy. The title will be burdened by a requirement to:

a) Conserve and manage all flora and fauna within the Relevant Area (as delineated by a Plan) in accordance with the terms of the Offset Management Plan which forms part of the documentation supporting a development application and any subsequent revisions; and

b) Permanently protect the land in the Relevant Area and exclude open cut mining activities and land clearing other than those associated with Permitted Uses (as defined).

This security will:

- meet biodiversity conservation outcomes;
- includes a specific plan of management for each lot;
- allocate through this plan, adequate resources to achieve plan based completion criteria;
- bind the current and future land owners in perpetuity
- cannot be altered without approval of the relevant minister, which will be Minister for Planning.

### 5.9.2 Approval Conditions

As part of the Springvale Coal Services project conditions of consent included rehabilitation of Lamberts Gully. The Lamberts Gully rehabilitation site has therefore been included in this Strategy.

Similar to Springvale Coal Services, the Neubeck Project EIS commits to the rehabilitation of Wangcol Creek. Rehabilitation of additional conservation areas as part of the Coxs River Restoration Program (Wolgan Road Southern, Commonwealth Colliery, Brays Lane and Coxs River, Angus Place) are also proposed. In proposing these commitments in this Strategy, Centennial is committing to undertaking these proposed conservation activities, which will be legally required as part of any consent granted for these major projects.

Similar to the protective covenants, the legal requirement of protecting and enhancing biodiversity as part of a development consent will:

- meet biodiversity conservation outcomes;
- includes a specific plan of management for each lot;
- allocate through this plan, adequate resources to achieve plan based completion criteria;
- bind the current and future land owners in perpetuity
- cannot be altered without approval of the relevant minister, which will be Minister for Planning.

### 5.9.3 In Perpetuity Protection

In perpetuity protection will be achieved through initial funding by Centennial Coal to undertake activities that will enhance the biodiversity of the offsets. The funding will be used to achieve an acceptable level of rehabilitation. An acceptable level of rehabilitation will be defined by completion criteria to be developed. The covenant will be supported by a Land Management Plan that will include established completion criteria required to achieve an improved biodiversity outcome on the land such that once criteria are met, Centennial's conservation obligation will have been realised.

Completion criteria will be focussed on achieving a conservation outcome and will include measures to:

- Repair and restore riparian habitat and values;
- Timetable and methods for feral animal control and weed management;
- Establishment and implementation of fire management practices, including fire breaks;
- Exclusion of cattle grazing; and
- Implementation of erosion control measures.

It is anticipated that these measures will result in an initial start-up investment by Angus Place Colliery and Springvale Mine together of $100,000 over three years with ongoing maintenance costs in the order of $15,000 per year until completion criteria are met. For the Neubeck Coal project it is anticipated that these measures will result in an initial start-up investment by Centennial Angus Place of $100,000 over three years with ongoing maintenance costs in the order of $15,000 per year until completion criteria are met. Long term management activities will be incorporated into the restrictive covenant for the land ensuring that the conservation values achieved will be maintained in perpetuity.

Ongoing management of the offsets will be undertaken under the terms of a protective covenant. The offset areas likely to be protected under Section 88B of the Conveyancing Act 1919; the terms of the Section 88B instrument will make reference to a Plan of Management.

Centennial will continue to consult with Office of Environment and Heritage and the Federal Department of the Environment to continue to refine this package.

### 5.9.4 Charbon Case Study

Charbon Colliery, an open cut coal mine, is operated by Centennial Coal Pty Limited, a joint venture between Centennial Coal Company Limited and SK Networks Resources Australia Pty Ltd.

The Project involved the expansion of the existing Southern Open Cut and operation of a number of other open cut underground operations at Charbon Colliery that resulted in the loss of 42 ha of native vegetation. The operations include the Southern Open Cut Extension, Southern and Western Outliers, 8 Trunk Central and Western Open Cuts and the Western Underground.

#### 5.9.4.1 Compensation for residual impacts

Existing compensatory habitat areas equated to approximately 72.8 ha which mitigated previous approvals for extensions to Charbon Colliery. New on-site compensatory habitat areas were prescribed to compensate for the current approved extension which included an area of approximately 265 ha, comprising 176 ha of Grey Gum- Stringybark Woodland, 23 ha of Mountain Grey Gum-Grey Gum-Mountain Hickory Sheltered Forest, 13 ha of Stringybark-Blakely's Red Gum-Yellow Box Woodland, 23 ha of Narrow Leaf Stringybark-Sydney Peppermint-Grey Gum Woodland, 13 ha of Yellow Box-Blakely's Red Gum Woodland and 17 ha of Cleared Land.

In addition to the on-site compensatory habitat outcomes, additional off-site lands have been conserved. Charbon identified 120 ha of land at Nullo Mountain 32 km NW of Charbon including 80 ha of White Box EEC equivalent land. The 120 ha was part of a larger portion of land. The land owners submitted a development application in June 2011 to Mid Western Regional Council to subdivide the 120 ha. The land has since been subdivided and purchased by Charbon accordingly. Outcomes for threatened biodiversity as a result of the off-site compensatory habitat areas are as follows:

#### 5.9.4.2 Approvals

Approval was granted in November 2005 to protect the offset sites under Section 88B of the Conveyancing Act 1919. The owner of the land is burdened by:

a) Conserve and manage all flora and fauna within the Relevant Area in accordance with the terms of the document entitled “Charbon Colliery Compensatory Habitat Management Plan” which forms part of the documentation supporting a development application giving rise to development consent number DA-122-3-2003 dated 19 December 2003 and any subsequent revisions; and

b) Permanently protect the land in the Relevant Area and exclude open cut mining activities and land clearing other than associated with the Permitted Uses.

#### 5.9.4.3 Additional Initiatives

Additional initiatives have occurred as a result of the habitat offsets including the following:

- Rehabilitation of existing cleared lands within the mine site;
- Development of a Compensatory Habitat Management Plan; and

Scientific studies within the offset lands such as soil microbial characterisation to provide baseline data for subsequent rehabilitation works.

## 5.10 Objectives for Conservation Land Management

Conservation, management and land improvement activities that include targeting the threats to vegetation communities, maximising species diversity and increasing connectivity will result in long term persistence of these communities over time. Habitat creation and thereat mitigation will be key land management objectives for conserving threatened flora, threatened fauna and their habitats.

Completion criteria will take into consideration these strategies and will be focussed on achieving a conservation outcome and will include measures to:

- Repair and restore riparian habitat and values
- Timetable and methods for feral animal control and weed management
- Establishment and implementation of fire management practices, including fire breaks

- Exclusion of cattle grazing
- Implementation of erosion control measures
- Habitat establishment for endangered species, including regent honeyeater, Gang Gang Cockatoo and other bird species

The following sections provide some additional site management objectives for the Box-Gum Woodland at Airly and specific threatened species.

### 5.10.1 Box-Gum Woodland

As identified in **Section 8**, completion criteria have been derived from the priority recovery actions described in *Caring for our Country: A Guide to Managing Box Gum Grassy Woodlands* (Rawlings et al 2010). Box-gum grassy woodlands have been nationally listed as a Critically Endangered Ecological Community that supports over 400 plant species and animals. Less than 5% of the original extent of box-gum grassy woodlands remains in good condition, and what does remain exists in isolated patches across a fragmented landscape (Rawlings et al, 2010). The effects of grazing, weeds, nutrient inputs, fire, salinity and soil erosion threaten the health of these communities.

Rawlings et al 2010 identified eleven management strategies that, alone or in combination, will likely result in this longer term objective. These management strategies are:

(4) Improve woodland condition
(5) Use of fire
(6) Weed management
(7) Nutrient management
(8) Strategic management of livestock and other herbivores
(9) Regeneration and revegetation
(10) Improving natural regeneration
(11) Tubestock planting and direct seeding
(12) Creating and improving buffers
(13) Retaining or adding habitat
(14) Looking after endangered plants and animals

### 5.10.2 Bathurst Copper Butterfly

Bathurst Copper Butterfly habitat establishment, through the planting of *Bursaria spinosa* subsp. *lasiophylla*, is proposed within conservation areas. Sites suitable for planting of *Bursaria spinosa* subsp. *lasiophylla* for the purpose of Bathurst Copper Butterfly habitat include:

- sites with a westerly to northerly aspect; and
- vegetation with an all-day sun and an open structure will also be targeted for habitat creation.

Additionally, targeted searches for the attendant ant *Anonychomyrma itinerans* can be considered to further assess site suitability. *Bursaria spinosa* subsp. *lasiophylla* can also be planted within less favourable locations for this species as part of general rehabilitation initiatives.

Suitable locations for Bathurst Copper Butterfly habitat creation occur at many of the proposed conservations sites, including, Wolgan Road North, Wolgan Road South and Brays lane. Successful habitat creation may lead to future opportunities to undertake translocation initiatives of the Bathurst Copper Butterfly and the attendant ant *Anonychomyrma itinerans,* which could improve the security of local populations of this species.

### 5.10.3 *Eucalyptus cannonii*

This species has been successfully used in mine site rehabilitation in the locality (i.e. Charbon Colliery and Springvale Coal Services). Planting of this species is proposed within the Airly Offset Site and the Wolgan Road North Offset Site, within derived grasslands components of suitable habitat. This species would be planted within a mosaic of other tree species that are locally endemic to the intended vegetation community. Whilst naturally occurring together, *Eucalyptus macrorhyncha* will not be planted with *Eucalyptus cannonii* as to limit the chance of hybridisation.

### 5.10.4 *Eucalyptus aggregata*

Planting of this species is proposed within Wolgan Road North, Wangcol Creek and as part of the Coxs River Restoration Program.

### 5.10.5 *Thesium australe*

Habitat for this species exists within in the conservation areas in the form of areas dominated by *Themeda triandra* (Kangaroo Grass). Whilst targeted surveys have not been undertaken for this species, potential habitat has been noted as occurring. The cessation of grazing will enable areas of low-lying fertile lands containing *Themeda triandra* to regenerate.

Management practices, including weed and Rabbit control is likely to provide an abundance of potentially suitable habitat for this species. Targeted surveys for this species in the region can also be considered to further the understanding of the local population as well as provide potential future possibilities of a population establishment strategy.

Whilst areas containing *Themeda triandra* occur throughout the locality, not all areas are providing occupied habitat for *Thesium australe*. The reason for this may be due to past disturbances or by due to other factors, such as habitat health and/or soil attributes. testing of soils to determine detailed habitat requirements could be considered to establish more specific habitat suitability for *Thesium australe*.

# 6.0 Supplementary Measures to Support Conservation Outcomes

Throughout the development of the Biodiversity Strategy, Centennial has undertaken a review of the Priority Actions for species and communities of concern to the Office of Environment and Heritage and the Department of the Environment. This review has identified a number of threatened species where actions for recovery can be supported by additional investment in research. These species include (but are not limited to):

- *Eucalyptus cannonii*
- *Bursaria spinosa* subsp. *lasiophylla*
- *Persoonia hindii*
- *Derwentia blakelyi*
- Bathurst Copperwing Butterfly
- Blue Mountains Water Skink
- Giant Dragonfly
- *Thesium australe*
- Temperate Highland Peat Swamps on Sandstone (incorporating NPSS and NPHS)

With a focus on those recovery actions towards which Centennial can contribute, the following list has been compiled to provide a suggested research program encompassing these species.

- Contributing research funding towards furthering recovery plans for the threatened species listed above. This research may include mapping the extent of species distribution in a regional context, include trials for the establishment of species habitat, studies of the nature, form and function of species within the landscape, ecology of fire and its impact on species and communities, seed collection and propagation techniques, habitat requirements, methods to communicate research findings, and short and long term goals to measure the effectiveness of the research.
- Working with government and community groups to provide remediation advice and in kind support, for the active rehabilitation of shrub swamp communities impacted by other anthropogenic activities (for example, four wheel drive tracks) on the Newnes Plateau.

The mechanisms for establishing these research programs will be investigated and may include:

- Direct funding of existing research programs to either enhance or redirect research efforts
- Adding funds to the existing agreement between Springvale Coal, Centennial Angus Place and the Australian National University. This agreement was established as the outcome of an enforceable undertaking (described in Chapter 2 of the Springvale and Angus Place EISs). The agreement, Temperate Highland Peat Swamps on Sandstone Research Program Agreement, establishes a research program with academic freedom (that is, funding is distributed through a steering committee with expert representation) to pursue research proposals specific to achieving recovery outcomes for the THPSS. This agreement could be amended and extended to include additional research components. To date, the Enforceable Undertaking has invested funding into the following research topics:
  - Mapping, location, distribution and extent of THPSS;
  - Functionality of swamp systems;
  - Ecology and biology of major structural species;

  - Environmental history of swamp communities, including resilience over time to fire;
  - Condition status and trends; and
  - Thresholds for recovery, including fire.

Centennial acknowledges that the existing approval condition requiring both the Angus Place and Springvale operations to develop and implement a *Persoonia hindii* Research and Management Plan is ongoing; the outcomes of this research and monitoring program will provide information to inform future management decisions regarding potential impacts to *Persoonia hindii*. To mitigate the unlikely event that this research program does not achieve the expected outcomes, the biodiversity package within this report includes consideration of *Persoonia hindii* and satisfies the requirement to provide additional offsets. The Management Plan is in the early stages of implementation and to date, the following actions have been undertaken:

- Initial survey and mapping of *Persoonia hindii* across parts of the Newnes Plateau
- Translocation of 62 plants, propagation trials via cuttings and seed collection
- Ongoing monitoring of translocated plants
- Consultation with Office of Environment and Heritage on the progress of the Plan

# 7.0 Coxs River Catchment Restoration Program

## 7.1 Introduction

As detailed in **Section 3.9** many cumulative impacts affect the nature and quality of the Coxs River catchments. Impacts include mine water discharge from both underground mine operations and from open cut mine operations. Impacts to water quality and quantity are also experienced from power generation and from the surrounding human settlements.

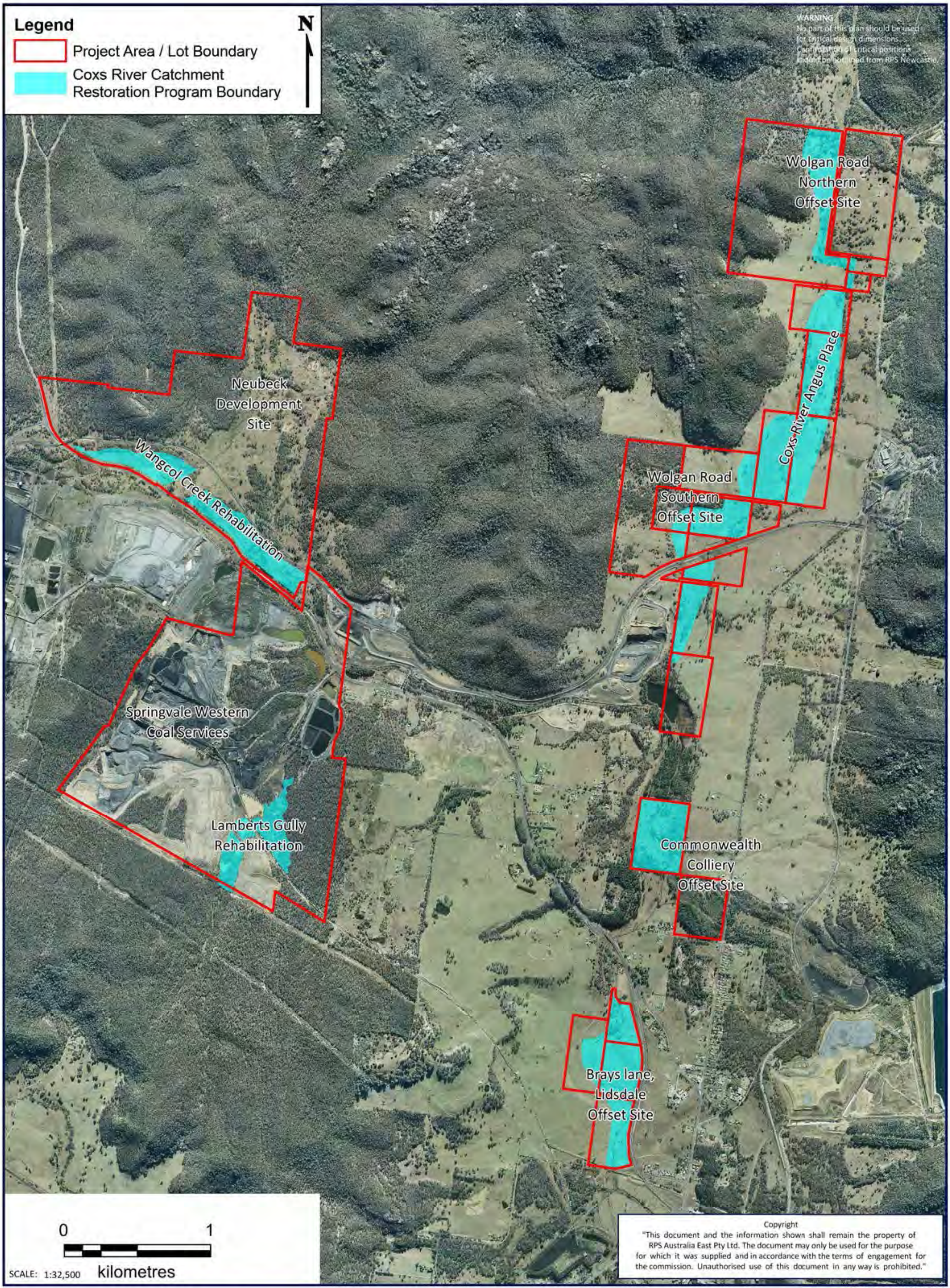
The Coxs River and its tributaries contain numerous biodiversity values, including the EECs Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland and Montane Peatlands and Swamps. *Eucalyptus aggregata* (Black Gum) species if tree listed under the TSC Act is common within the lower reaches of this catchment, however often occurs as scattered individual tress within predominately cleared landscapes. Clearing of vegetation along Coxs River has resulted in channelization along parts of the river. Other parts, however, other parts still exist as wide wetland environments providing habitat for wetland birds and amphibians.

This Regional Strategy provide an opportunity to implement the Coxs River Catchment Restoration Program, which is aimed to further enhance the biodiversity values that exist within the Coxs River Catchment and ameliorate the cumulative impacts associated with Centennial projects and the many other projects that influences the physical and chemical nature of the Coxs River. The physical parameters of the restoration program are within Centennial owned and/or operated lands. The Coxs River Catchment Restoration Program boundary is presented in **Figure 14**. The bounds of the program overlap with many of the conservation sites and have been included in the offsets analysis in order to provide a measure of the adequacy of all initiatives proposed in the Regional Strategy.

## 7.2 Management and Objectives

The core objective of the Coxs River Catchment Restoration Program is to improve the terrestrial and aquatic biodiversity value of the Coxs River. This is proposed to be achieved through the following activities:

- removal of grazing pressures;
- riparian areas restoration;
- native species planting within derived native grasslands, including:
    - species associated with Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland EEC,
    - *Eucalyptus aggregata;*
    - *Themeda triandra* (habitat for *Thesium australe*); and
    - *Bursaria spinosa* subsp. *lasiophylla* (habitat for the Bathurst Copper Butterfly)
- weed removal / control including Willows.



TITLE: FIGURE 12 COXS RIVER CATCHMENT RESTORATION PROGRAM
LOCATION: LITHGOW, NSW
DATUM: DATUM
PROJECTION: MGA ZONE56
DATE: 18/09/2014
PURPOSE: REGIONAL BIODIVERSITY STRATEGY
LAYOUT REF: J:\JOBS\Centennial\All Jobs\123063 OEH Submissions - Fassifern\10 - Drafting\MapInfo Workspaces\Eco Biobanking Report
VERSION (PLAN BY): PH (A-A4)
CLIENT: CENTENNIAL
JOB REF: 123063

# 8.0 Monitoring Program

Centennial has invested considerable research and monitoring effort on the Newnes Plateau over the last 15 years of mining operations. In particular, Centennial's investment has focussed on monitoring the THPSS. Centennial's monitoring effort on the Newnes Plateau is extensive (refer to Figure 3.9 of the EIS) and contributes to an increase in other anthropogenic impacts, such as recreational 4WDs, through the establishment of access tracks for monitoring. Should the current suite of monitoring persist, these incidental (but not insignificant) impacts will continue across the Newnes Plateau, placing greater pressure on areas where conservation values are currently retained.

The biodiversity strategy will enable Centennial to redirect this monitoring investment towards those conservation outcomes described above. The monitoring program will be regionalised with greater effort on remote sensing data collection across a wider distribution of the Newnes Plateau and will focus on supporting research into rapid mapping techniques and defining vegetation community boundaries.

This current monitoring effort is approximately $2 million per year. The implementation of this Biodiversity Strategy will see the surrendering of all previous consents. The current research and monitoring techniques will be modified to achieve the requirements of the relevant conditions of consent. This may include current monitoring funds being reduced or diverted to monitor the success of conservation sites management and supplementary measures.

The redefined monitoring program, including the management actions identified above, will be incorporated into an agreed, combined Biodiversity Management Plan for the Projects, thereby reducing the current suite of management plans required for compliance to one. This Biodiversity Management Plan will be developed in consultation with OEH (including NPWS), DotE and the Forestry Corporation of NSW and will:

- Identify and incorporate the direct offset package identified in this report and Plan of Management for each lot;
- Establish the Land Management Plan, including management actions and completion criteria;
- Establish the Rehabilitation Plan, including management actions and completion criteria;
- Describe the research and monitoring program that will be implemented to focus on mapping the extent of species distribution in a regional context, include trials for the establishment of species habitat, studies of the nature, form and function of species within the landscape, ecology of fire and its impact on species and communities, seed collection and propagation techniques, habitat requirements; and
- Describe the measures that will be taken to rehabilitate shrub swamp communities impacted by other anthropogenic activities, using the Save Our Swamps Guideline.

The existing and future monitoring programs will focus on establishing these conservation outcomes. Each Plan of Management will include how the land will be monitored to achieve completion criteria. Where trends indicate criteria are not being met, contingencies and adaptive management strategies will be included in the Plan.

# 9.0 Regional Strategy Financial Contributions

The land proposed for the offset is Centennial owned land; regardless, there is an opportunity cost to the Company of $140,000 per hectare (as per the BioBanking Calculator) that will be lost once this land is offset for these projects. Ancillary costs, including taxes, conveyancing and current land management expenses are incidental.

It is anticipated that the management actions identified above will result in an initial start-up investment by Angus Place Colliery and Springvale Mine together of $100,000 over three years with ongoing maintenance costs in the order of $15,000 per year until completion criteria are met. Long term management activities will be incorporated into the restrictive covenant for the land ensuring that the conservation values achieved will be maintained in perpetuity.

Centennial's current monitoring investment on the Newnes Plateau will be redirected following the implementation of the above monitoring program. The ongoing monitoring investment for both Projects will be in the order of $250,000 per year across ecology (terrestrial and aquatic), water (surface and groundwater) and subsidence.

## 9.1 Economic and Social Costs and Benefits of the Biodiversity Strategy

The offsets required for the project have been quantified in the context of the biodiversity values lost or gained as a result of the predicted impacts of the Projects. The costs borne by Centennial through avoidance and mitigation measures, including reduced mine footprint, reduced longwall widths and, where economically practical, complete avoidance of sensitive surface features, are significant (see Chapter 6 of the EISs). This significance needs to be considered in the context of the ongoing benefits afforded to the community through the management and research actions taken to date for activities on the Newnes Plateau. These actions have contributed to a greater understanding of this environment, such that the results of these studies can be incorporated into broader recovery and conservation outcomes.

Balanced with this, are the benefits generated through this Biodiversity Strategy that may otherwise not be realised, by providing for:

- conservation in perpetuity of high priority biodiversity values;
- ongoing financial support to achieve agreed criteria for conservation;
- access to conserved land adjacent to the Mugii Murum-Ban State Conservation Area for tourism and recreational purposes; and
- investment in research, recovery and maintenance plans to understand potential threats to conservation outcomes and integrate this understanding with values of adjacent National Parks, World Heritage Areas and National Heritage Places.

# 10.0 Conclusion

Centennial will continue to consult with Office of Environment and Heritage and the Federal Department of the Environment to continue to refine this Biodiversity Strategy. This Strategy, combined with the current measures taken to avoid and minimise impacts, will compensate for the residual impacts, enhance biodiversity outcomes, conserve high conservation communities, and the associated flora and fauna, and will enable focussed effort on improving understanding of the biodiversity values within the region.

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# Appendix 1

## Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps (Centre for Mined Land Rehabilitation 2014)

# Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps

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This handbook outlines the datasets, analyses and reporting required to conduct a statistically rigorous and sensitive flora monitoring program to detect change in Newnes Plateau Shrub Swamps and Hanging Swamps (hereafter refered to collectively as swamps), at an individual swamp community scale, due to underground mining. It is proposed as a replacement for the current Centennial Coal Newnes Plateau Temperate Highland Peat Swamps on Sandstone (THPSS) vegetation monitoring program as it contains the following improvements: 1) sufficient replication at the swamp scale such that analysis of key indicators of community composition and health can be assessed in a statistically rigorous manner, 2) clearly defined and ecologically meaningful trigger values and 3) a clear framework outlining required management actions.

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# 1. Monitoring handbook outline

## 1.1 Overview of the handbook

This document outlines a statistically rigorous and ecologically meaningful method for flora monitoring of Newnes Plateau Shrub and Hanging Swamps that is suitable for use across Centennial Coal's Angus Place, Springvale and Clarence collieries. The proposed monitoring program would replace the existing flora monitoring outlined (and currently applied across the three collieries) in the Angus Place Colliery Subsidence Management Plan and Environmental Monitoring Program (specifically Section 7.3, see Appendix C) that in its current form is unable to determine if vegetation in a Newnes Plateau swamp has been impacted (or not) by mining. In addition the flora monitoring methodology outlined in this document addresses the requirements of the Department of Sustainability, Environment, Water, Population and Communities (DSEWPAC) condition 7 of approval 2011/5949 (Appendix B). As a result this program may be applied to meet the monitoring requirements of both state and federal governments for evaluating potential mining related impacts to Newnes Plateau swamps that fit the definition of Temperate Highland Peat Swamps on Sandstone (THPSS).

Sections 2 and 3 of this document provide a brief background and context of historic flora monitoring on the Newnes Plateau. Section 4 gives an overview of the objectives and trigger values of the recommended flora monitoring. Sections 5 and 6 detail the sampling design and protocols required for data collection and analysis. Reporting and data management procedures are outlined in Sections 5.4 and 6.4. The appendices contain supporting information including background on why the existing monitoring program requires adjustment, justification for the revised sampling design and trigger values, and example data sheets.

The flora monitoring program recommended here relies on data from the subsidence and groundwater/surface water monitoring to inform areas that require monitoring and to produce a complete assessment of impacts of mining activity by Centennial Coal on the Temperate Highland Peat Swamps on Sandstone (THPSS). The subsidence and groundwater/surface water monitoring are detailed in the "Temperate Highland Peat Swamps on Sandstone Monitoring and Management Plan for LWs 415 - 417" and the above mentioned Angus Place Colliery management plans, hence are not discussed further in this document.

This flora monitoring program follows an adaptive approach with data collection informing revisions to ensure scientific rigor and to meet future site management requirements. Procedures for flora monitoring program revisions are detailed in Section 4.

## 1.2 Monitoring objectives

The Newnes Plateau Flora monitoring program aims to detect negative impacts on the vegetation structure and condition of TPHSS as a result of subsidence and/or changes to ground and surface water flows associated with mining activity by Centennial Coal. A negative impact is defined as a value(s) exceeding the trigger(s) outlined in Section 4. The measures of vegetation structure and condition are summarised in Section 4, these measures develop a multivariate approach to assessing swamp health. Based on the DSEWPAC condition 7 (Appendix B), the Newnes Plateau Flora monitoring program includes the following:

- A focus on vegetation community structure and diversity, including biological indicator species
- Trigger values focused on detecting impacts of subsidence or/and changes in groundwater and surface water flows associated with ongoing mining activity
- Information about how the trigger values were derived
- Reference sites in THPSS that will never be impacted by subsidence
- A method for defining and describing baseline conditions of individual THPSS for both impacted and reference sites
- Details of the parameters monitored along with the methods, timing, frequency and locations of both baseline and ongoing monitoring of reference and impacted sites
- A sampling design which is statistically capable of detecting changes in the defined indicator variables
- A description of how potential impacts arising from the monitoring and mitigation measures themselves will be minimised or avoided
- An outline of the data management and analysis procedures required to maintain and report verifiable data and results
- An adaptive management mechanism for refining trigger values and determining the length of time a THPSS site is monitored.

# 2. Newnes Plateau THPSS overview

The Newnes State Forest (encompassing the Newnes Plateau) is an economically, environmentally and socially significant area. Managed by the Forestry Corporation of NSW for harvesting of native and introduced timbers, this area is ecologically significant due to the presence of the Newnes Plateau Shrub Swamps (NPSS), an Endangered Ecological Community (EEC) listed under the Threatened Species Conservation Act 1995. Also present are Newnes Plateau Hanging Swamps (NPHS), which together with NPSS form part of the threatened ecological community 'Temperate highland peat swamps on sandstone' (THPSS), protected under the Environmental Protection and Biodiversity Conservation Act 1999.

DEC (2006) list the key features of the NPSS vegetation type as: a moderately dense to open shrub layer with very dense understorey of sedges. The NPSS are found on semi-permanently saturated soils with high organic content in the lowest footslopes, broad valley floors and alluvial flats (DEC 2006). The key features described for the NPHS vegetation type include: a low dense fern-dominated community usually perched on a hillside with few trees present and; groundwater dependence (DEC 2006). However, in reality NPSS and NPHS are diverse plant communities, often with few species in common between swamps. For example, during the spring 2013 survey, of the 185 species recorded, 56% were recorded in five plots or less (Blick et al., 2013).

The vegetation patterns of the NPSS and NPHS are closely associated with local hydrology and are currently classified into two broad swamp categories: Type A and Type C. The type A are periodically wet with rainwater as the main source of water, while the Type C are permanently wet with groundwater as the main source of water. Conceptual models of these shrub and hanging swamp systems are shown in Figures 2.2 and 2.1. Due to the underlying geology, a single swamp can contain both type A and C areas leading to heterogeneity in vegetation composition. This difference in hydrological regime effects predictions of impacts from changes to ground and surface water flows. Regardless of type, due to close links between vegetation and hydrology, changes to the hydroplogy will effect the vegetation.

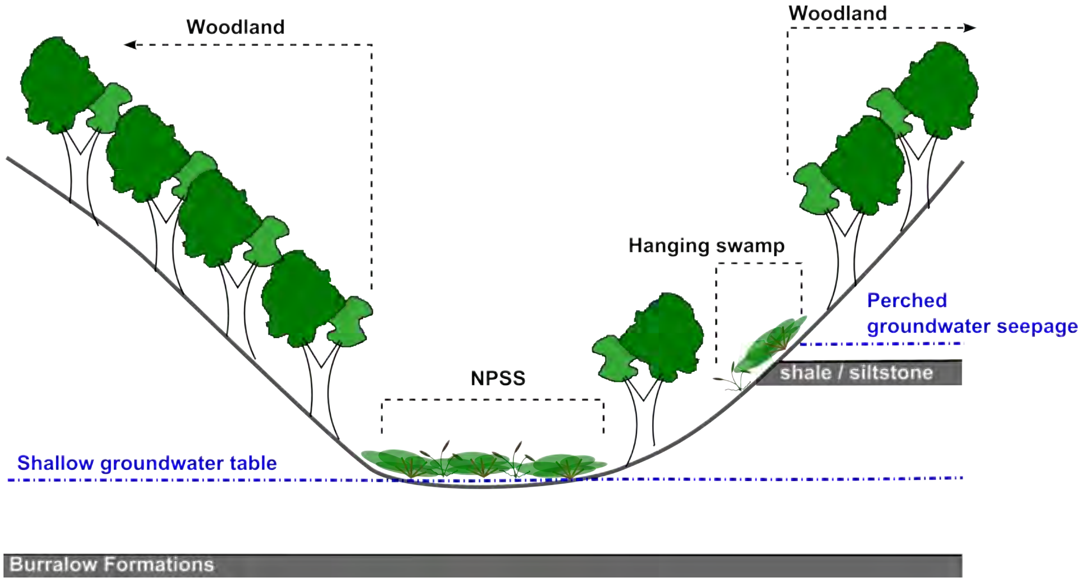

Figure 2.1: Conceptual model of Type C THPSS.

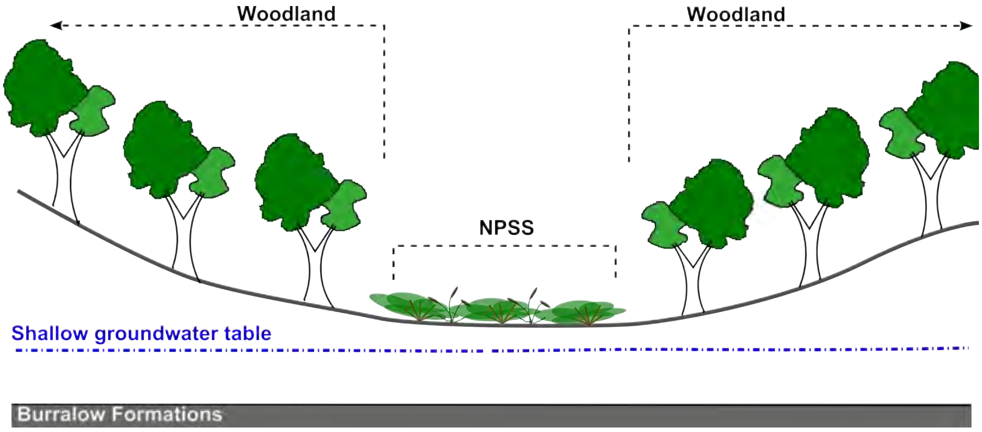

Figure 2.2: Conceptual model of Type A THPSS.

# 3. Why monitoring is required

Newnes Plateau vegetation experiences a range of disturbances (*e.g.* forestry, fire, mining and recreational uses). The monitoring program outlined here focuses on detecting impacts of underground mining on the THPSS. Active coal mining started in the Newnes Plateau and Lithgow area in 1838 and three mines operated by Centennial Coal are currently located beneath the Newnes State Forest. Two are longwall mines (Angus Place and Springvale Collieries) while the third is a bord and pillar mine (Clarence Colliery). Longwall underground mining is considered a key threatening process to wetlands by State and Federal governments. As such this requires Centennial Coal to demonstrate that mining activities are not impacting on overlying THPSS.

## 3.1 Primary objective

The primary objective of the monitoring program is to determine whether mining activities impact the condition, species composition and/or extent of Newnes Plateau THPSS plant communities. Undermining results in subsidence, which in turn has potential to alter ground and surface water hydrology. As THPSS are hydrologically restricted communities there is a clear link between changes in hydrology and potential impacts on swamp vegetation. However, these communities exist across a range of hydrological conditions and the plant species comprising these communities are generally thought to be tolerant of a fluctuating water table and moisture availability. Therefore, 1) vegetation impacts are likely to occur where hydraulic modifications are sufficiently large and 2) a time lag between change in hydrology and change vegetation is likely. Identifying this change is the goal of the monitoring program (Figure 3.1). Changes in vegetation patterns are inextricably linked with changes in surface and groundwater availability, therefore hydrological data (e.g. piezometer data) are essential to interpreting changes in Newnes Plateau THPSS vegetation.

## 3.2 The existing monitoring program

Flora monitoring of shrub swamps by Centennial Coal commenced in 2003 with seasonal monitoring protocols beginning in 2005 following the listing of the swamp communities by

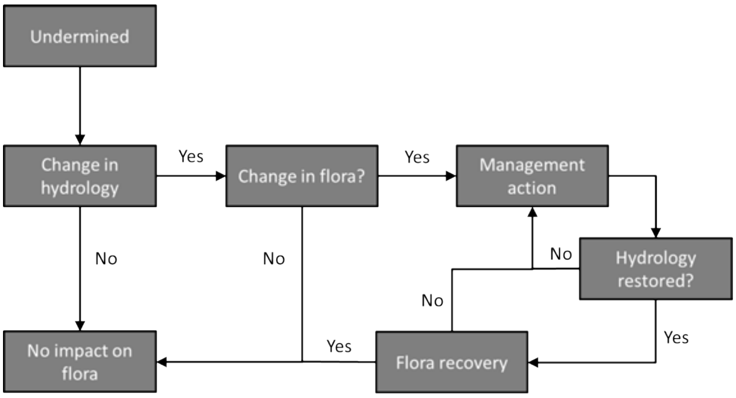

Figure 3.1: Conceptual model of how mining associated changes to hydrology could potentially impact the THPSS and the role of monitoring.

State and Federal governments (NPSS and THPSS respectively). A review and redesign of the program was initiated in 2012 after the existing monitoring program failed to identify a number of obvious community impacts, primarily to East Wolgan and Narrow shrub swamps. Most likely reasons for failure to detect change were 1) a lack of clear connection and feedback linking the mine operational plan with monitoring and management of environmental risk, 2) absence of clearly defined and ecologically meaningful trigger values and 3) the inability of the sampling design to detect adverse impacts. Until 2012 monitoring was only required by the New South Wales Government. In 2010 the Federal Government determined that mine water discharge by Centennial Coal into Newnes Plateau THPSS was a threatening process that had failed to be reported to the appropriate federal regulatory bodies. As a result, federally imposed monitoring of Newnes PlateauTHPSS has been conducted since 2012 (Appendix B).

Currently the monitoring program 1) lacks replication at the individual swamp scale, 2) involves large sampling errors related to plot size and abundance estimation, 3) lacks parameters for defining changes in vegetation structure, 4) lack of understanding of the variability within and between swamps, and 5) includes no plan for defining when and how long monitoring must continue (Appendix D, Brownstein et al. (2013)). Also of concern are the cumulative impacts introduced by flora monitoring activities; adjustments to the status quo are required to limit impacts of monitoring while collecting appropriate data to detect change. Appendix A contains a summary of research conducted by the University of Queensland in 2012-2013 to determine the limitations of the current vegetation monitoring program and how these limitations can be overcome. Table 3.1 broadly outlines how the recommended method addresses the issues identified above.

Table 3.1: Comparison of current statutory monitoring and reporting activities with the method recommended here.

| Component | Current State | Current Federal | Recommended |
|---|---|---|---|
| Quantification of vegetation cover | visual cover/abundance estimation within 400m$^2$ plots | Point intercept (frequency) within 400m$^2$ plots | Cover in cross community transects |
| Replication within community | NIL or variable | Nil or variable | 3 or more, scaled to community size |
| Monitoring Interval | 3 seasons (spring, summer, autumn) | 4 seasons | Annual (spring) |
| Statistical Analyses | SIMPER, PERMANOVA | 1 tail t-test | 1 tailed t-test |
| Trigger values | Significant decline in condition/health; decline in population numbers compared to baseline (not related to rainfall); increase in exotic species compared to last year; major dieback of flora compared to baseline monitoring (not related to climate, bushfire or other anthropogenic cause not associated with subsidence); significant change in species diversity; significant increase in exotic species | Species assemblage >30% change in 3 yrs; increase in eucalypts 3 plants in 1yr period; 1.5 unit decline in average condition in one year; increase in bare ground more than 100m$^2$ over 3yr; increase in exotic biodiversity of four in one year at BB score 4 or higher | Significant: increase in non-vegetated area; decrease in live vegetation cover; decrease in proportion amphibious species cover; change in terrestrial damp species cover; increase in exotic vegetation cover; increase in establishment of eucalyptus or pine (Table 6.2) |
| Remote sensing | Nil | Nil | 5-15cm resolution, 4 band covering community, 4 seasons |
| Field measures concurrent with Remote Sensing | N/A | N/A | Fixed random 1m plots at minimum 100m separation across community |
| Reporting | Seasonal and Annual | Annual | Annual, trigger event |
| Duration | none specified | Minimum 10 years, intensity decrease after 3yrs | Minimum 10 years, intensity decrease after 3yrs |

# 4. The proposed monitoring design

To meet the requirements outlined in Section 1.2 the new monitoring program must clearly link data from floristic surveys with the data derived from hydrological and subsidence monitoring programmes. The information from subsidence risk maps will inform which areas are more intensively surveyed and areas considered as appropriate reference sites. As mining progresses, hydrological data combined with floristic data will be used to assess if changes in floristic data are linked with mine related impacts, e.g. changes in hydrology (Figure 3.1). The types of data required for each of the environmental components is outlined in Table 4.1.The proposed flora monitoring program will follow an adaptive management approach. Data from monitoring will be analysed to inform successive monitoring activity relative to potential environmental risks of Centennial Coal operations (Figure 4.1).

Table 4.1: The data types required for effective flora monitoring

| Environmental Component: | Data required: |
|---|---|
| Geology | Subsidence |
| Hydrology | Water chemistry<br>Rainfall<br>Stream flow<br>Groundwater |
| Flora | Community composition<br>Community condition |

## 4.1 Overview of the performance indicators

The performance indicators cover three broad groups: vegetation composition, vegetation condition and community condition, Table 4.2 outlines the parameters measured for each performance indicator and the trigger levels to be reported for vegetation. These measures and trigger values capture vegetation structure and condition changes that THPSS could undergo due to undermining impacts. These measures and trigger values can only be meaningfully assessed in conjunction with hydrological data (e.g. piezometer data).

## 4.2 Overview of the survey methods

The sampling methodology consists of two components: a seasonal aerial survey and an annual intensive ground survey; designed to assess the full extent of each community under investigation. The aerial seasonal monitoring measures vegetation and swamp condition by capturing changes in live canopy cover and the extent of non-vegetated areas. In addition the seasonal aerial mapping will detect rapid changes in the environment from direct and indirect impacts (*e.g.* 4x4 activity). The time series of air photos will provide a clear record of change throughout the duration of the monitoring program. The annual intensive ground survey will measure parameters associated with vegetation composition and condition by recording individual species abundance and the extents of non-vegetated areas. The annual survey records trends in species presence and abundance at an ecologically relevant time scale. It is

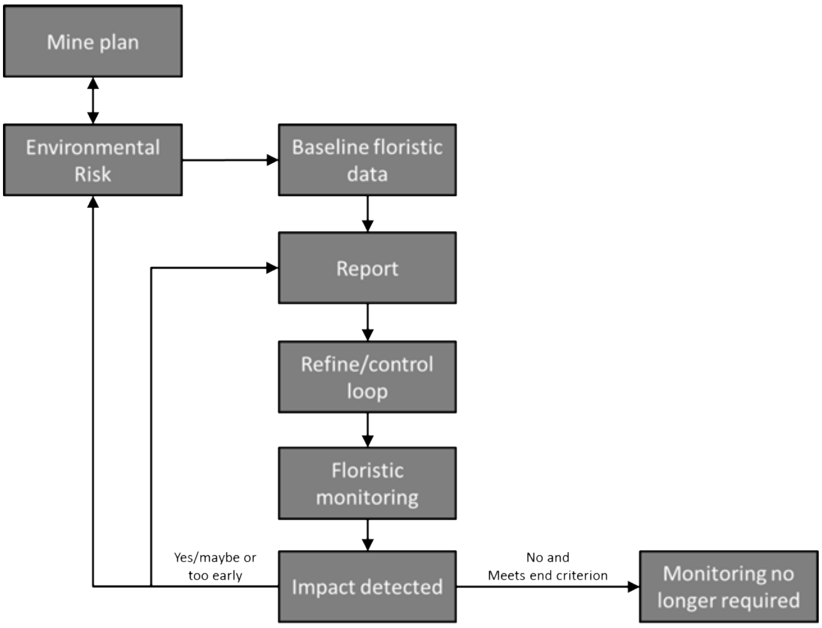

Figure 4.1: Conceptual framework showing how data from flora monitoring informs the environmental risk assessment and monitoring conclusions.

recommended that ground surveys are carried out when species are most easily identified (i.e. summer). This approach increases the quantity and quality of floristic information recorded while minimising impact from trampling.

## 4.3 Overview of the sampling design

The sampling design and data analysis is based on a Before-After-Control-Impact (BACI) approach. This approach is commonly used to monitor for potential environmental impacts and allows for unrelated changes (*e.g.* temporal variability due to rainfall) to be assessed in the analyses. This type of analysis requires that 'impact' and 'control' sites are monitored with similar methods over similar periods of time. Here a potential 'impact' site is defined as a community that is within the subsidence zone. A 'control' site is a community that has not been and is not expected be undermined in the future and is not within 200m of mine activity (as per SEWPAC condition 7 of approval 2011/5949).

**Terminology:**
**Site** is a mapped NPSS or NPHS (*i.e.* MU 50 or MU51) community (VISMap 2231)
**Control** sites have not been and will not be undermined and are beyond measurable subsidence associated with mine activity.
**Impact** sites will be or have been undermined or are within an area of measurable subsidence.

Sites will be classified using a subsidence risk map (high, medium or low risk) and hydrological information (type A, type C or combination A/C swamp). Subsidence related risks are predicted and measured deformations associated with mining activities including (*a*) subsidence, (*b*) tilt and (*c*) strain, that are combined with surface topography and geology which may magnify impacts. Hydrological information will be based on natural fluctuations in ground water levels prior to mining recorded in shallow piezometers. This classification will inform the distribution of sampling plots within the community. Effective selection of

Table 4.2: Performance indicators for shrub swamp vegetation monitoring.

| **Performance indicators** | **Parameter measured** | **Trigger level** |
|---|---|---|
| Hydrology | Water table depth and stability | Evidence of a reduction in water table depth or stability, due to underground mining, from piezometers located in impact sites (refer to hydrology monitoring reports) |
| | Flow path | Evidence of a change in flow path due to subsidence, based on aerial imagery and field observations |
| Vegetation structure | Abundance of native wetland species | A statistically significant reduction in the abundance of native wetland species in impacted community relative to the previous survey |
| | Live Shrub cover | A statistically significant reduction in the percent live cover of native shrub species in impacted community relative to the previous survey |
| | Abundance and diversity of exotic species | A statistically significant increase in abundance and/or diversity in the ratio of exotic to native species in an impacted community relative to the previous survey |
| Vegetation condition | Live native canopy cover | A statistically significant reduction in the percent live cover of native species in impacted community relative to the previous survey |
| Swamp condition | Non-vegetated areas | A statistically significant increase in the percent area of non-vegetated (bare ground) in impacted community relative to the previous survey |

control and impact sites absolutely requires:

1. Information on when and where new areas will be undermined.
2. Accurate and up to date undermining extents.
3. Predicted and measured subsidence zone extents and magnitudes.
4. Up-to-date piezometer and surface water data from control and impact communities.

Control sites should be selected that are as similar as practical to impact sites in terms of hydrology (type A, C or A/C) and vegetation structure (e.g. shrub-dominated, sedge-dominated or mixed). There should be at least three control sites for each impact site to provide a reasonable basis for statistical comparison. However, control sites may be used for comparisons across multiple impact sites (i.e. unique control sites are not required for matching with each impact site). Consideration also needs to be given to the potential for fire or other impacts to affect the comparability of some control and reference sites over time. Therefore, it is good practice to include some additional control sites as insurance against temporary or permanent loss of controls due to unforseen impacts.

### 4.3.1 Rationale underpinning data analysis

There are multiple possible ways of analysing the data collected. Univariate analyses are recommended as the preferred option in the current context (i.e. where there is a need to demonstrate a specified statistical power) because it is much easier to calculate power for these tests than for their multivariate alternatives. We also recommend a very simple approach to Before-After-Control-Impact (BACI) data analysis, based on one-tailed paired-sample t tests, for the following reasons:

- For some of the more complex BACI analyses (e.g. the beyond BACI design), formal power analysis procedures have not been published and are very complicated (Downes et al., 2002)).
- Paired-BACI designs require a single reference site to be allocated to each impact site. The results of tests conducted using this design may vary depending on which reference site is selected.
- In a multiple-BACI design (i.e. comparing multiple reference sites to multiple impact sites), power will depend on the extent that similar changes occur across each group. This test may be a less suitable option if we are more interested in detecting cases where just one site has been impacted by drying.
- All, except the most basic BACI designs (i.e. one control site, one impact site, one before impact survey, one after impact survey), require multiple monitoring surveys to be conducted in both the before and after impact periods. These tests are also based on the assumption that surveys are conducted at large enough time intervals that they are independent. Historically, it has not always been possible to conduct multiple surveys before undermining has occurred. If logistical constraints are similar in future, it would be useful to select a data evaluation method that does not depend on this level of replication in time.

## 4.4 Overview of sampling frequency and duration

The Before—After component of the BACI analysis requires that site data is collected before mine activities occur; the recommendation made here is that baseline data is collected for one year prior to impact so that ”before impact” imagery is available for all four seasons and one intensive on ground survey has been conducted. Monitoring at a site is recommended to continue for three years post undermining, at that time if no impact has been detected within the site, monitoring is reduced to an annual aerial survey. If no impacts are detected after 10 years, monitoring ceases at the site. Impacts in this case include anomalous changes in hydrology and/or where a flora monitoring trigger value is reached at the site.

## 4.5 Overview of reporting structure and adaptive monitoring

The monitoring reports will focus on determining if any changes have occurred at the impacted sites related to hydrological changes caused by mining. In addition the annual report will include a review of the current trigger values based on monitoring data from reference sites and recommendations for any adjustments required. The report should be more than a simple report card, rather it should include actionable management options in regards to THPSS.

# 5. Seasonal monitoring

The season monitoring proposed here is composed of two components: remote sensing and a low-impact ground-truthing survey. Current intensive ground monitoring at seasonal intervals (4 times per year) causes significant and visible trampling of swamp vegetation, opens up bare ground and potentially introduces exotic species by creating habitat niches. This is particularly so with quantitative measures requiring revisits to specific points within a fixed area on a seasonal basis. A remote sensing approach at sufficient spatial and spectral resolution provides coverage at a whole community scale. When combined with a minimal access quantitative ground based observation protocol at a community scale, applied concurrently by a trained ecologist, the result is a comprehensive and sensitive monitoring program. The direct comparison of ground based observation and remotely sensed imagery provides a report that can be interpreted with a high level of confidence. The main components of the seasonal monitoring and their processes are outlined in Table 5.1 and the workflow is outlined in Figure 5.2.

## 5.1 Remote sensing

Image source is less important than the spatial and temporal resolution of the imagery collected. A spatial resolution lower limit of 15cm is required to effectively track change within a community using object based image analysis. Temporal resolution must align with concurrent field observation which is used to confirm aerial imagery interpretation. The development of this handbook utilised a small UAV (Unmanned Aerial Vehicle, <5kg) to demonstrate capture of imagery at a community scale. The Newnes Plateau is a rugged location for the operation of small UAS (Unmanned Aerial Systems), however, seasonal aerial imagery collection by traditional methods is likely to be prohibitively expensive. As this is a monitoring program routine collection of imagery is essential to change detection, particularly where it is desirable to limit physical access.

Imagery collection must result in generation of a georeferenced orthophoto mosaic and digital surface model in traditional colour and near infrared bands. Where a UAV is applied to capture remote sensed imagery it must be capable of GPS guided flight paths with dual digital SLR camera payload. The experimental airframe used for developing this handbook was a flying wing design with battery powered pusher propeller and 2m wingspan. During development Sony NEX-5 mirrorless DSLR digital cameras with Sony 16mm pancake lenses were used. Image processing was conducted using computer vision software (Pix4UAV, Pix4D, Lausanne, Switzerland). At 400ft above ground level this resulted in approximately 5cm resolution aerial photography. A spatial resolution between 5-10cm improves object detection by clearly delimiting vegetation features within a community.

The othromosaic image is segmented using multi-resolution segmentation algorithm (eCognition Developer v8.7 scale 30, shape 20, compactness 30) and segments are converted to geospatial features as a shape file and exported to ArcGIS (v10.1, ESRI, CA, U.S.A.). Manual interpretation is applied to each segment to assign a class of shrub vegetation, or bare ground/dead vegetation.

- Dead vegetation is characterized by high reflectance while bare peat in eroded areas

Table 5.1: Detail of resources, sources and data types required to perform seasonal converged remote sensing and field monitoring.

| Components | Description and sources of resources |
|---|---|
| Metadata (from CEY) | Subsidence Model Controlled Action Area: (a geospatial file provided by CEY outlining area of surface potentially affected by subsidence)<br>Measured Subsidence: Monitoring line locations and measurement point elevation changes where these intersect swamp communities (.xls or geospatial file of high precision GPS records)<br>Local Precipitation: Plateau temperature and rainfall data from CEY weather station (.xls or .csv)<br>Groundwater Depths: current piezometer records of depth to groundwater within monitored plots (.xls file)<br>Mine Workings: updated monthly production and mine face locations (.shp or .dxf). |
| Wetland Extent Polygons (publicly available spatial data) | OEH data download VISMap 2231: Vegetation communities of the Western Blue Mountains (.shp or .tab) |
| GME Spatial Ecology | Geospatial Modelling Environment (www.spatialecology.com) (free software that uses ArcGIS and R statistics)<br>genrandompnts: tool to generate random sampling points within polygons, settings (polygon from VISMap 2231, mindist 100) |
| Locating/ Marking Plots | Centroid of plot requires star picket inserted to 1m depth to ensure permanency, a 1m$^2$ plot is centred on the star picket and 3m from swamp boundary by on ground observation of vegetation<br>Use foam or flagging tape to ensure picket is visible in imagery |
| Ground control | Proportion of plot vertical projection representing (a) live vegetation, (b) dead vegetation, (c) bare ground (d) exotic species in each 1m$^2$ plot<br>Identify exotic species in plot |
| Imagery Collection | Red Green Blue and Near Infrared at 5-15cm ground sampling distance, extent of imagery cover is mapped polygon with 30m buffer, imagery overlap sufficient to produce orthophoto mosaic and digital surface model |
| Image Processing | Four band Orthophoto (geotiff) digital surface model (geotiff or 3D point cloud)<br>Object segmentation (recommend eCognition but not essential, segment image based on colour and texture at scale that captures individual button grass tussocks (30:20:30 settings in multiresolution segmentation algorithm eCognition) |
| Analyses | Ground control: plot repeat measure trend analysis of cover proportions, exotic species richness change over time, correlates: historic rainfall, mine workings/subsidence. Mapped community mean and variance for proportional cover 1-tail t-test.<br>Remote sensing: buffer ground plot centroid markers with a 0.5m buffer, compare with plot measures from field. Segment image and compare polygon boundaries and extents with premining. Map expanded bare ground or perennial vegetation senescence. Correlate changes with piezometer depths to ground water, recreational and forestry impacts, rainfall data and mine workings. |
| Reporting | Ground control: trends in bare, dead vegetation, exotic cover/richness<br>Correlation between plot and imagery (mean, SE/Variance)<br>Comparison of premining thematic cover type with current imagery<br>Change in vegetation live cover correlation with mine workings, piezometer depths, rainfall and other non-mining impacts |

was dark in colour.

- Shrub vegetation is defined by a combination of colour, surface elevation (digital surface model to assess canopy height) and texture.

Original data collection and image processing is then used to evaluate aerial imagery from subsequent seasons (tabulate, overlap or intersect using ArcGIS). This is summarised in Table 5.2

## 5.2 Ground control surveys

To both validate the aerial imagery and collect additional information on exotic species, a minimum of five plots should be assigned to each community. These should be randomly located prior to going in to the field using a minimum distance between points function (GME Spatial Ecology for ArcGIS) to ensure community coverage (Figure 5.1). As each wetland is typically a long and narrow ecological community, the minimum distance set between each plot defines the spatial extent and plot placement. Therefore, plot location is stratified to ensure broad spatial coverage of the whole community and to operate as ground control points for image validation, rather than focusing on a cross-sectional interpretation of geomorphology or hydrological patterns.

The THPSS boundaries delineated in VISMap2231 should be used initially to randomly locate the plots. Once on the ground the location of the plots may need to be adjusted to correct for THPSS boundary mapping and/or GPS location inaccuracies. Where random points are on or outside the boundary of the THPSS, plots should be moved the minimum distance required to fall 3m inside the boundary of swamp vegetation (as a useful guideline, we consider the boundary to be the point at which shrub and/or understorey vegetation cover in a sampling quadrat is dominated by amphibious and/or terrestrial damp habitat vegetation, see Section 6 below).

Minimum distance between plots should never exceed 100m to retain coverage, however, oversampling will lead to trampling and vegetation impacts due to the frequency of monitoring. Sampling number is therefore derived as a function of swamp dimensions rather than area. Plots are $1m^2$ centred on a star picket. Pickets should have post top markers so as they can be identified in the aerial imagery. This approach allows direct correlation of field observations with UAV imagery and also ensures on-ground observations are conducted at the extents of the community in all seasons. In each plot, an ecologist will record three variables:

1. percentage live vegetation (photosynthetically active plant material)
2. percentage non-vegetated area (bare ground, water, litter and standing dead biomass)
3. percentage cover of each exotic plant species

The percentages of live and non- vegetated area should sum to 100%. The plot data should be collected each time, and within a few days of collecting, the aerial imagery. Additional information should be collected where other possible changes are observed throughout the community using the data sheet in Appendix I.

## 5.3 Data analysis and trigger values

For each season, the newly derived orthomosaic image will be compared to the baseline thematic map to calculate the intersection between images (carried out using ArcGIS v10.1, ESRI, CA, U.S.A.). For each community the change in the variables related to trigger levels 1 and 2 listed below will be calculated from the maps and expressed as a percentage of total community area. Trigger level 3 is calculated using the exotic species cover from the ground control plot data. For each trigger level variable a single sample t-test comparing baseline with current data will be conducted, any significant differences ($p \leq 0.10$) will be reported.

**Trigger level:**

1. A reduction in live vegetation cover of more than 20% within the community compared with baseline data.
2. A single patch of non-vegetative cover greater than $400\text{m}^2$ doubles in size compared with baseline data.
3. A significant increase in exotic species cover compared with the baseline data.

It is important to compare current with baseline values with each community as these are highly variable systems. For example the total amount of land cover classified as non-vegetated can be similar between impacted and non-impacted sites. Sunnyside Swamp (control) has an estimated non-vegetated land cover of 29-34%, while East Wolgan (impacted by mine-waterdischarge) has an estimated non-vegetated land cover of 26% within the map boundary line (Appendix E). Therefore, we recommend that values for each community are compared with baseline (pre-undermining) data from that community, the differences between the pre- and post-impact values is the measure of change. A key performance indicator will be the relative change in bare ground between seasons, in the context of change experienced in other wetlands considered to be a suitable control.

## 5.4 Reported information and management actions

The reported information should include the change in values related to trigger levels (live vegetation cover, non-vegetated cover and exotic species cover). Values from both impacted and control swamp need to be reported to examine if the magnitude of change in the impacted swamps is outside the natural range.

If a trigger value is exceeded there are several measures to inspect prior to initiating a management action. The first is to investigate if a sudden increase in bare ground may have occurred from a tree falling into the community, or the development of 4x4 tracks. Secondly, investigate the aerial imagery as an explanation for a change in vegetation cover(*e.g.* ground sampling distance, flight conditions and camera equipment). A final course of action will be to initiate intensive sampling to ensure that a structural change has occurred. Seasonal variation is the exception and is expected, especially between winter and summer, to avoid change due to seasonal variation between-year comparisons should only be made within season (e.g. between summer—summer).

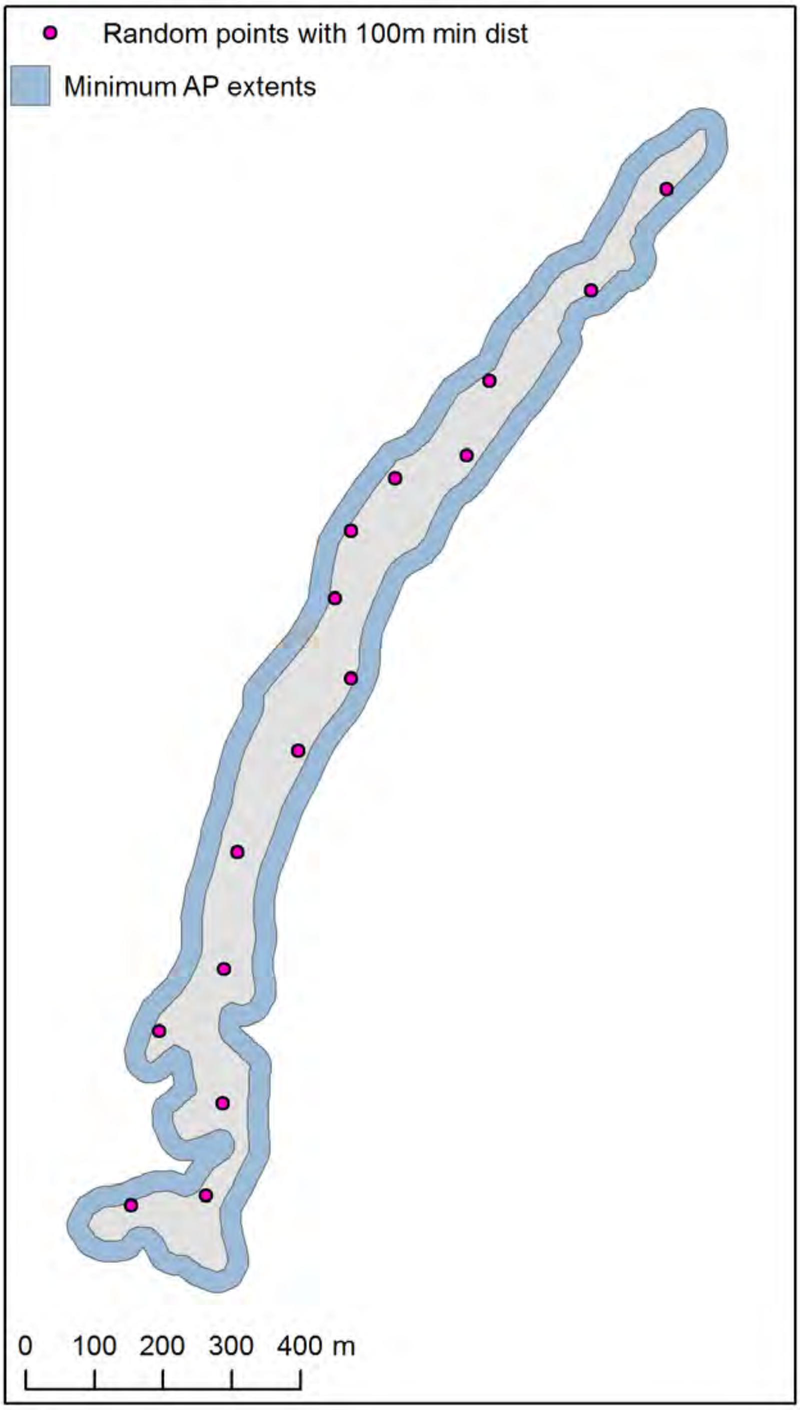

Figure 5.1: Diagram illustrating ground sampling protocols for each community. West Carne shrub swamp is provided as a case study. AP refers to the spatial extent of aerial photography. Monitoring plots are placed randomly at 100m minimum distance throughout each community. At each location, a single assessment plot sized $1m^2$ is inspected for live vegetation cover, dead/bare ground cover and exotic plant cover.

Table 5.2: Remote sensing collection and analysis parameters for the season monitoring program.

| **Remote Sensing Component** | **Specifications** |
|---|---|
| Spatial Resolution | <15cm |
| Temporal Resolution | Seasonal |
| Spectral Resolution | R,G,B,NIR |
| Products | Orthophoto, digital surface model |
| Object Based Image Analysis | eCognition multiresolution segmentation |
| Segmentation parameters | Scale 30, Shape 20, Compactness 30 |
| Change Detection | Pre-impact thematic polygons |

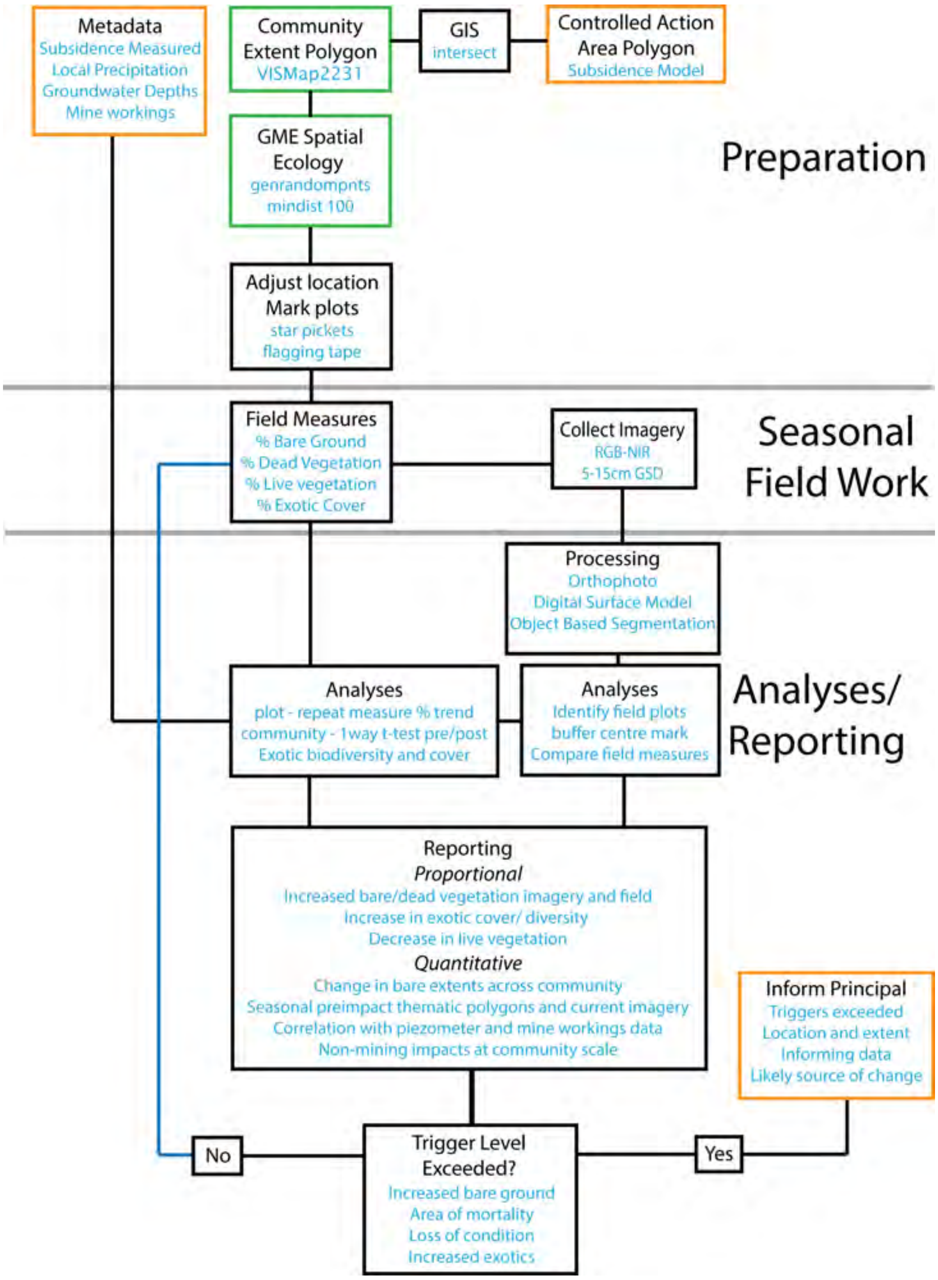

Figure 5.2: Work flow for monitoring preparation, seasonal monitoring and reporting. Orange boxes outline input required from or reporting to Centennial Coal. Green boxes are publicly available data or resources required. Black boxes are monitoring works conducted by contracted ecological/remote sensing service.

# 6. Annual monitoring

The annual monitoring is an intensive ground-based sampling effort. The sampling design is a series of 3 or more permanently marked transects spanning the width of each community. Along each transect, $1\text{m}^2$ plots are placed at set intervals. Within each plot, the percentage cover of each species is recorded along with percentage cover of bare ground. These data are then used to calculated changes in the indicator values to assess if triggers have been exceeded (Table 6.1). The work flow for the annual monitoring is outlined in Figure 6.1 and detailed below.

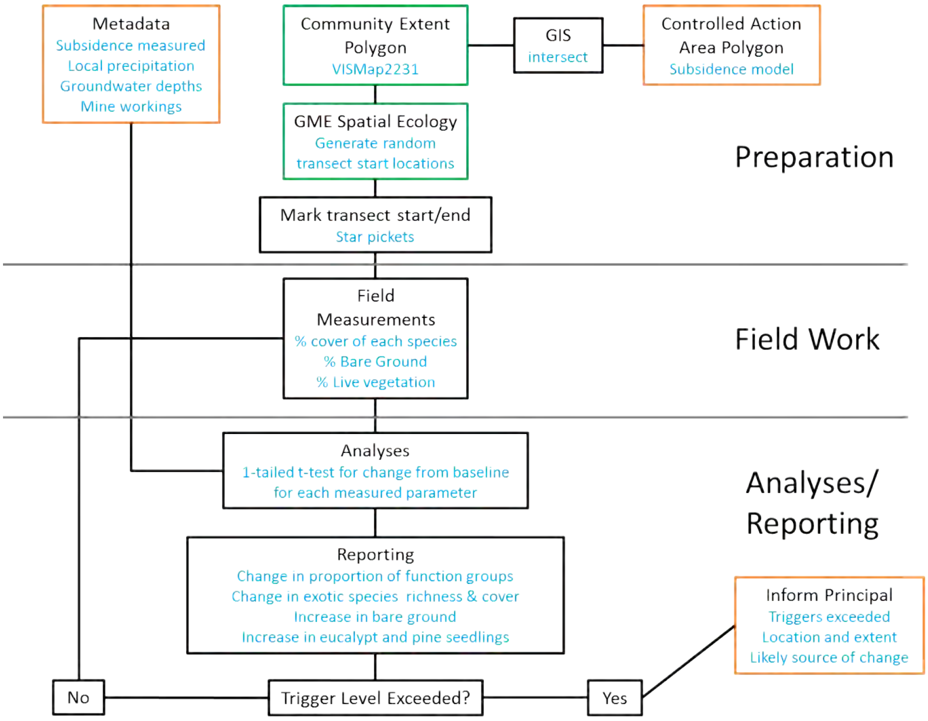

Figure 6.1: Work flow for annual monitoring preparation, monitoring and reporting. Orange boxes outline input required from or reporting to Centennial Coal. Green boxes are publicly available data or resources required. Black boxes are monitoring works conducted by contracted ecological/remote sensing service.

## 6.1 Transect sampling method

The sampling regime we outline here involves floristic data collection in small quadrats distributed along a number of fixed transects that span the full soil moisture gradient (from edge to edge) in each community, instead of the large fixed plots used in previous monitoring. Our reasons for recommending this transect-based method for future vegetation monitoring are outlined in Appendix F.

### 6.1.1 Initial site set-up and pilot study to determine required sampling intensity

When setting up new sites the sampling design should adhere to the following general principles:

- A minimum of 3 replicate samples (i.e. transects) are necessary per swamp to be able to detect changes in vegetation at specific swamps between surveys, or to compare vegetation between different swamps, using standard statistical methods.
- The initial number of transects set up per swamp to collect baseline data should be proportional to swamp area to ensure representative sampling of vegetation across the whole swamp i.e. replication will be higher in larger swamps. (One randomly positioned transect for every 200m of swamp length was found to be sufficient for this purpose in the pilot study outlined in Appendix G.)
- Transect start points should be positioned at the swamp edge using a stratified random sampling approach (e.g. after dividing the length of the swamp into sections, transect start positions should be located at a random point along the swamp edge, within each section).
- Transect start points should be determined before going into the field, to avoid unintentional sampling bias.
- During the initial baseline survey, 100cm x 100cm quadrats should be positioned at a sampling interval of approximately one quadrat per 4m. This sampling intensity has been demonstrated to be sufficient for detecting changes in the proposed indicator variables based on pilot study data (refer to Appendix G)

**Transect setup:**

- In the field, transect start points determined using wetland map layers in ArcGIS (e.g. VISMap 2231, New South Wales Office of Environment and Heritage; Information and Assessment Section, 2006) may need to be adjusted to correct for wetland boundary mapping and/or GPS location inaccuracies. Transect start and end points should be located at or just inside the swamp edge. As a useful guideline, we consider this to be the point at which shrub and/or understorey vegetation cover in a sampling quadrat is dominated by amphibious (Amp) and/or terrestrial damp habitat (Tda) vegetation (i.e. more than 50% of the vegetation cover present belongs to one of these categories).
- Transect start and end points should always be the same between monitoring surveys to ensure that comparable data are collected. Start and endpoints should therefore be marked with both stakes and waypoints during site set-up.
- A compass bearing should also be recorded from the start point and taken in the field for reference in future surveys, in case the end point is obscured by vegetation and/or GPS location accuracy is poor.
- Assessors should avoid walking directly through the areas where quadrats will be placed, for example by always placing quadrats slightly offset (e.g. 50cm upslope) of the walked transect line.

**Data to be collected:** An example data sheet is provided in Appendix H.

- **Metadata** including Date; Swamp ID; Transect ID; Quadrat No; Assessor; Photo number.
- **Identity and percent canopy cover of each shrub and understorey species present.** Total canopy cover per quadrat may sum to greater than 100% due to layering. Canopy cover should not be assessed for established trees (i.e greater than approximately 6m in height)
- **Extent of non-vegetated area (i.e. % of total quadrat area), divided into to the following sub-categories:**
    1. **The % of bare ground only** (i.e. areas with no overhanging shrub or understorey species present)
    2. **The % of leaf litter only** (i.e. only scored when there are no overhanging shrub or understorey species present)
    3. **The % of large woody debris only** (i.e. only scored when there is no overhanging or underlying shrub or understorey vegetation present)
    4. **The % of standing water only** (i.e. open water with no shrub or understorey vegetation present)
- **Extent of live green vegetation cover** (i.e. % of quadrat area that is covered by photosynthetically-active material)
- **Eucalypt and/or pine seedling presence and abundance** (i.e. % cover and total count of seedlings less than 1m height per quadrat)
- **Photos:** Photos should be captured from each transect start point, focused along the length of the transect. Photo location and direction must be the same for all survey times. Where the end stake is not visible, a compass should be used to ensure consistency in photo direction across surveys.
- **Site condition report:** At each swamp an overall appraisal of condition should be made, including any evidence of potential mining-related impacts not captured by transect-based sampling or indirect impact from recreational or forestry related surface activities. Where potential impacts are noted, GPS waypoints and photographs should be recorded along with a description of any evidence. A *pro forma* for recording site condition is provided in Appendix I.

## 6.2 Key indicator variables

Two types of indicators are proposed here: 1) changes in water plant functional group (WPFG) cover and 2) changes in vegetation structure and condition. Appendices L, N, M give detailed background information about how and why these indicators were chosen. Table 6.1 contains a summary of all variables recommended for monitoring understorey vegetation in Newnes Plateau swamps, and the directions in which these variables are expected to change if mining leads to a reduction in groundwater or surface flows. The preliminary trigger levels are defined in Table 6.2, with details on defining and revising trigger levels in Appendix K.

Table 6.1: Summary of indicator variables and changes to test for

| **Indicator of drying** | **Apply to:** | **Notes** |
|---|---|---|
| Increase in the extent of non-vegetated area | All sites | Does not include areas covered by standing water. |
| Decrease in the proportion of spatial area sampled that is scored as green (i.e. live photosynthetic) vegetation cover. | All sites | |
| Reduction in amphibious (A) vegetation as a proportion of total vegetation cover | All sites | |
| Increase in terrestrial dry habitat (Tdr) vegetation as a proportion of total vegetation cover | All sites | |
| Increase in terrestrial damp habitat (Tda) vegetation as a proportion of total vegetation | Sites dominated by amphibious vegetation before mining (i.e. wetter sites) | At these sites, drying would be expected to cause an increase in Tda and/or Tdr cover. |
| Decrease in Tda vegetation as a proportion of total vegetation cover | Sites dominated by Tda vegetation before mining (i.e. damp/dry sites) | At these sites drying would be expected to cause a reduction in Tda cover and/or an increase in Tdr cover. |
| Increase in exotic vegetation as a proportion of total vegetation cover | All sites | |
| Increased establishment of eucalypt and/or pine seedlings ($\leq$1m in height) | All sites | The validity of this variable as an indicator of drying in NPHS and NPSS requires further testing. |

Table 6.2: Preliminary trigger levels defined

| **Indicator of drying** | **Trigger level (preliminary only*)** | **Notes** |
|---|---|---|
| Increase in the extent of non-vegetated area (excluding areas covered by standing water) | 20% increase | |
| Decrease in the proportion of spatial area sampled that is scored as green (i.e. live photosynthetic) vegetation cover. | 20% reduction | |
| Reduction in amphibious (A) vegetation as a proportion of total vegetation cover | 30% reduction | At NS, SSE and BN, smaller changes i.e. =15% were able to be detected using the sampling regimes tested (Appendix G). |
| Increase in terrestrial dry habitat (Tdr) vegetation as a proportion of total vegetation cover | 10% increase | Pilot study data indicate that a change of this magnitude should be detectable across a range of sites. |
| Increase in terrestrial damp habitat (Tda) vegetation as a proportion of total vegetation | 10% increase | |
| Decrease in Tda vegetation as a proportion of total vegetation cover | 10% decrease | |
| Increase in exotic vegetation as a proportion of total vegetation cover | 10% increase | |
| Increased establishment of eucalypt and/or pine seedlings ($\leq$1m in height) | 30% increase in frequency (presence/absence in quadrats) | The validity of this variable as an indicator of drying in NPHS and NPSS requires further testing (refer to notes in previous section outlining rationale for indicator value selection). |

*Because these trigger values were derived using data from a small number of sites, they should currently be considered as preliminary only. While indicative of the range of effect sizes we can expect to detect at the sites that were surveyed, they will be refined when transect data have been obtained from a larger number of sites.

**A management response will be triggered if the following criteria are met:**

1. There is evidence from of a change in ground or surface water depth and stability or flow path at the site due to mine subsidence.
2. Analysis of vegetation survey data from an impact site demonstrates that a significant ($p \leq 0.10$) change has occurred, between surveys conducted before and after mining, that exceeds the trigger levels specified for one (or more) of the indicators of drying outlined in Table 6.2, and
3. Changes of an equivalent type, magnitude and direction have not occurred at any of the reference sites over the same time period.

## 6.3 Power analysis and optimisation of the sampling design

Power analysis of pilot study data is important at the initial stages of monitoring, both for ensuring that sampling is adequate to detect a change of the magnitude desired and also for streamlining, to ensure that sampling effort is not unnecessarily high (Downes et al., 2002). After the initial baseline survey is complete, the sampling regime can be refined based on the results of post-hoc power analyses (Downes et al., 2002; Quinn and Keough, 2002). For example, in very wide swamps, it may be possible to reduce transect length to half the swamp width (i.e. from edge to centre) to reduce sampling time. Such adjustments to sampling design (numbers of transects per site, sampling intervals within transects and full vs half width transects) may be made, provided it can be demonstrated that enough statistical power is retained to detect if a trigger level has been exceeded.

Conversely, if analysis of pilot study data shows that power to detect a change is poor and that additional sampling is required, these adjustments should be made and data collected according to the finalised monitoring design at least once before any potential mining impact occurs. Before/After comparisons testing for changes over time at the within-swamp scale should be made using equivalent numbers of samples per monitoring survey. On this basis, it is better to deliberately oversample during the initial baseline/preliminary/pilot survey than to under sample. If it is found that a site has been under-sampled (i.e. the design is not sensitive enough to detect if a trigger level has been exceeded), an additional survey will be required (preferably in the same season/year) to set up more transects. However, if surplus samples are collected some of these may be discarded later to reduce the field sampling time required in subsequent surveys, once it has been shown via a post-hoc power analysis that this will not have an impact on ability to detect change (Downes et al., 2002).

## 6.4 Guidelines for data analysis and reporting

The power analyses we have trialled, using Newnes Plateau transect data, were based on testing for differences between two points in time (i.e. monitoring surveys) at the individual site scale, using one-tailed paired-sample t tests (i.e. before vs after). A t-test was selected here because it is simple to perform and has greater power to detect (before/after impact) changes than an equivalent ANOVA test (Downes et al., 2002). We recommend analysing future monitoring data using a similar approach, as follows:

- Total values for each indicator variable should be determined at the individual transect scale, as per the methodology outlined in Appendix J. **(Note: When assessing**

**changes in vegetation cover, only shrub and understorey cover are included. Canopy cover from overhanging trees (e.g. mature eucalypts) should be excluded.)**

- For each impact swamp, a one-tailed t test should be used to test for significant differences between indicator values obtained in the current survey and those obtained from the baseline before-impact survey.
- If a significant change is detected between these times at an impact site, then data collected from reference sites at the same time points should also be tested (i.e. site by site, comparing the same two survey times) to determine if a change of the same direction and magnitude has occurred in the same time period at any of these non-mining-impacted sites.

The report should include what (if any) change in indicator value(s) was found for both impact and control swamps, with an indication of which (if any) swamps exceed the trigger values. In addition any recommendations for adjustments to trigger values required should also be listed. The preliminary trigger levels are defined in Table 6.2, with details on defining and revising trigger levels in Appendix K.

# 7. Time and Resources required

## 7.1 Seasonal monitoring

Initial (manual) classification of imagery is time consuming (approx. 2 days per swamp community × 1 person), however subsequent analysis is rapid (1 hour per swamp community × 1 person). Each season, four swamp communities per day (two people) for the field work and five office days (1 person) to carry out data analysis and report writing (Table 7.1).

## 7.2 Annual monitoring

The initial intensive on the ground monitoring will require roughly 1 day (2 people) of field time per community. However once the initial data have been analysed and the number of transects and the quadrat spacing adjusted (roughly 1 hour of office time per community, 1 person), the subsequent surveys should only require half day (2 people) of field time per community. Data analysis and reporting will require five office days (1 person, Table 7.1).

Table 7.1: Estimated number of person days required for each component of the monitoring method

| Survey type | Location | Component | Person days required per swamp |
|---|---|---|---|
| Seasonal | Field | Image capture | 0.25 |
| | | Ground survey | 0.25 |
| | Office | Initial image classification | 2 |
| | | Image re-classification | 0.1 |
| | | Data analysis and reporting | 0.1 |
| Annual | Field | Initial transect survey | 2 |
| | | Re-survey of transects | 1 |
| | Office | Initial data analysis | 0.1 |
| | | Data analysis and reporting | 0.1 |

# 8. Data management and storage

Maintaining data integrity is a key component of a long term monitoring program. For all data types, *e.g.* imagery and floristic data, it is very important to have the complete meta-data including date of collection, location of collection, assessor/recorder, how the data were collected and what post-collection processing was conducted. In the case of species data a link to a voucher specimen and which species identification keys were used to identify the plant should also be included. Great care should be taken in maintaining consistent species names as variation in naming protocols can lead to false change in the data set. For the imagery, metadata should also include altitude and camera information.

Before the data are stored and/or analysed they should be checked for completeness (have all data been collected and have the metadata been filled in completely) and accuracy (*e.g.* species percentage cover values are within a realistic range). Data should be stored in a digital format that is easily assessed by non-proprietary software (*e.g.* .txt or .csv file types) and in multiple locations (*e.g.* in different buildings and/or different computer systems).

# 9. Summary

This document proposes a monitoring program for the NPSS and NPHS that is robust and statistically valid. The proposed method vastly improves the current method employed for monitoring (Appendix C) and more than meets the requirements laid out in the DSEWPAC condition 7 (Appendix B). As a result this program may be applied to meet the monitoring requirements of both state and federal governments for evaluating potential mining related impacts to swamps on the Newnes Plateau.

The two components, named here ”Seasonal” and ”Annual” for their suggested timing together make up a very robust program. An alternative application of these two components is the Annual intensive ground based method is applied once before undermining and then again once a trigger value has been reached in the Seasonal aerial monitoring. We do not recommend the Annual intensive ground survey being conducted more than once per year as this is likely to cause negative impacts to the NPSS and NPHS vegetation.

# 10. Acknowledgments

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# A Research completed by the University of Queensland underpinning the methodology proposed in the draft Newnes swamp vegetation monitoring handbook:

**Research completed by the University of Queensland underpinning the methodology proposed in the draft Newnes swamp vegetation monitoring handbook:**

Testing the effectiveness of subjective estimates of cover/abundance using BB methodology for change detection in Newnes plateau swamp vegetation. Manuscript submitted Dec 2013(Blick et al. In prep.-a).

Experimental methods for detecting and quantifying weed abundance at a community scale (strip adaptive, transect intercepts, 1m2, large plot searches). Work completed October 2012 - June 2013. Manuscript to be submitted early 2014 (Blick et al. In prep.-c).

East Wolgan UAV ground survey proof of concept (July 2013). Manuscript in review *Biodiversity and Conservation* (Blick et al. In prep.-b)

Pilot study: eCognition for vegetation cover and condition for monitoring handbook recommendations (November 2013)

Cleaning and compilation of historical BB and PIM monitoring data into a relational database, to ensure comparability of nomenclature across datasets and facilitate statistical comparison of data between surveys (mid-late 2012) These data were subsequently supplied to Centennial Coal for Envirosys, to comply with SEWPaC conditions for Longwall panels 415-417.

Classification of Newnes Plateau wetland plant species into functional groups based on water requirements (literature & herbarium database records review, completed late 2012-mid 2013).

Validation of wetland plant functional group (WPFG) classification in glasshouse experiment: Effects of water table depth and stability on germination, establishment and survival of native and exotic macrophytes in highland temperate peat swamps (soil collection early 2013, experiment mid-late 2013, manuscript in preparation for submission mid 2014 (Johns et al. In prep.-b)).

Demonstrated effectiveness of WPFG as indicators for detecting differences in swamp vegetation due to differences in hydrology, using Newnes field data (late 2013). Manuscript in preparation for submission early 2014 (Johns et al. In prep.-c).).

Testing methodology for statistically rigorous ecological monitoring of shrub swamp communities using quantitative data:

> (a) Mini-plots- seven swamps assessed with approximately 350 1m2 plots (data collected in summer 2012-2013, including species abundance, soil moisture and peat depth).
>
> (b) Transects - 4 swamps at two time points with two observers, six plot sizes and 20 transects in total (data collected Autumn 2013).
>
> (c) Test of plot size and distribution required for biodiversity capture - manuscript demonstrating BB plots only capture general characteristics, suitable for mapping but not monitoring (submitted to *Wetlands,* late 2014 (Brownstein et al. In review)).

(d) Ecotones as indicators: Manuscript examining changes across swamp edge as a monitoring tool to detect community change. In preparation for submission to *Journal of Vegetation Science* in early 2014 (Brownstein et al. In prep.).

(e) Expansion of current 400m$^2$ to demonstrate monitoring capacity of current method under replication (4 swamps sampled with up to 8 new plots each, Autumn 2013). Manuscript submitted to *Wetlands* late 2014 (Brownstein et al. In review).

(f) Comparison of functional group classification methods for describing vegetation differences associated with hydrology on the Newnes Plateau. Manuscript in preparation for submission to *Freshwater Biology* in early 2014 (Johns et al. In prep.-c).

(g) Transect based sampling regime to detect hydrological change in shrub swamp communities: Sampling design and statistical power considerations. Manuscript in preparation for submission to *Applied Vegetation Ecology,* mid 2014 (Johns et al. In prep.-a).

**Manuscripts in preparation or submitted:**

Blick, R.A.J., Brownstein, G., Johns, C.V., Bricher, P., Fletcher, A. & Erskine, P. In prep.-a. Should ecologists have access to site information prior to floristic surveys? *In preparation for submission to Methods in Ecology and Evolution*.

Blick, R.A.J., Fletcher, A. & Erskine, P. In prep.-b. Assessing vegetation impacts and informing restoration: A role for unmanned aerial systems. *Submitted to Biodiversity and Conservation December 2013*.

Blick, R.A.J., Johns, C.V., Brownstein, G., Fletcher, A. & Erskine, P. In prep.-c. Are adaptive sampling strategies appropriate for monitoring weed abundance in subalpine shrub swamps? *In preparation for submission to Ecological Management and Restoration*.

Brownstein, G., Blick, R., Johns, C., Bricher, P., Fletcher, A. & Erskine, P. In review. Many small vs few large: Applying species-area relations in sampling heterogeneous wetlands. *Submitted to Wetlands*.

Brownstein, G., Johns, C.V., Pritchard, D., Fletcher, A. & Erskine, P. In prep. Ecotones as indicators: Do they have potential as a monitoring tool for wetland plant communities? *In preparation for submission to Journal of Vegetation Science*.

Johns, C., Brownstein, G., Blick, R., Fletcher, A. & Erskine, P. In prep.-a. Development of a transect-based sampling regime to detect changes in shrub swamp communities: Sampling design and power considerations. *In preparation for submission to Applied Vegetation Ecology*.

Johns, C., Fletcher, A. & Erskine, P. In prep.-b. The effects of water table depth and stability on establishment and persistence of wetland macrophytes from Newnes Plateau wetland soil seed banks. *Manuscript being prepared for submission to Aquatic Botany*.

Johns, C.V., Brownstein, G., Blick, R., Fletcher, A. & Erskine, P. In prep.-c. Detecting the effects of water regime on wetland plant communities: Which plant functional groups perform best? *In preparation for submission to Freshwater Biology*.

# B Flora Monitoring Requirements Springvale EPBC

Australian Government

Department of Sustainability, Environment, Water, Population and Communities

## Approval

Mining of Longwalls 415, 416 and 417 at Springvale Colliery, NSW, EPBC 2011/5949

This decision is made under sections 130(1) and 133 of the *Environment Protection and Biodiversity Conservation Act 1999*.

### Proposed action

| | |
|---|---|
| **person to whom the approval is granted** | Springvale Coal Pty Ltd |
| **proponent's ACN (if applicable)** | 052096769 |
| **proposed action** | Coal extraction using longwall mining techniques of three longwall panels at the existing Springvale Mine, including Longwalls 415–417 [See EPBC Act referral 2011/5949]. |

### Approval decision

| Controlling Provision | Decision |
|---|---|
| Listed threatened species and communities (sections 18 & 18A) | Approved |

### Conditions of approval

This approval is subject to the conditions specified below.

### expiry date of approval

This approval has effect until 19/03/2032

### Decision-maker

| | |
|---|---|
| **name and position** | The Hon Tony Burke MP<br>Minister for Sustainability, Environment, Water, Population and Communities |
| **signature** | Tony Burke |
| **date of decision** | 14.3.12 |

**Conditions attached to the approval**

1. Unless agreed by the minister in writing, longwall mining is not to be undertaken in areas directly below known **high quality** sites of temperate highland peat swamps on sandstone or within approved buffer zones (as per condition 2). If at any time the person taking the action seeks the **minister's** agreement to vary this condition the person taking the action must demonstrate in writing that a proven technology or engineering methodology will be used for the proposed longwall mining that prevents **severe impacts** of **subsidence** on temperate highland peat swamps on sandstone, or that would allow any **severe impacts** on temperate highland peat swamps on sandstone to be successfully remediated.
2. Within three months of the date of this approval, the person taking the action must submit details of proposed buffer zones around **high quality** temperate highland peat swamps on sandstone for the **minister's** approval. The buffer zones must be approved by the **minister** before mining of longwalls 416 and 417 can commence.
3. The person taking the action must monitor **subsidence** resulting from the proposed longwall mining in accordance with the *Springvale Colliery Subsidence Management Plan: Proposed Subsidence Monitoring and Reporting program LW415 to 417* to monitor **subsidence** effects on the endangered temperate highland peat swamps on sandstone ecological community.
4. If **anomalous subsidence** is detected within 200 metres of an area of temperate highland peat swamps on sandstone ecological community using the method defined in condition 3, the person taking the action must submit to the **department** a report detailing:
    a) the extent and level of **subsidence** recorded
    b) likely reasons for the **anomalous subsidence**
    c) potential **impacts** on the temperate highland peat swamps on sandstone ecological community resulting from the **anomalous subsidence**.
5. The report in condition 4 must be submitted to the **department** within 10 business days of detecting the **anomalous subsidence**.
6. Within six months of the date of this approval, the person taking the action must submit a Temperate Highland Peat Swamps on Sandstone Monitoring and Management Plan ('Monitoring and Management Plan') for the **minister's** approval, to define clear, quantifiable and measurable criteria for monitoring the **impact** of longwall mining on temperate highland peat swamps on sandstone.
7. The Monitoring and Management Plan must include prevention, monitoring, mitigation and management actions for all potential **impacts** on the temperate highland peat swamps on sandstone ecological community arising from the action. The Monitoring and Management Plan must be a stand-alone document and include but not be limited to:
    a) monitoring must take into account the geological and hydrological context in which the swamps sit, i.e. monitoring must include methods to detect potential geological and hydrological impacts upstream of temperate highland peat swamps on sandstone
    b) monitoring must focus on surface and groundwater hydrology (including at least one piezometer per swamp), surface and groundwater quality, vegetation community structure and diversity, and biological indicator species
    c) monitoring must include at least one sample per season (four samples per year) at each sampling location for each parameter measured, though more frequent sampling may be required for some parameters
    d) monitoring post-mining must continue for a period of at least 10 years. Monitoring frequency may be reduced once three years of post-mining swamp monitoring has been undertaken if swamp condition has not degraded as a result of mining activity

e) monitoring must include all temperate highland peat swamps on sandstone (including but not limited to both Newnes Plateau Shrub Swamps and Newnes Plateau Hanging Swamps) potentially affected by the proposed action (**impact sites**) as well as **reference sites**. **Reference sites** must include temperate highland peat swamps on sandstone that have never been subjected to, or are not predicted to be impacted by, **subsidence** impacts

f) details of the parameters monitored, methods, timing, frequency and location of baseline monitoring within the temperate highland peat swamps on sandstone ecological community

g) definition and description of baseline conditions of individual temperate highland peat swamps on sandstone (including both **impact** and **reference sites**), including biological processes, condition, threats and the range of natural variability observed in parameters monitored

h) trigger levels sufficient to detect potential **impacts** of **subsidence** on the temperate highland peat swamps on sandstone ecological community, including information on how the triggers were derived using baseline monitoring and desktop study data. Triggers should be specific and measureable

i) details of the parameters monitored, methods, timing, frequency and location of **reference site** monitoring within the temperate highland peat swamps on sandstone ecological community

j) allowance and methods for trigger levels to be refined as more monitoring data is collected

k) details of the parameters monitored, methods, timing, frequency and location of **impact site** monitoring within the temperate highland peat swamps on sandstone ecological community, sufficient to detect changes in the defined trigger levels

l) corrective actions to be taken should the defined trigger levels (as at condition 7h) be exceeded. These should be clear, measurable, auditable and include specific timing (e.g. within 6 months of **impact** detection). Implementation of a Response Strategy (as required at condition 13) should be included as a corrective action should **severe impacts** be detected.

m) details of how data collected by the proposed monitoring methods will be analysed. This must include a method to analyse data sets in an holistic manner to produce an overall indication of swamp health

n) description of how potential **impacts** arising from the monitoring and mitigation measures themselves will be minimised or avoided

o) maps illustrating the location of the longwall mining activity, past mining activities, expected **subsidence** limits, location of temperate highland peat swamps on sandstone within a 5 kilometre radius of the longwall mining activity, and past and proposed monitoring locations for all parameters

p) description of record keeping and reporting procedures

q) the plan must clearly state the person responsible, including their position or status

r) the plan must include a timeline for review, and provision for revisions to be approved by the **department** prior to their implementation

8. The Monitoring and Management Plan must be reviewed by two **independent reviewers** approved by the **department** prior to the submission to the department for approval.

9. If the **minister** approves the Monitoring and Management Plan then the approved Monitoring and Management Plan must be implemented.

10. A report detailing the results of actions carried out under the Monitoring and Management Plan must be prepared and provided to the **department** annually on the anniversary of the date of this approval. The **minister** may request that the report be reviewed by an **independent reviewer** approved by the **department**.

11. The person taking the action must, when first becoming aware of an **impact** to temperate highland peat swamps on sandstone:
    a) when the **impact** is a defined trigger level (as defined in condition 7h) being exceeded, report the **impact** to the Department within five business days
    b) when the **impact** is a defined trigger level (as defined in condition 7h) being exceeded, report the implementation of the corrective action (as defined at condition 7l) within such time as is reasonable in the circumstances, unless required to report outcomes within a time frame specified in writing by the department
    c) when exceedence of a trigger level is not detected, but an **impact** is apparent, report the **impact** to the department within 20 business days with details of proposed corrective actions
    d) in all of the above cases (conditions 11a to 11c inclusive), provide the results of monitoring data relating to the **impact** and an explanation of the expected cause of the impact.

12. If at any time the **minister** determines that data provided in the report at condition 10 or 11 indicates that the action has had a **severe impact** on the temperate highland peat swamps on sandstone ecological community and/or any associated threatened species, the **minister** will inform the person taking the action in writing ('the **severe impact** notification letter'), particularising all **severe** impacts. Once the person taking the action receives the **severe impact** notification letter, conditions 13 to 18 (inclusive) will apply.

13. When the person taking the action receives a **severe impact** notification letter, the person taking the action must prepare and submit a Temperate Highland Peat Swamps on Sandstone Response Strategy (the 'Response Strategy') for the **minister**'s approval within three months of the date of the letter.

14. The Response Strategy must include measures for remediating or offsetting all **severe impacts** particularised by the Minister on the temperate highland peat swamps on sandstone ecological community arising from the action. The Response Strategy must be a stand-alone document and include but not be limited to:
    a) a description of the **severe impact** including extent, duration, and expected cause. This should include a description of how the **impact** may affect temperate highland peat swamps on sandstone
    b) the objectives of the Response Strategy
    c) the proposed response actions to be taken and how the proposed actions will be implemented
    d) a description of how the strategy will deliver an overall conservation outcome that improves or maintains the viability of temperate highland peat swamps on sandstone and associated threatened species
    e) the estimated cost of all proposed response actions
    f) the strategy must clearly state the person responsible for implementing remediation actions, including their position or status and contact details
    g) description of record keeping and reporting procedures

15. The Response Strategy must be reviewed by two **independent reviewers** approved by the **department** prior to the submission to the department.

16. If the **minister** approves the Response Strategy then the approved Response Strategy must be implemented.

17. A report detailing the results of actions carried out under the Response Strategy must be prepared and provided to the **department** at a time agreed to in writing by the **department** upon receiving the Response Strategy. The report must be reviewed by an **independent reviewer** within a timeframe determined in agreement with the department prior to being provided to the department.

18. The person taking the action must, if required in writing by the minister, stop all work associated with the proposed action within sixty days of the date of the letter referred to in condition 12. Work may be resumed if indicated in writing by the **minister**.

19. If at any time the **minister** determines in writing that s/he is not satisfied that adequate financial arrangements are in place to ensure that a Response Strategy (as required under condition 13) could be implemented, the **minister** may require the person taking the action to provide an arrangement (in the form of a bond, financial guarantee or similar arrangement (in these conditions 'a bond')), as directed by the **minister**.

20. The value of a bond that may be required by the **minister** under condition 19 is the amount determined by the **minister** as required to implement of a Response Strategy.

21. The **minister** may increase or decrease the bond amount required where the person taking the action has increased or decreased, respectively, the liability.

22. In providing for or varying a bond amount in accordance with these conditions, the **minister** may request the person taking the action to obtain written quotes for the cost of potential actions under the Response Strategy from a third party approved by the **minister** within a timeframe determined in agreement with the department.

23. The bond is to remain in force until the **minister** is satisfied that no claim is likely to be made on the assurance.

24. The person taking the action must meet all the charges and costs in obtaining and maintaining the bond.

25. The person taking the action must meet all the charges and costs associated with independent review of documents required under these conditions.

26. The person taking the action must publish all documents required under these conditions on their website, except where agreed in writing with the **department** on grounds of potentially sensitive commercial information.

27. Within 30 days after the **commencement** of the action, the person taking the action must advise the **department** in writing of the actual date of **commencement**.

28. The person taking the action must maintain accurate records substantiating all activities associated with or relevant to the conditions of approval, including measures taken to implement the management plans, report, strategy, etc. required by this approval, and make them available upon request to the **department**. Such records may be subject to audit by the **department** or an independent auditor in accordance with section 458 of the EPBC Act, or used to verify compliance with the conditions of approval. Summaries of audits will be posted on the **department**'s website. The results of audits may also be publicised through the general media.

29. Within three months of every 12 month anniversary of the **commencement** the person taking the action must publish a report on their website addressing compliance with each of the conditions of this approval, including implementation of any management plans, report, strategy etc. as specified in the conditions. Documentary evidence providing proof of the date of publication and non-compliance with any of the conditions of this approval must be provided to the **department** at the same time as the compliance report is published. The person taking the action must also notify any non-compliance with this approval to the department in writing within two business days of becoming aware of the non-compliance.

30. Upon the direction of the **minister**, the person taking the action must ensure that an independent audit of compliance with the conditions of approval is conducted and a report submitted to the **minister**. The independent auditor must be approved by the **minister** prior to the commencement of the audit. Audit criteria must be agreed to by

the **minister** and the audit report must address the criteria to the satisfaction of the **minister**.

31. If the person taking the action wishes to carry out any activity otherwise than in accordance with the management plans report, strategy etc, as specified in the conditions, the person taking the action must submit to the **department** for the **minister**'s written approval a revised version of that management plan, report, strategy etc. The varied activity shall not commence until the **minister** has approved the varied management plan, report, strategy etc in writing. The **minister** will not approve a varied management plan, report, strategy etc unless the revised management plan, report, strategy etc would result in an equivalent or improved environmental outcome over time. If the **minister** approves the revised management plan, report, strategy etc that management plan, report, strategy etc must be implemented in place of the management plan, report, strategy etc originally approved.
32. If the **minister** believes that it is necessary or convenient for the better protection of threatened species and communities to do so, the **minister** may request that the person taking the action make specified revisions to the management plan, report, strategy etc specified in the conditions and submit the revised management plan, report, strategy etc for the **minister**'s written approval. The person taking the action must comply with any such request. The revised approved management plan, report, strategy etc must be implemented. Unless the **minister** has approved the revised management plan, report, strategy etc. then the person taking the action must continue to implement the management plan, report, strategy etc. originally approved, as specified in the conditions.
33. If, at any time after two years from the date of this approval, the person taking the action has not substantially **commenced** the action, then the person taking the action must not substantially commence the action without the written agreement of the **minister**.
34. Unless otherwise agreed to in writing by the **minister**, the person taking the action must publish all management plan, report, strategy etc referred to in these conditions of approval on their website. Each management plan, report, strategy etc must be published on the website within one month of being approved.

### Definitions

**Anomalous subsidence:** any and all ground movements that result from mining in excess of that predicted to impact the temperate highland peat swamps on sandstone ecological community (Longwall 415: 1.5 metres of subsidence, 6-10 millimetres per metre of maximum panel tilt, maximum compressive strains of 18 millimetres per metre and maximum tensile strains of 15 millimetres per metre. Longwalls 416 and 417: 1.1 metre of subsidence, 4–7 millimetres per metre of maximum panel tilt, 3–6 millimetres per metre maximum compressive strain [with a maximum of 14 millimetres per metre maximum compressive strain in alluvium-filled valleys] and 2–5 millimetres per metre of maximum tensile strain).

**Commencement:** The extraction of coal associated with the proposed longwalls.

**Department:** The Australian Government Department administering the *Environment Protection and Biodiversity Conservation Act 1999*.

**High quality:** pertaining to temperate highland peat swamps on sandstone, this means those parts of Sunnyside East and Carne West swamps as marked on the map at Appendix 1 to this approval.

**Impact/s:** as defined in section 527E of the EPBC Act.

**Impact site/s:** a site/s potentially subject to impacts of the action.

**Independent Reviewer/s:** third party/parties with relevant experience and background, not associated with any party involved in the action.

**Minister:** The Minister administering the *Environment Protection and Biodiversity Conservation Act 1999* and includes a delegate of the Minister.

**Reference site/s:** a site/s not likely to be subject to impacts of the action

**Severe Impacts:** Impacts to temperate highland peat swamps on sandstone that indicate a long-term change in swamp hydrology, water quality or flora composition. This includes fracturing of the rock strata beneath the swamp, evident through an extended (longer than that recorded in reference sites during the same time period) reduction in groundwater levels.

**Subsidence:** any and all ground movements that result from mining.

# C Flora monitoring statutory conditions Angus Place including East Wolgan shrub swamp March 2006

- Ridge between Narrow Swamp and East Wolgan Swamp - 1 piezometer to a depth of 54 m.

All groundwater piezometers are shown on **Figure 2**.

**Frequency**

All swamp piezometers are monitored continuously for water level, and the logged data is downloaded manually every two months. The ridge piezometers will initially be monitored for water level at two monthly intervals. When one of these bores is within the zone of influence of an active longwall panel, instrumentation will be installed to allow continuous water level monitoring until the influence of mining (if any) has ceased.

Angus Place currently engages Connell Wagner to download, manage and analyse data.

**Analysis of Results**

The results from the monitoring program will identify potential effects from longwall mining or rainfall and will be correlated with the results from the relevant subsidence line monitoring results and the relative position of the longwall. All this data will assist in explaining any changes in groundwater levels.

Connell Wagner will prepare a short report every two months to present the analysis of the monitoring results. A more detailed report presenting all the data from the year will be prepared on an annual basis.

It is worth noting that the new piezometer within the West Wolgan North Extension area was installed approximately eight weeks prior to its affectation by subsidence. Consequently, there will be minimal baseline data to compare results and understand the response to climatic variations. The objective of installing the piezometer and subsequent gathering of data is to understand the potential impact from subsequent longwall extraction. It is noted that should drought conditions continue to prevail, the monitoring results will be complicated in terms of fulfilling the original objective.

## 7.3 Flora

**Location**

Vegetation monitoring will continue to be carried out in each swamp using manual inspection of quadrats (400m$^2$). Flora monitoring locations, parameters and reporting details are detailed in the EMP (**Appendix 1**, **Section 6.2**). The number of quadrats per swamp is summarised below.

- West Wolgan Swamp – 2 vegetation monitoring quadrats established in 2002.
  2 additional vegetation monitoring quadrats established in 2004
- West Wolgan North Ext.[4] – 2 vegetation monitoring quadrats to be established in 2006
- Narrow Swamp – 4 vegetation monitoring quadrats established in 2004 (one located at edge).
- East Wolgan Swamp – 2 vegetation monitoring quadrats established in 2005

**Frequency**

Monitoring is carried out seasonally during Summer, Autumn, Winter and Spring.

**Rationale**

This special sub-section has been included as a request by DEC during the consultation process.

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[4] The DEC Draft vegetation mapping identified this area to be a further potential swamp. Upon confirmation of this mapping, consider review of West Wolgan North Extension area. The monitoring sites have been installed as requested by DEC.

The experimental design seeks to ensure that there is sufficient power to effectively detect changes in vegetation structure, composition and condition. Paired quadrats are used at sampling sites to allow comparison between quadrats located within and at the margin of swamp vegetation. Regionally there are a number of control swamp quadrats including four at Carne West Swamp, two at Sunnyside Swamp and two at Prickly Swamp. The two quadrats at Kangaroo Creek Swamp, whilst already the subject of mining, provide a level of control as they provide an indication of the response of swamp vegetation to ongoing climatic conditions. Relevant literature regarding vegetation dynamics and monitoring have been reviewed in an effort to ensure that the techniques applied will meet the monitoring objectives.

Careful thought was given to the potential application of more intensive flora monitoring (including the tagging of individual plants), but this has not been adopted to date as it was considered that it would not lead to any significant additional power in terms of detection of the relatively localised and temporary changes predicted in the risk assessment process, and there would be a disproportionate increase in the amount of time involved in collecting and maintaining data. Flora monitoring techniques will be further reviewed in light of future survey results and as new techniques for analysis emerge.

Indicator species will be determined as part of the review of monitoring results up until the end of 2005. In identifying indicator species, regard will be paid to those species which are increasing or decreasing in abundance, exotic species and species which typically occur along swamp margins or in woodland communities close to swamp margins.

### Analysis of Results

Flora monitoring results will be analysed to determine species diversity and abundance. These results will be correlated with the groundwater monitoring results, photographic monitoring results, rainfall records, subsidence line survey results and the relative locations of the longwalls. All this data will assist in explaining any potential changes in species diversity, composition and vegetation health. If threatened species are located/reported within the Swamps, specific monitoring for each species will be conducted during subsequent surveys.

Angus Place currently engages Gingra Ecological Services (Roger Lembit) to undertake the monitoring detailed in this Section. A report will be prepared following each monitoring session with a more comprehensive report prepared annually.

## 7.4 Fauna

### Location

Fauna monitoring will be carried out in each swamp using trapping techniques, call broadcasting and manual inspections. Fauna monitoring locations, frequency and reporting details are detailed in the EMP (**Appendix 1**). The number and locality of sites is summarised below:

- West Wolgan Swamp – 1 site.
- Narrow Swamp – 1 site.
- East Wolgan Swamp – 1 site.

Additional detail on the Fauna monitoring program (including GPS locations of quadrats can be found in **Section 6.3** of the EMP (**Appendix 1**).

### Frequency

The sites are surveyed during Autumn (good for mammals – March), Spring (good for birds, mammals and reptiles – September/October) and Summer (good for birds, amphibians and reptiles – December/January). Additionally, targeted searches will be carried out for threatened species during the seasons where they are most active.

### Analysis of Results

# D Addressing the limitations of the current methodology

**Could small adjustments to the current monitoring design address the short falls?**

**Brief Outline of Problem:** A key objective of the monitoring program is to detect change in the Newnes Plateau THPSS. The current monitoring design consists of 53 400m$^2$ plots spread over 27 swamps, with between one and six plots per swamp. At each plot all species are recorded and assigned a cover/abundance category (based on a modified Braun-Blanquet scale).

Replication is currently missing in 12 of the 27 swamps, and nine of the 27 swamps have only two plots. Replication is needed to test for statistically significant changes in any vegetation parameter. When sampling from a homogeneous area three replicates are considered the minimum, though the data have shown that these swamps not homogeneous. We ask the question; would 3 to 10 replicate 400m$^2$ plots (scaled to size of swamp) provide sufficient replication to detect a change in vegetation structure of 20%, with a power of $\geq 0.80$ at a significance level of $p \leq 0.10$?

A second problem requiring assessment is the use of a modified Braun-Blanquet scale (ordinal data type), which restricts the statistical methods and analysis. For example, it is not possible to add scores together to get a total cover value using categorical data. We addressed this problem by testing if the categorical estimates are precise enough for this monitoring program.

**Question 1:** Can increasing the number of 400m$^2$ plots in a swamp provide enough detail to meet the requirements of the monitoring program?

**Question 2:** Are the measurements obtained from 400m$^2$ plots sufficiently precise to allow detection of an ecologically appropriate effect size (i.e. are statistically significant changes able to be detected while impacts remain small to moderate)? The vegetation measures examined:

- Species diversity
- Proportional abundance of wetland vs non-wetland species
- Weed species diversity and abundance
- Eucalypt seedling encroachment
- Extent of bare ground

**Methods:** The number of 400m$^2$ plots per swamp was increased to one plot for every 100m swamp edge, with a minimum of three plots per swamp. Due to the area of the plot, in the smaller swamps (West Wolgan North and Bungleboori North) the sampling area was nearly equal to the swamp area. Original refers to plots included in the current monitoring program. Expanded refers to the combination of original and the additional plots sampled for this test. For the purpose of this test weeds and weedy species are defined as exotic species, eucalyptus seedlings and native species that often colonise disturbed areas.

**Results:**
**Species Richness:** The total number of species found across all swamps was 152 species. With the increase in number of plots, the total number of species found per swamp increased

(on average by 25 species), with the greatest increase seen in Sunnyside East where the greatest number of plots were added and new habitat types were sampled (Table 1).

The mean number of species per plot tended to be slightly higher in the expanded data set (Table 10.1). With the expanded data set, the variance in number of species per plot increased (again due to sampling a greater number of habitats).

The mean constancy (the number of plots in which a species occurs) was lower in the expanded data set (Table 10.1). The two larger swamps (Sunnyside East and Narrow Swamp) had the lowest constancy. The habitat in Sunnyside East naturally ranges from wet at the low north end to dry at the upper south end, with wet habitat species in the lower end and dry habitat species in the upper end of the swamp. Roughly two thirds of Narrow Swamp has been impacted by mine water discharge, with different vegetation communities found in the affected and unaffected portions. Increasing the number of plots does not lower the overall variance.

**Proportional abundance of wetland vs non-wetland species:** Given the ordinal nature of the data, calculations like addition and subtraction are not possible, hence total cover or proportional abundance of species or groups of species cannot be calculated; though counts of species or groups of species within the cover/abundance categories is possible. Figure 10.1 shows the frequency of each cover/abundance category for the function groups in each swamp using the original plots (left) and the expanded plots (right). The main difference is the higher number of low cover/abundance terrestrial species in both Narrow Swamp (NS) and Sunnyside East (SSE). The two small swamps show little difference in cover/abundance distribution between data sets (this is probably due to similar habitat throughout out the swamp). The proportion of wetland species per plot is similar for all but Sunnyside East, again due to the extended plots sampling the drier areas of the swamp (Table 10.2).

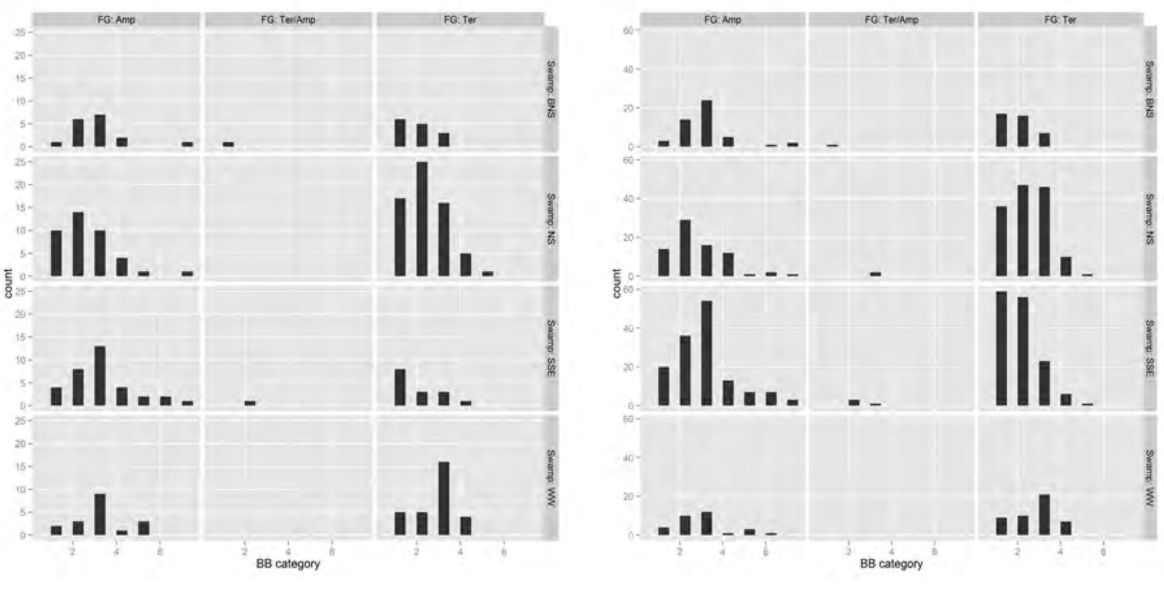

Figure 10.1: The frequency of species in each cover/abundance category for each functional group and swamp. The original plots (left) and the expanded plots (right).

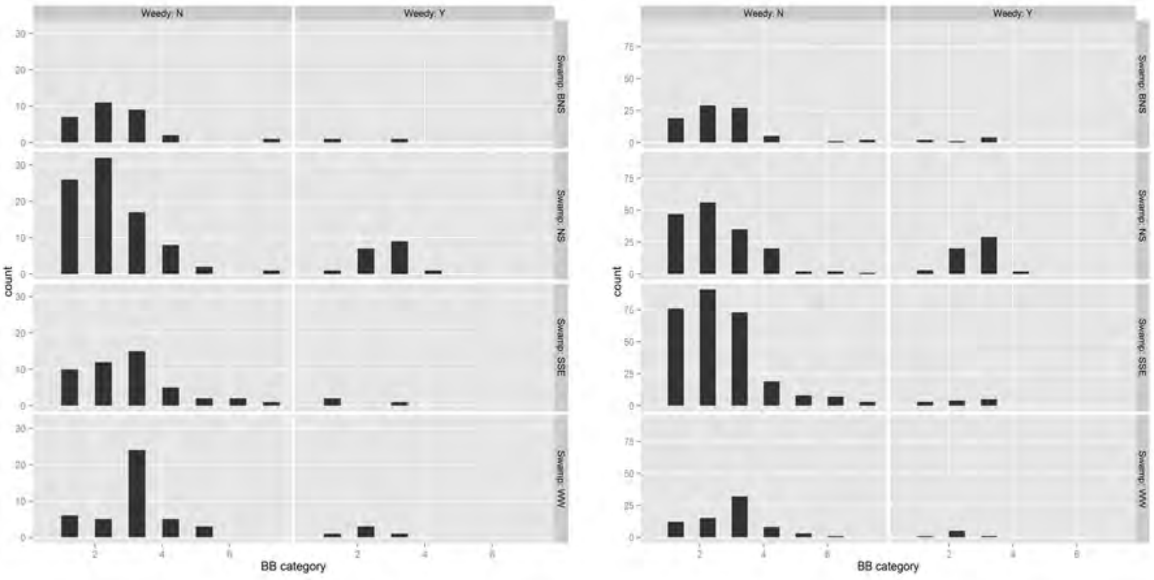

Figure 10.2: The frequency of species in each cover/abundance category for weedy and non-weedy species for each swamp. The original plots (left) and the expanded plots (right). N=no, Y=yes

**Weed diversity and abundance** The number of weed species per swamp ranged from one to 13, with more weed species found with the expanded data set (Table 10.3). The trends in weed number, abundance and proportion in the original and expanded data sets are similar (Figure 10.2 and Table 10.3). Note the lower standard deviation in the expanded data set for Narrow Swamp and Sunnyside East (Table 10.3).

**Eucalypt seedling encroachment** Eucalypt seedlings were found in every swamp in the expanded data set but only three of the four swamps with the original data set. The percentage of plots where eucalypts were present ranged from 29% to 100% in the expanded data set and 0% to 50% of the plots in the original data set (Table 10.4).

**Extent of bare ground** The bare soil/litter was recorded in all four swamps in both the original and expanded data set (Table 10.4). Though the maximum and minimum cover/abundance scores for bare soil/litter remained similar between the two data sets (Table 10.5).

**The multivariate approach:** A dissimilarity measure can be used to summarise the differences between plots within a swamp (the modified Gower dissimilarity is often used for ordinal data). To assess variance the average distance to the group centroid is calculated (here a group is all plots in a swamp); in addition distances of individual plots from the group centroid can be examined. Greater variance (larger distances to group centroid) could indicate a greater number of habitats within the swamp. Forming hypotheses about how the mean and variance will change due to undermining is difficult. Determining what a significant level of change in the mean consists of and predicting how the mean will change are very difficult. Both an increase and decrease in variance could indicate impact depending on the extent of the impact (e.g. part vs. all plots affected). An analysis examining the dissimilarity could be used as a starting point or summary but changes in these values cannot be used as indicators, hence we leave this out.

**Are the measurements obtained from 400m$^2$ plots sufficiently precise enough to allow detection of a meaningful effect size?** As is evident from the summary of the main indicators power analysis for this data set is only possible when examining numbers (or proportions) of species. Calculating a meaningful variance in abundance (hence effect size) is not possible with this data set. The tables below show the effect size (delta) that could be detected with the original and expanded data sets, with a power of 0.80 at a significance level of 0.10 using a one-sample two-tailed test. In nearly all cases, increasing the sample size decreased the minimum detectable effect size. The exception is the proportion of wet and dry habitat species in Narrow Swamp. The analysis suggest that using 400m$^2$ plots detecting a 30% to 50% change in the indicators would be the best could be achieved with the expanded number of plots (though in many cases its much worse!).

**Conclusions:** Increasing the number of 400m$^2$ plots in a swamp does not provide enough detail to meet the requirements of the monitoring program. The measurements obtained from 400m$^2$ plots are not sufficiently precise enough to allow detection of small to moderate changes in vegetation cover (whether due to altered hydrology or any other cause).

Table 10.1: Summary stats for the 400m$^2$ plots (BNS, NS, SSE and WW) ± 1 standard deviation.

| | Number of plots sampled per swamp | | Number of species found per swamp | | Mean number of species per plot | | Mean constancy per swamp (%) | |
|---|---|---|---|---|---|---|---|---|
| **Swamp** | Original | Expanded | Original | Expanded | Original | Expanded | Original | Expanded |
| BNS | 1 | 3 | 32 | 52 | 32 | 32 ± 5 | 100 | 58 ± 27 |
| NS | 3 | 7 | 67 | 78 | 36 ± 3 | 32 ± 5 | 53 ± 24 | 40 ± 28 |
| SSE | 2 | 10 | 36 | 100 | 27± 3 | 30 ± 11 | 70 ± 25 | 29 ± 25 |
| WW | 2 | 3 | 32 | 38 | 25 ± 1 | 27 ± 4 | 75 ± 25 | 68 ± 30 |

Table 10.2: The proportion of wet habitat and dry habitat species per plot in the original plots and expanded plots, ± 1 standard deviation. Tdr = Terrestrial dry group; Tda = Terrestrial damp group

| | Proportion Amphibious | | Proportion Tdr | | Proportion Tda | |
|---|---|---|---|---|---|---|
| **Swamp** | Original | Expanded | Original | Expanded | Original | Expanded |
| BNS | 0.5 | 0.51 ± 0.02 | 0.29 | 0.25 ± 0.1 | 0.09 | 0.07 ± 0.04 |
| NS | 0.37 ± .01 | 0.33 ± 0.05 | 0.24 ± 0.12 | 0.19 ± 0.1 | 0.19 ± 0.08 | 0.25 ± 0.09 |
| SSE | 0.63 ± 0.07 | 0.5 ± 0.19 | 0.17 ± 0.04 | 0.28 ± 0.17 | 0.04 ±0.004 | 0.05 ± 0.04 |
| WW | 0.37 ± 0.05 | 0.38 ± 0.05 | 0.24 ± 0.05 | 0.25± 0.04 | 0.2 ± 0.006 | 0.19 ± 0.02 |

Table 10.3: Weed diversity in each swamp for the original plots and expanded plots.

| | Number of weed species in a swamp | | Mean number of weed species per plot | | Mean proportion of weed species per plot | |
|---|---|---|---|---|---|---|
| **Swamp** | Original | Expanded | Original | Expanded | Original | Expanded |
| BNS | 1 | 2 | 1 | 1.3 ± 0.58 | 0.03 | 0.05 ± 0.02 |
| NS | 10 | 13 | 6.0 ± 4.4 | 7.4 ± 2.9 | 0.17 ± 0.13 | 0.24 ± 0.11 |
| SSE | 2 | 3 | 1.0 ± 1.4 | 0.5 ± 0.85 | 0.04 ± 0.05 | 0.01 ± 0.02 |
| WW | 2 | 2 | 1.5 ± 0.7 | 1.3 ± 0.58 | 0.06 ± 0.03 | 0.05 ± 0.03 |

Table 10.4: Eucalypt seedling and extent of bare ground in each swamp for the the original plots and expanded plots.

| | Percentage of plots with eucalypts in a swamp | | Percentage of plots with bare soil/litter in a swamp | | Percentage of plots with bare water in a swamp | |
|---|---|---|---|---|---|---|
| **Swamp** | Original | Expanded | Original | Expanded | Original | Expanded |
| BNS | 100% | 100% | 100% | 67% | 100% | 67% |
| NS | 0 | 29% | 100% | 85% | 0 | 0 |
| SSE | 50% | 60% | 100% | 100% | 0 | 0 |
| WW | 100% | 100% | 50% | 67% | 0 | 0 |

Table 10.5: The minimum and maximum cover/abundance scores for bare ground in each swamp.

| | Min and Max score for bare ground in a swamp | |
|---|---|---|
| **Swamp** | Original | Expanded |
| BNS | 1 | 1-3 |
| NS | 3-4 | 3-4 |
| SSE | 1-4 | 1-4 |
| WW | 2 | 2-3 |

Table 10.6: Detectable effect size for species richness and constancy

| | | Mean number of species per plot | | Mean constancy per swamp (%) | | Mean number of weed species per plot | | Mean proportion of weed species per plot | |
|---|---|---|---|---|---|---|---|---|---|
| | Swamp | Avg | Effect | Avg | Effect | Avg | Effect | Avg | Effect |
| Original | BNS | 32 | na | 100 | na | 1 | na | 0.03 | na |
| Expanded | BNS | 32 | 11.48 | 58 | 62.03 | 1.3 | 1.33 | 0.05 | 0.05 |
| Original | NS | 36 | 6.89 | 53 | 55.1 | 6 | 10.1 | 0.17 | 0.3 |
| Expanded | NS | 32 | 5.3 | 40 | 29.86 | 7.4 | 3.1 | 0.24 | 0.12 |
| Original | SSE | 27 | 17.34 | 70 | 144.8 | 1 | 8.1 | 0.04 | 0.29 |
| Expanded | SSE | 30 | 9.3 | 29 | 21.3 | 0.5 | 0.72 | 0.01 | 0.017 |
| Original | WW | 25 | 5.79 | 75 | 144.8 | 1.5 | 4.1 | 0.06 | 0.17 |
| Expanded | WW | 27 | 9.19 | 68 | 68.9 | 1.3 | 1.33 | 0.05 | 0.07 |

Table 10.7: Detectable effect size for the wetland species indicators. Tdr = Terrestrial dry group; Tda = Terrestrial damp group

| | | Proportion of amphibious species | | Proportion Tdr | | Proportion Tda | |
|---|---|---|---|---|---|---|---|
| | Swamp | Mean | Effect size | Mean | Effect size | Mean | Effect size |
| Original | BNS | 0.5 | na | 0.29 | na | 0.09 | na |
| Expanded | BNS | 0.51 | 0.046 | 0.258 | 0.23 | 0.07 | 0.092 |
| Original | NS | 0.37 | 0.023 | 0.24 | 0.27 | 0.19 | 0.18 |
| Expanded | NS | 0.33 | 0.053 | 0.19 | 0.01 | 0.25 | 0.096 |
| Original | SSE | 0.63 | 0.4 | 0.17 | 0.23 | 0.04 | 0.023 |
| Expanded | SSE | 0.5 | 0.16 | 0.28 | 0.14 | 0.05 | 0.03 |
| Original | WW | 0.37 | 0.29 | 0.24 | 0.29 | 0.2 | 0.035 |
| Expanded | WW | 0.38 | 0.12 | 0.25 | 0.09 | 0.19 | 0.04 |

# E A pilot study providing details of the image classification process

We evaluated image classification by testing (i) the accuracy of the segmentation process and the detection of indirect impact, (ii) the accuracy of image classification between seasons of a single shrub swamp, and (iii) we compared an automatic classification process (Nearest neighbour analysis NN: eCognition Developer v8.7 scale 30, shape 20, compactness 30, spectral difference 5) with manual classification using an orthodem and orthomosaic.

The segmentation process was tested using imagery covering 6.2ha in *Sunnyside Swamp* (Figure 10.3). When we evaluated tree trunks (white linear objects) as a separate category we estimated 23-37% bare ground (Figure 10.3c; n=15 trials). By including tree trunks in the same category as bare ground we decreased variation and improved the accuracy in estimating non-vegetated areas (i.e., **29-34%**; n=5 trials). Live vegetation and shadows were easily discriminated (Figure 10.3d-e). These results suggest that shrub swamp habitat can be reliably classified in three categories (live vegetation, non-vegetative and unknown/shadows/canopy).

Between season variation was tested using imagery covering 7ha in *Carne Central* (Figure 10.4). We found a substantial decrease in live vegetation cover and an increase in non-vegetated areas between February 2012 and June 2013 (Figure 10.4c; n=5 trials). Even though bare ground was estimated at **16.2%** in February 2012 and **21.1%** in June 2013, only 4.6% of the total area of bare ground was estimated in both years. This discrepancy between years could be due to stretching of vegetation (image stitching error) and/or shadows that were present in 13% of the target area (June 2013 image). Ground surveys are needed to validate this change.

We evaluated the classification algorithm using imagery covering 4.1ha in *East Wolgan* (Figure 10.5). The NN algorithm revealed on average **41%** of bare ground in East Wolgan (95% confidence interval = **38-44%**; n= 10 trials). However, just **25%** of East Wolgan was classified consistently with bare ground. Using a manual classification, 47,095 polygons were evaluated and classified according to three categories described above (live, dead/bare, unknown). Within the mapped boundary of East Wolgan we considered **26%** to have bare ground indicating high correspondence with NN classification. However, on further inspection only 17% agreement was found between NN and manual classification.

Overall, results support manual classification of three categories (live vegetation, non-vegetative areas and other). Ground surveys are needed to validate imagery. Primary classification (baseline data) should be used to investigate the spatial structure of bare ground each season. Importantly, indirect impact from (i) forestry, (ii) recreational activity, (iii) mine related surface activity (e.g. subsidence lines) can be monitored using UAS imagery.

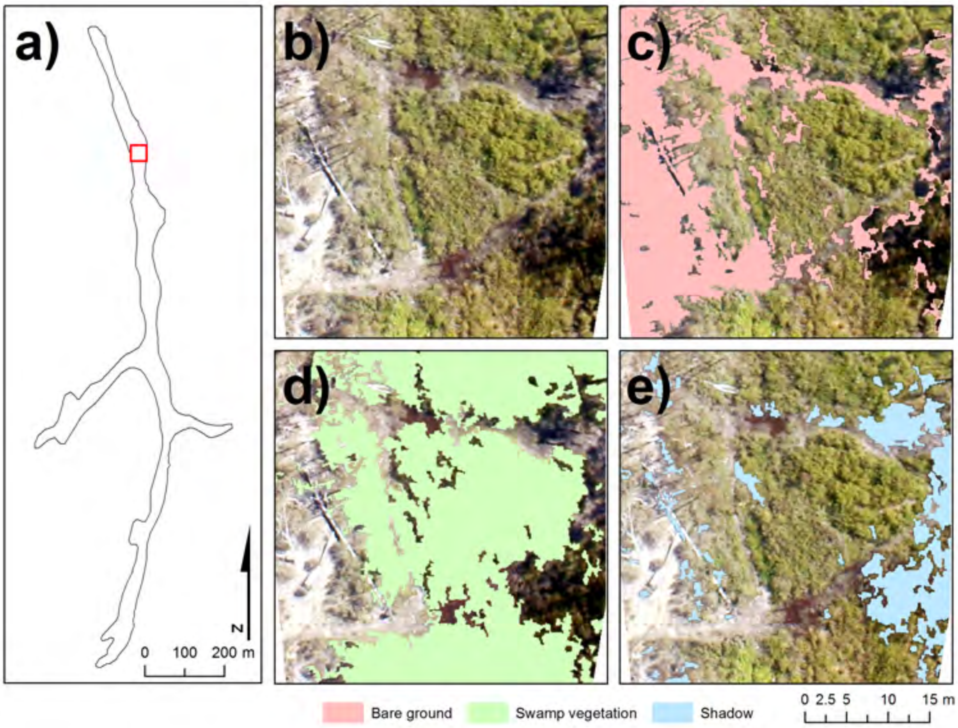

Figure 10.3: Figure showing the classification of indirect impacts (4x4 track) in Sunnyside Swamp. Environmental conditions can cause shadows to appear in the aerial imagery (e).

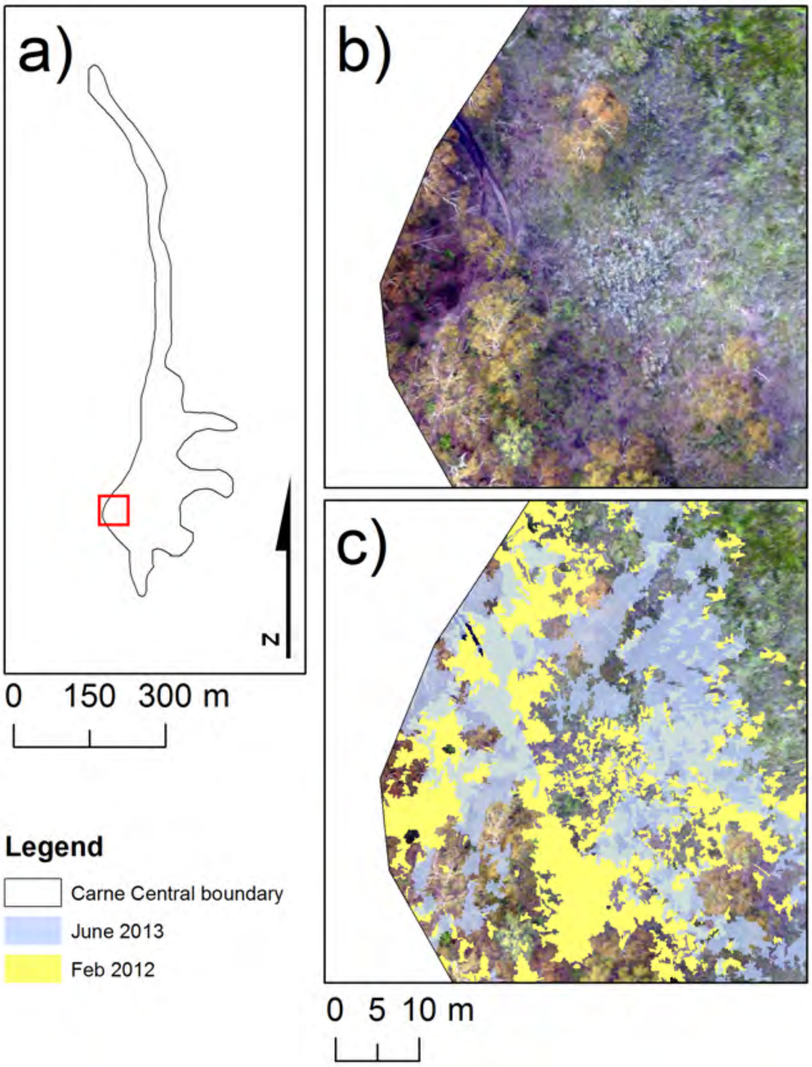

Figure 10.4: Figure showing the classification of non-vegetated areas in Carne Central over two years (a). Bare ground and the formation of a motorbike trail was visible along the western side of Carne Central in February 2012 (b). The thematic map (image classification) had poor correspondence (5% overlap) between years (c) including sections of a motorbike trail which remains clearly visible from the ground. Ground surveys are required to validate a change in dead trees and bare ground in Carne Central during June 2013.

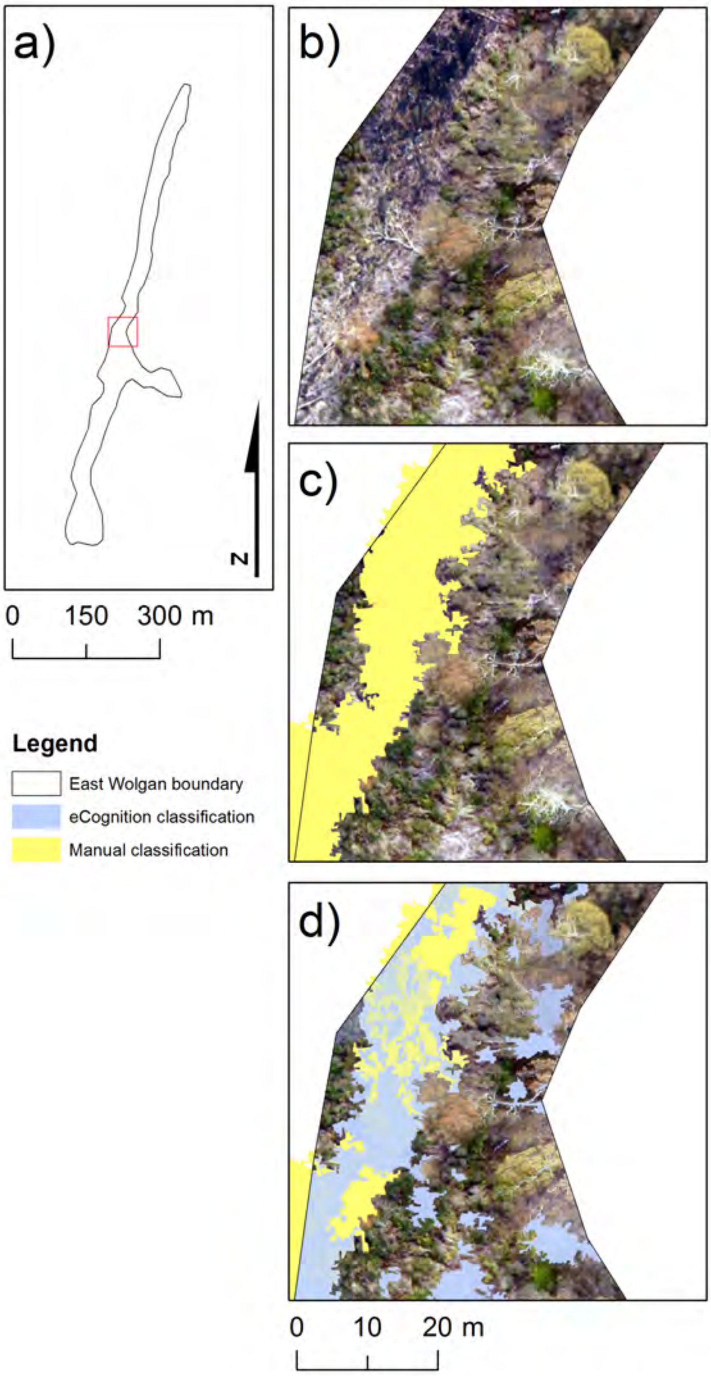

Figure 10.5: Figure illustrating two methods of classifying East Wolgan Swamp (ab). Manual classification (c; yellow fill) shows a continuous band of impact indicating channelization of shrub swamp habitat. Classification using a nearest neighbour (NN) algorithm indicates a less continuous band of non-vegetated area (d; purple fill) and has omitted low reflectance objects as they were mistaken for shadows, and detected high reflectance objects such as standing eucalypts along the boundary line. Manual classification is recommended to provide baseline data and deviations each season can be used to qualify impacted areas of swamp habitat. Initial (manual) classification is time consuming (2 days per swamp), however subsequent analyses could be rapidly assessed (1 hour per swamp).

## F Justification for the use of cross-swamp transects

**Why transects?** Hydrologic variables including the depth, frequency and duration of inundation are key factors affecting the establishment, growth and reproduction of wetland macrophytes (Casanova and Brock, 2000; Keddy, 2010). Within wetlands, species composition is rarely uniform. Instead wetland vegetation communities are typically characterised by zonation along a water availability gradient, with species occupying different ranges along this gradient according to their relative tolerance to waterlogging, inundation and drying (Keddy, 2010). Other abiotic and biotic factors also affect zonation patterns e.g. substrate type, interspecific competition and herbivory.

If mining activities have an impact on ground water or surface flow paths, vegetation condition and abundance effects may differ according to gradient position and impact type. For example, during a prolonged drying event it is likely that encroachment of non-wetland species into wetland plant communities would initially be most detectable in edge zones. In contrast, at sites affected by previous mine water discharge (e.g. East Wolgan Swamp and Narrow Swamp), the effects of alterations to surface and groundwater flows on the plant communities including localised vegetation dieback and increases in bare ground and weed establishment are most apparent close to the drainage line i.e. at lower elevations. Sampling restricted to fixed plots located at a single elevation increase the risk that changes could be missed due to plot placement. Sampling vegetation at regular intervals along transects that span the full wetland elevation gradient, from edge to middle, will help to reduce this risk.

**Advantages of small plots** It has been demonstrated that subjective estimates of species abundances in large plots (including modified Braun-Blanquet scores derived 20 x 20m plots used in the previous monitoring program design) lack precision and repeatability (Appendix Sampling size). Use of small (1m x 1m) quadrats will allow more precise estimates of cover to be obtained.

## G Pilot study: Optimisation of transect sampling regimes and determination of minimum detectable effect sizes, using post-hoc power analysis

A transect survey pilot study was conducted in 2013 with the following aims:

1. To determine the optimum sampling regime (quadrat size x sampling interval) for measuring the abundance of each of the following vegetation indicator variables, at the swamp scale
    - Extent of non-vegetated area
    - Proportion of quadrat area scored as “green” vegetation cover
    - Amphibious (Amp) vegetation as a proportion of total vegetation cover
    - Terrestrial dry (Tdr) habitat vegetation as a proportion of total vegetation cover
    - Terrestrial damp (Tda) habitat vegetation as a proportion of total vegetation cover
    - Exotic vegetation as a proportion of total vegetation cover
    - Frequency of eucalypt seedling detection (proportion of quadrats sampled)
    - Frequency of exotic species detection (proportion of quadrats sampled)
2. To quantify the extent of variability between repeat surveys using this optimum sampling regime.
3. To determine minimum detectable effect sizes for each indicator variable, by conducting a *post-hoc* power analysis.

*Site selection*

We selected four wetlands that broadly spanned the range of hydrological states (from permanently wet with standing water to predominantly damp to dry), vegetation types (from shrub-dominated to open) and wetland sizes present in the Centennial Coal mine lease areas (Table 1).

**Table 1** Overview of sampling site traits

| Swamp | Hydrological class | Size | Vegetation |
|---|---|---|---|
| Bungleboorie North (BNS) | Wet swamp | Small | Uniformly dense, shrubby, vegetation community |
| West Wolgan, northern subsection (WW) | Dry swamp | Small | Heterogeneous vegetation, consisting of a mixture of grasses, sedges and forbs with a patchy shrub layer |
| Narrow Swamp (NSN) | Dry swamp, affected by previous mine-water discharge | Intermediate | Heterogeneous vegetation. Dense shrub cover at upstream end and low shrub cover downstream. Weed cover and extent of bare ground high compared to other swamps. |
| Sunnyside East Swamp (SSE) | Mixed: Surface water present at downstream end, dry at upstream end | Large | Vegetation community dominated by *Gleichenia dicarpa* and *Baloskion* spp. at top end, with higher cover of *Baumea rubiginosa* and various shrub species downstream. |

*Vegetation survey 1: Comparing sampling regimes*

The first transect survey was conducted in April 2013. For each swamp between 3 and 10 transects were sampled, spanning the width the swamp. The number of transects surveyed per swamp (Table 1) was determined based on wetland size. Transects locations were determined before going into the field by using ArcGIS to divide the length of each swamp into 200m sections, then randomly position a transect start point within each of these sections along the edge of the mapped swamp boundary. The resulting transects were spaced between 50m to 175m apart. A hand-held GPS device was used to locate the start location of each transect in the field.

We collected vegetation and bare ground data along these transects using: 1) a point intercept sampling method, 2) presence/absence data collected from small quadrats of two sizes and 3) % cover data (including % green vegetation cover) from nested quadrats that could be aggregated to create and compare % cover scores and variability for six different quadrat sizes (sizes ranging from 50 x 50cm, to 100cm x 400cm), at a range of different sampling intervals (from 1 to 4 quadrats per 8m of transect length). The nested point and quadrat sampling design is illustrated in Fig. 1.

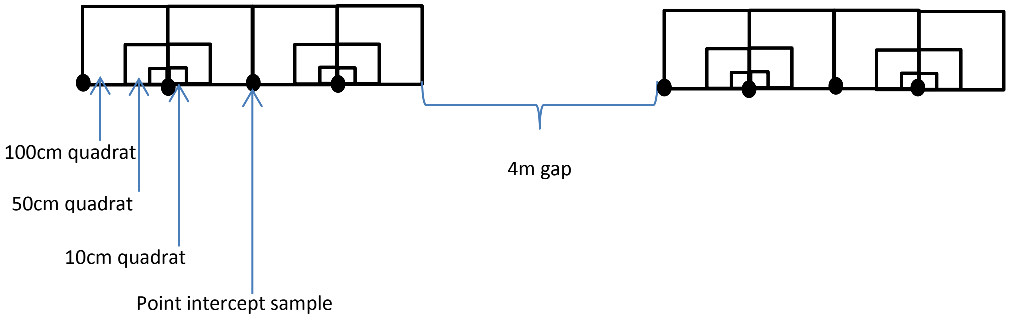

**Figure 1.** Nested sampling design repeated along transects

*Vegetation survey 2: Variability in results between two surveys*

In September 2013, 18 of the 24 transects surveyed in April 2013 were resampled so that variability between the two survey times could be assessed. Waypoints and photos were used to relocate the original transect start and end points in the field. Percentage cover scores were recorded in 100cm x 100cm quadrats, using the first and third quadrat per set of four (refer to Fig. 1). In total, half of the quadrats sampled per transect in April were resampled in September 2013 (refer to Figure 1).

*Data analysis*

In total, 17 sampling regimes (i.e. quadrat sizes x sampling intensities) were compared. For each sampling regime, abundance scores were calculated at the transect level for every indicator variable. For each variable, the mean values obtained per swamp and standard deviations between transects from each of the sampling regimes were plotted and compared (e.g. Figure 2). The optimum sampling regime, for the total number of transects surveyed, was then determined per variable by identifying the quadrat size x sampling interval combinations that:

- Were sufficient to detect the variable of interest across all four swamps (including groups with low and/or patchy cover at some sites i.e. exotic species and eucalypt seedlings).
- Appeared to provide a robust approximation of the mean (i.e. values did not change substantially with further increases in quadrat size and/or sampling intensity)
- Resulted in the lowest overall variability between transects, across the four swamps.

Power analyses were conducted using the power.t.test function in the statistical package R and were conducted in two stages using slightly different methods:

First, after the initial survey in April, the data obtained were used to calculate the minimum detectable effect size for each variable, per swamp. This initial power analysis was based on analysing the data with  a one-tailed **two-sample t test**, with a specified statistical power of 0.80 and significance level of $p = 0.10$. For this test, minimum detectable effect sizes are determined by the number of transects surveyed (n) and the extent of variability between transects (i.e. standard deviation) (Downes et al. 2002, Quinn and Keough 2002).

After the September survey, we used the results obtained from both surveys to calculate the extent of variability between survey times. This allowed minimum detectable effect sizes to be calculated for a one-tailed **paired-sample t test**, based on data from the two time points with a specified power of 0.80 and significance level of $p = 0.10$. Paired sample t tests were used for the comparison between survey times because samples obtained from the same transect location at different time points are not independent (i.e. vegetation cover observed in one survey is expected to influence the cover found at the same transect in subsequent surveys). Unlike two-sample t tests, paired-sample t tests do not require independent samples and are therefore more appropriate for comparing repeated measurements from the same transects. Minimum detectable effect sizes for this test are affected by the number of transects surveyed (n) and the variability in the extent of change recorded between survey times, per transect (Downes et al. 2002, Quinn and Keough 2002).

## Results and interpretation

### *Selection of optimum sampling regime*

Of the 17 sampling regimes compared, the use of 100cm x 100cm quadrats, at a sampling intensity of two quadrats per set of four, was identified as the optimum design for sampling the majority of indicator variables across the four swamps. This sampling regime was sufficient to detect weeds and eucalypt seedlings and eucalypt seedlings across all four wetlands, despite the low cover and patchy distribution of these groups at most sites. This sampling regime also minimised variability between transects for most indicator variables (i.e. proportional cover of key water plant functional groups, non-vegetated area and live green vegetation). Increases in quadrat size and sampling intensity also led to no appreciable change in mean % cover scores recorded for these variables; this was verified using one-way ANOVAs, where no significant changes were detected.

*Power analysis 1: Minimum detectable effect sizes based on data from a single time point*

Swamps that displayed a high degree of spatial heterogeneity in indicator variables had higher minimum detectable effect sizes for those variables than swamps that were less heterogeneous. Minimum detectable effect sizes were often higher for WW than for the other swamps, due to a combination of heterogeneity in the vegetation community and the lower number of transects surveyed. Minimum detectable effect sizes for each indicator variable, per swamp, based on a two-sample t test on April survey data only are shown in **Table 2.** These values are based on data obtained using the sampling regime selected above. The minimum detectable effect sizes calculated for the % cover based indicator variables (e.g. non-vegetated area, wetland plant functional group abundance and live green vegetation extent) were generally quite low, indicating that this sampling regime should be rigorous enough to detect small to moderate changes in these indicator variables (i.e. 10-30%).

In contrast, the minimum detectable effect sizes for the two frequency-based variables (i.e. frequency of tree seedling and exotic species detection) were much higher. This was because detection frequencies varied extensively between transects (Table 2). For the 17 sampling regimes we tested, frequency scores did not appear likely to be effective for detecting changes over time in the abundance of vegetation indicator groups characterised by low abundances and patchy distributions. Therefore, a different method may be required to detect changes in exotic species and tree seedling abundance (e.g. % cover scores or seedling counts). The results of this pilot study also indicate that frequency of eucalypt seedling detection may not be a reliable indicator of site dryness, because eucalypt seedling detection frequencies in the two wet swamps (BNS and SSE) were similar or higher than those in the dry swamps (WW and NSN).

*Power analysis 2: Accounting for effect of variability between survey times on minimum detectable effect sizes*

The minimum detectable effect sizes calculated in paired-sample t tests increased with variability in the extent of change (per transect) between surveys and decreased with the number of transects surveyed (Table 3). For BNS, NSN and WW, this paired-sample power analysis used the same number of transects in total as the earlier power analysis (April survey data only), while at SSE fewer transects were compared in the second analysis. For BNS and NSN and SSE, detectable effect sizes were quite similar in magnitude to those derived from the initial baseline data analysis, despite the lower number of transects surveyed in SSE. This suggests that 4 to 7 transects should be sufficient for detecting small to moderate changes in key indicator variables at these sites.

WW had the smallest number of transects and quadrats per transect sampled and the highest heterogeneity in the extent of change per transect between surveys for a number of variables.

This resulted in low power to detect changes in a number of indicator variables, including the extent of non-vegetated areas, terrestrial dry (Tdr) vegetation cover and terrestrial damp (Tda) vegetation cover (refer to minimum detectable effect sizes in Table 3).

The results demonstrate that more than three transects will be required to detect small to moderate changes in key indicator variables at this site, at the specified power and significance levels. Further power analyses were conducted on the data from WW to demonstrate how increasing the number of transects would affect minimum detectable effect sizes (Figure 3).

**Caveats and additional recommendations re optimising sampling design:**

The extent of variability observed at West Wolgan is likely to have been driven, in part, by the lower number of quadrats sampled per transect in this wetland. The area sampled was very small and transects were consequently both few in number and short compared to the other sites. Vegetation within the area was also quite heterogeneous, potentially contributing to differences in the extent of change over time between individual transects.

We have not determined whether similar results (i.e. means, extent of variability between transects and minimum detectable effect sizes) can be obtained by spacing quadrats further apart if sampling in very wide shallow wetlands with broader zonation patterns (e.g. Carne Central, West Wolgan main section). This should be tested, because increasing the sampling interval in wider swamps would potentially greatly reduce the amount of time needed to complete surveys in these larger swamps.

## Results: Figures and tables

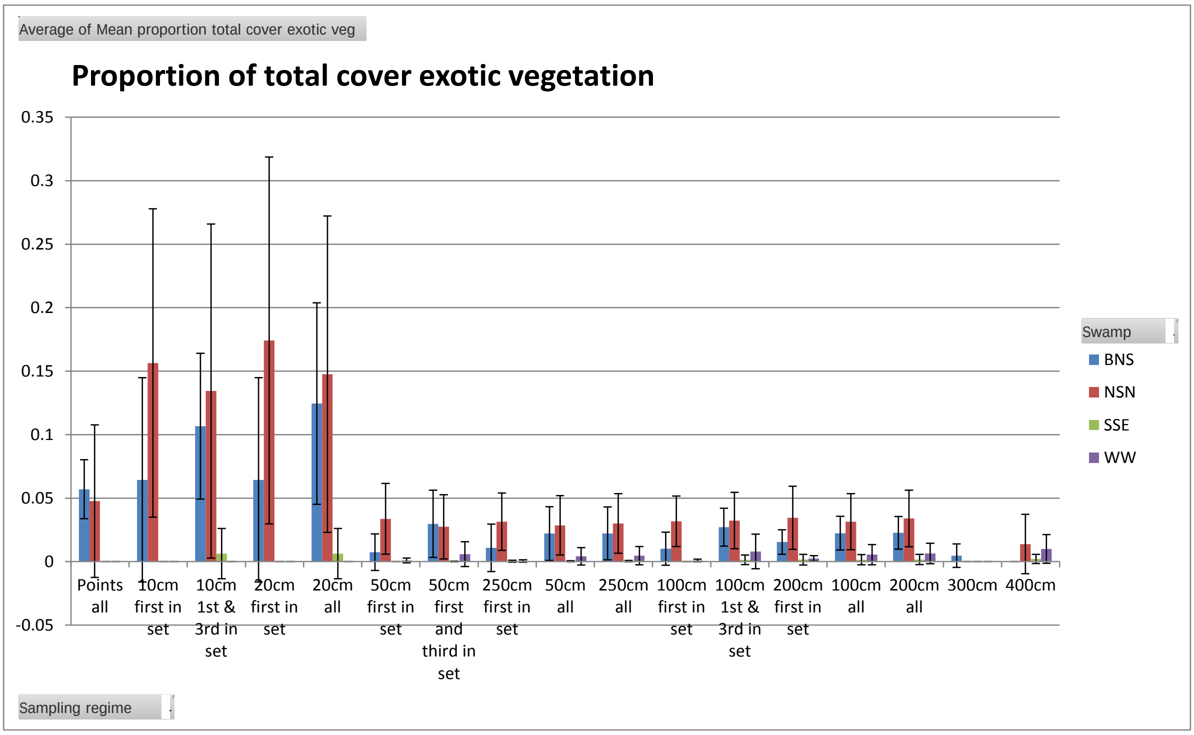

**Figure 2.** Mean proportion exotic vegetation cover detected (± standard deviation) using each sampling regime, per swamp.

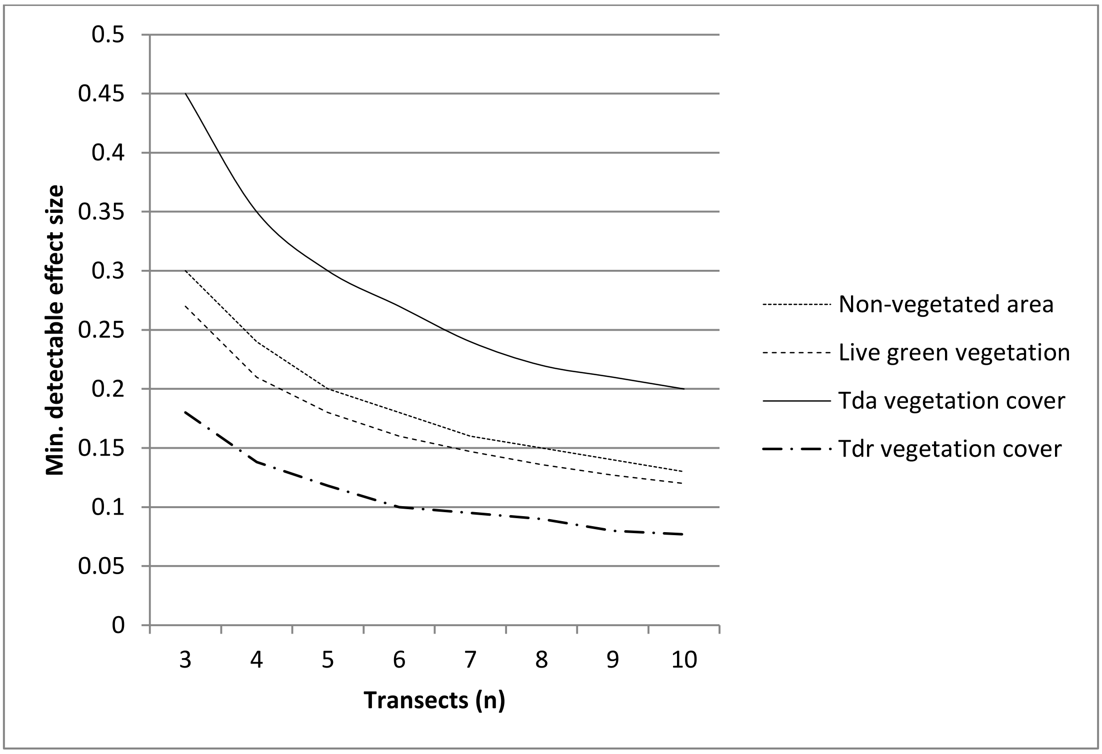

**Figure 3.** West Wolgan - the effects of increasing total transect number on minimum detectable effect sizes (based on the std.dev. of the change per transect between April & September surveys, a power of 0.80 and *p* = 0.10).

**Table 2.** Indicator variable baseline values (April 2013) and minimum increase or decrease that could be detected at the swamp scale, using a one-tailed two sample t test, with power = 0.80 and p = 0.10.

| **Indicator variable** | **Wetland (n = transects)** | **Mean** | **Std. dev.** | **Min. detectable effect size (i.e. absolute change detectable)** | **Min. detectable effect size as a proportion of the mean** |
|---|---|---|---|---|---|
| *Extent of non-vegetated area (includes bare ground, leaf litter, large woody debris and water) | BNS (n = 4) | 0.09 | 0.05 | 0.09 | 1.01 |
| | NSN (n = 7) | 0.34 | 0.11 | 0.12 | 0.36 |
| | SSE (n = 10) | 0.30 | 0.15 | 0.14 | 0.48 |
| | WW (n = 3) | 0.15 | 0.07 | 0.14 | 0.97 |
| Proportion of quadrat area scored as “green” vegetation cover | BNS (n = 4) | 0.79 | 0.08 | 0.13 | 0.17 |
| | NSN (n = 7) | 0.48 | 0.14 | 0.16 | 0.34 |
| | SSE (n = 10) | 0.57 | 0.15 | 0.15 | 0.26 |
| | WW (n = 3) | 0.60 | 0.05 | 0.09 | 0.16 |
| Amphibious (Amp) vegetation as a proportion of total vegetation cover | BNS (n = 4) | 0.84 | 0.06 | 0.10 | 0.12 |
| | NSN (n = 7) | 0.71 | 0.12 | 0.15 | 0.21 |
| | SSE (n = 10) | 0.90 | 0.09 | 0.08 | 0.09 |
| | WW (n = 3) | 0.48 | 0.13 | 0.26 | 0.53 |
| Terrestrial dry (Tdr) habitat vegetation as a proportion of total vegetation cover | BNS (n = 4) | 0.09 | 0.04 | 0.07 | 0.85 |
| | NSN (n = 7) | 0.15 | 0.06 | 0.07 | 0.49 |
| | SSE (n = 10) | 0.08 | 0.08 | 0.07 | 0.91 |
| | WW (n = 3) | 0.09 | 0.02 | 0.04 | 0.45 |
| Terrestrial damp (Tda) habitat vegetation as a proportion of total vegetation cover | BNS (n = 4) | 0.04 | 0.04 | 0.06 | 1.31 |
| | NSN (n = 7) | 0.13 | 0.08 | 0.09 | 0.72 |
| | SSE (n = 10) | 0.01 | 0.03 | 0.03 | 2.11 |
| | WW (n = 3) | 0.21 | 0.01 | 0.02 | 0.08 |
| Exotic vegetation as a proportion of total vegetation cover | BNS (n = 4) | 0.00 | 0.00 | NA | NA |
| | NSN (n = 7) | 0.10 | 0.06 | 0.07 | 0.75 |
| | SSE (n = 10) | 0.00 | 0.00 | 0.00 | 1.96 |
| | WW (n = 3) | 0.00 | 0.00 | 0.00 | 1.83 |
| Disturbed habitat vegetation as a proportion of total vegetation cover | BNS (n = 4) | 0.01 | 0.01 | 0.01 | 1.44 |
| | NSN (n = 7) | 0.15 | 0.08 | 0.10 | 0.65 |
| | SSE (n = 10) | 0.02 | 0.04 | 0.04 | 2.58 |
| | WW (n = 3) | 0.01 | 0.01 | 0.01 | 1.76 |
| †Frequency of eucalypt seedling detection (proportion of quadrats sampled) | BNS (n = 4) | 0.10 | 0.11 | 0.18 | 1.90 |
| | NSN (n = 7) | 0.01 | 0.04 | 0.04 | 3.11 |
| | SSE (n = 10) | 0.09 | 0.11 | 0.11 | 1.22 |
| | WW (n = 3) | 0.15 | 0.13 | 0.26 | 1.72 |
| †Frequency of exotic species detection (proportion of quadrats sampled) | BNS (n = 4) | 0.00 | 0.00 | NA | NA |
| | NS (n = 7) | 0.30 | 0.15 | 0.18 | 0.59 |
| | SSE (n = 10) | 0.02 | 0.05 | 0.05 | 2.07 |
| | WW (n = 3) | 0.17 | 0.14 | 0.28 | 1.69 |

*NB: Extent of non-vegetated area differs from extent of bare ground because other types of cover were included in this category in this pilot study. These include areas that lacked standing vegetation cover due to dense leaf litter, large woody debris and standing water.

†For low abundance x patchily distributed species, frequency data was typically highly variable between transects (i.e. more variable than % cover data), leading to low power to detect a change.

NA indicates inability to specify minimum detectable effect size because calculation requires a standard deviation >0.

**Table 3.** Minimum detectable effect sizes obtained after accounting for between-survey variability. (Power analysis based on one-tailed paired-sample t tests, with power = 0.80, p = 0.10, n = transects surveyed and standard deviation as indicated.)

| Variable | Wetland (n = transects) | Mean score April 2013 | Mean score Sept 2013 | Mean change per transect (April to Sept) | Std. dev. (change per transect) | Min. detectable effect size |
|---|---|---|---|---|---|---|
| Extent of non-vegetated area (water not included) | BNS (n = 4) | 0.073 | 0.14 | 0.07 | 0.12 | 0.15 |
| | NSN (n = 7) | 0.354 | 0.42 | 0.08 | 0.10 | 0.09 |
| | SSE (n = 4) | 0.306 | 0.29 | 0.08 | 0.12 | 0.15 |
| | WW (n = 3) | 0.151 | 0.14 | 0.15 | 0.19 | 0.30 |
| Proportion of quadrat area scored as "green" vegetation cover | BNS (n = 4) | 0.74 | 0.78 | 0.04 | 0.14 | 0.18 |
| | NSN (n = 7) | 0.49 | 0.51 | 0.02 | 0.08 | 0.07 |
| | SSE (n = 4) | 0.53 | 0.62 | 0.09 | 0.11 | 0.14 |
| | WW (n = 3) | 0.60 | 0.75 | 0.15 | 0.17 | 0.27 |
| Amphibious (Amp) vegetation as a proportion of total vegetation cover | BNS (n = 4) | 0.85 | 0.87 | 0.03 | 0.13 | 0.16 |
| | NSN (n = 7) | 0.71 | 0.76 | 0.05 | 0.11 | 0.10 |
| | SSE (n = 4) | 0.92 | 0.92 | 0.00 | 0.03 | 0.04 |
| | WW (n = 3) | 0.49 | 0.60 | 0.11 | 0.09 | 0.14 |
| Terrestrial dry (Tdr) habitat vegetation as a proportion of total vegetation cover | BNS (n = 4) | 0.08 | 0.07 | -0.01 | 0.07 | 0.09 |
| | NSN (n = 7) | 0.08 | 0.08 | 0.00 | 0.06 | 0.05 |
| | SSE (n = 4) | 0.03 | 0.03 | 0.01 | 0.03 | 0.04 |
| | WW (n = 3) | 0.12 | 0.21 | 0.08 | 0.11 | 0.18 |
| Terrestrial damp (Tda) habitat vegetation as a proportion of total vegetation cover | BNS (n = 4) | 0.05 | 0.03 | -0.02 | 0.06 | 0.08 |
| | NSN (n = 7) | 0.14 | 0.08 | -0.05 | 0.07 | 0.06 |
| | SSE (n = 4) | 0.10 | 0.10 | 0.00 | 0.01 | 0.01 |
| | WW (n = 3) | 0.50 | 0.24 | -0.27 | 0.28 | 0.45 |
| Exotic vegetation as a proportion of total vegetation cover | BNS (n = 4) | 0.01 | 0.00 | -0.01 | 0.02 | 0.03 |
| | NSN (n = 7) | 0.10 | 0.07 | -0.03 | 0.04 | 0.03 |
| | SSE (n = 4) | 0.00 | 0.00 | 0.00 | 0.00 | NA |
| | WW (n = 3) | 0.01 | 0.01 | -0.01 | 0.01 | 0.02 |
| Frequency of eucalypt seedling detection (proportion of quadrats sampled) | BNS (n = 4) | 0.11 | 0.09 | -0.02 | 0.16 | 0.20 |
| | NSN (n = 7) | 0.00 | 0.06 | 0.06 | 0.06 | 0.05 |
| | SSE (n = 4) | 0.12 | 0.09 | -0.03 | 0.12 | 0.15 |
| | WW (n = 3) | 0.15 | 0.11 | -0.04 | 0.19 | 0.30 |
| Frequency of exotic species detection (proportion of quadrats sampled) | BNS (n = 4) | 0.12 | 0.07 | -0.05 | 0.07 | 0.09 |
| | NSN (n = 7) | 0.54 | 0.57 | 0.02 | 0.10 | 0.09 |
| | SSE (n = 4) | 0.08 | 0.00 | -0.08 | 0.06 | 0.08 |
| | WW (n = 3) | 0.71 | 0.39 | -0.32 | 0.16 | 0.26 |

NA indicates inability to specify minimum detectable effect size because calculation requires a standard deviation >0.

## References

Downes, B. J., L. A. Barmuta, P. G. Fairweather, D. P. Faith, M. J. Keough, P. S. Lake, B. D. Mapstone, and G. P. Quinn. 2002. Monitoring ecological impacts: Concepts and practice in flowing waters. Cambridge University Press, Cambridge.

Quinn, G. P. and M. J. Keough. 2002. Experimental design and data analysis for biologists. Cambridge University Press.

# H Transect survey datasheet

**Transect sampling**
Swamp:
Transect no:
Assessor:
Date:
Camera:

**Notes:**

Start point:
Direction:

Photo no:

**% cover per quadrat**

| **Species / Non-vegetated category** | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 | Etc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E.g. Live “green” veg cover | | | | | | | | | | | | | | | | | | | | | |
| Bare ground | | | | | | | | | | | | | | | | | | | | | |
| Standing water | | | | | | | | | | | | | | | | | | | | | |
| Species 1 | | | | | | | | | | | | | | | | | | | | | |
| Species 2 | | | | | | | | | | | | | | | | | | | | | |
| Species 3 | | | | | | | | | | | | | | | | | | | | | |
| Etc | | | | | | | | | | | | | | | | | | | | | |
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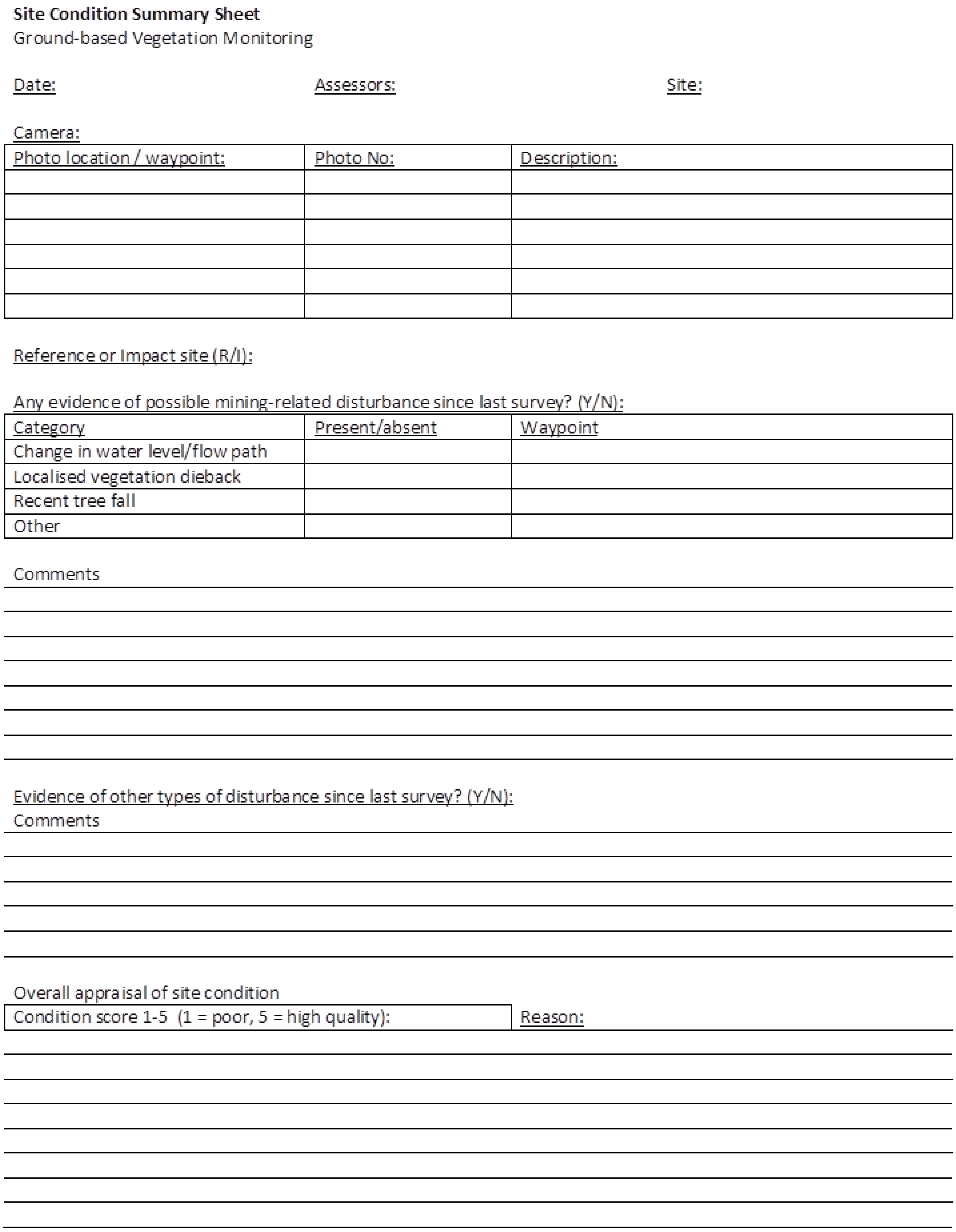
# I Site condition datasheet



**Site Condition Summary Sheet**
Ground-based Vegetation Monitoring

Date: Assessors: Site:

Camera:

| Photo location / waypoint: | Photo No: | Description: |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

Reference or Impact site (R/I):

Any evidence of possible mining-related disturbance since last survey? (Y/N):

| Category | Present/absent | Waypoint |
|---|---|---|
| Change in water level/flow path | | |
| Localised vegetation dieback | | |
| Recent tree fall | | |
| Other | | |

Comments

Evidence of other types of disturbance since last survey? (Y/N):
Comments

Overall appraisal of site condition

| | |
|---|---|
| Condition score 1-5 (1 = poor, 5 = high quality): | Reason: |

Figure 10.6: A site condition datasheet used to summarise swamp condition.

# J Transect data analysis method

# Transect data analysis method

### Step 1 For ease of analysis, compile the raw data from all swamps, transects and quadrats into a single file per monitoring survey as shown in the example below:

| **Year** | **Season** | **Assessor** | **Swamp** | **Transect** | **Quadrat** | **Field name** | **Scientific name / final determination** | **WPFG** | **Exotic?** | **% cover score** |
|---|---|---|---|---|---|---|---|---|---|---|
| 2013 | Spring | A.B. | Sunnyside | 1 | 1 | Grass 1 | Austrostipa rudis | Tdr | | 3 |
| 2013 | Spring | A.B. | Sunnyside | 1 | 1 | Baum_rubi | Baumea rubiginosa | Ate | | 50 |
| 2013 | Spring | A.B. | Sunnyside | 1 | 1 | Prunella | Prunella vulgaris | Tda | Y | 1 |
| 2013 | Spring | A.B. | Sunnyside | 1 | 1 | Bare area | Non-vegetated (bare) | Non-vegetated (bare) | | 30 |
| 2013 | Spring | A.B. | Sunnyside | 1 | 1 | Bare area, inundated | Non-vegetated (inundated) | Non-vegetated (inundated) | | 20 |
| 2013 | Spring | A.B. | Sunnyside | 1 | 1 | Total live green veg cover | % Green | % Green | | |
| 2013 | Spring | A.B. | Sunnyside | 1 | 2 | ….. | ……. | …… | …… | ……Etc |
| ….. | ….. | ….. | ….. | ….. | ….. | ….. | ….. | ….. | ….. | ….. |
| | | | | | | | | | | |

Once compiled all survey data should be retained in a database for use in future data analyses.

### Step 2 Calculate the following summary statistics for each swamp, per transect:

| **Summary statistic** | **Description** |
|---|---|
| Proportion of total area sampled that is non-vegetated (excluding inundated areas) | Sum of non-vegetated % cover scores across whole transect / Number of quadrats sampled |
| Proportion of area scored as live vegetation cover | Sum of all % green cover scores across transect / Number of quadrats sampled |

| **Summary statistic** | **Description** |
|---|---|
| Total vegetation cover | Sum of all individual species % cover scores for the whole transect. (Exclude cover scores for % green cover and non-vegetated area classes.) |
| Proportion amphibious vegetation cover | Sum of all A, Amp, Ate, Atl, Atw & Arp species % cover scores / Total vegetation cover |
| Proportion Tdr vegetation cover | Sum of all Tdr species % cover scores / Total vegetation cover |
| Proportion Tda vegetation cover | Sum of all Tda species % cover scores / Total vegetation cover |
| Proportion exotic vegetation cover | Sum of all exotic species % cover scores / Total vegetation cover |
| *Frequency of eucalypt &/or pine seedling detection | Total quadrats with eucalypt seedlings present / Number of quadrats sampled |
| *Abundance of eucalypt &/or pine seedlings | Total eucalypt seedling count |

*If eucalypt seedlings are found not to be a useful indicator of drying, these may be dropped (i.e. if numbers of eucalypt seedlings present at wet sites is not found to be lower than numbers at drier sites, based on baseline transect surveys).

**Step 3 For each variable, conduct a one-tailed paired sample t-test, comparing data between surveys at the swamp scale:**

E.g. Test for increase in proportion non-vegetated area at Sunnyside Swamp after undermining.

**Data:** Sunnyside Swamp, proportion non-vegetated area per transect

| Transects | Sample 1 (Before undermining) | Sample 2 (Current monitoring survey – After undermining) |
|---|---|---|
| 1 | 0.10 | 0.20 |
| 2 | 0.15 | 0.15 |
| 3 | 0.20 | 0.24 |
| 4 | 0.05 | 0.04 |
| 5 | 0.10 | 0.20 |
| 6 | 0.11 | 0.19 |

**Results:** t = 2.57, degrees of freedom = 5, p-value = 0.025. Mean increase in proportion non-vegetated area = 0.052 (i.e. ~5% of the area surveyed)

**Interpretation:** The proportion of non-vegetated area recorded in the current monitoring survey was significantly higher than recorded in the baseline survey (p = 0.025). However, the magnitude of the change was small and did not exceed the trigger level for this variable.

# K Methods for defining and revising trigger levels

**Defining trigger levels** Here we have defined some preliminary trigger levels for the indicator variables listed in Table 6.2. These are based on analysis of transect data collected during a pilot study, involving a limited number of sites (n = 4). The four swamps selected included one swamp impacted by previous mine water discharge (Narrow Swamp), two reference swamps that have not been undermined (Sunnyside East and Bungleboorie North) and one site that has been undermined but does not exhibit obvious signs of hydrological disturbance (West Wolgan, northern section). The preliminary trigger levels shown here were selected on the basis that pilot study data demonstrated changes of these magnitudes, or lower, could be detected using the methodology outlined in this handbook, across all four pilot study sites, with a statistical power of 0.80 and a significance level of $p \leq 0.10$.

For further details of the pilot study, including methods, the data collected (means and standard deviations for each indicator variable per swamp) and minimum detectable effect sizes based on power analysis, for each site, refer to Appendix G.

**Revision of trigger levels** For each of the indicators described in the above section, trigger levels will be reviewed and updated on an individual monitoring report basis, by comparing the values of each indicator variable recorded at potential impact sites with those recorded at reference sites as defined by DSEWPAC (2012). This model complies with an adaptive management framework and will ensure that trigger levels are kept up to date on an ongoing basis, as new data are collected and as additional sites are added.

# L Justification of indicator selection

**Changes in water plant functional group (WPFG) cover** Freshwater wetland plant communities are often highly variable in species composition and abundance, at both the local and regional scale (Boulton and Brock, 1999). Monitoring reports produced to date have shown that this is also true for Newnes Plateau THPSS plant communities (Brownstein et al., 2013). The inherent variability in vegetation composition and structure found both between swamps and between different areas within swamps on the Newnes Plateau makes it difficult to: i) make overarching predictions about the changes in species composition likely to occur if water regimes are altered, ii) choose indicator species to monitor, or iii) define management response triggers, based on species composition, that will be relevant across the full range of wetlands involved. Assessments of plant functional group composition, rather than species composition, have been recommended for addressing these issues by a number of researchers both in Australia and overseas (Reid and Quinn, 2004; Casanova, 2011; Cole and Kentula, 2011).

Classifying species into groups based on their hydrological requirements (e.g. hydrophytes versus non-hydrophytes) makes it easier to identify and describe differences in vegetation community composition linked to differences in water availability. The water plant functional group (WPFG) classification developed by Brock et al. (Britton and Brock, 1994; Brock and Casanova, 1997; Casanova, 2011) is widely recognised and has been successfully used to demonstrate the effects of differences in water regime on wetland plant communities in a range of contexts (Leck and Brock, 2000; Liu et al., 2006; Robertson and James, 2007). WPFG composition and abundance have been used specifically as indicators for monitoring wetland condition in other, past and current/ongoing, Australian wetland monitoring programs (Reid and Quinn, 2004; Alexander et al., 2008; Campbell et al., 2014) and are recommended here. In Appendix N we demonstrate that WPFG categories are effective for demonstrating differences in NPSS and NPHS vegetation composition based on differences in water availability between monitoring sites.

Table 10.8 contains a list of WPFG categories that are applicable to Newnes Plateau swamp species and their definitions. Details of how to classify species into these categories can be found in Britton and Brock (1994), Reid and Quinn (2004) and Casanova (2011). A list of NPSS and NPHS species recorded in previous monitoring surveys and their applicable WPFG categories is also provided in Appendix N.

**Other vegetation condition indicators** Other indicator variables to detect the effects of drying on Newnes Plateau swamp vegetation include senescence of vegetation, increases in the extent of bare ground, increases in the abundance of opportunistic pioneer species and increases in eucalypt seedling establishment. Increases in bare ground could occur in swamps that are subject to large and/or sudden surface or groundwater level fluctuations, as seen in East Wolgan swamp following the cessation of mine-water discharge (see Appendix E). Senescence of wetland vegetation (i.e. reduction in the extent of live, green vegetation cover) may occur before increases in bare ground become apparent. Changes in the extent of bare ground and in live green vegetation cover are therefore both recommended here as indicators of severe and/or rapid drying. For these variables cover scores can also be used to ground-truth and classify high-resolution aerial imagery (refer back to 5).

Increases in exotic and/or opportunistic species abundance can provide a useful indicator of change because early-successional invasive plants are often the first to colonise after a

Table 10.8: Water plant functional groups applicable to Newnes Plateau swamp species (from Brock and Casanova, 1997; Casanova, 2011)

| **Functional group** | **Definition** |
|---|---|
| **Terrestrial (T)***  | Species that do not possess adaptations that will help them withstand flooding while in the vegetative state. |
| Terrestrial, damp habitat (Tda) | Terrestrial species that characteristically inhabit damp habitats. |
| Terrestrial, dry habitat (Tdr) | Terrestrial species that typically occur in drier habitats. |
| **Amphibious (A)*** | Species that tolerate (AT) or respond (AR) to fluctuations in surface water presence/absence. |
| Amphibious emergent (ATe) (fluctuation tolerator) | Emergent species, including sedges and rushes, that tolerate fluctuations in surface water availability without changing growth form. |
| Amphibious low growing (ATl) (fluctuation tolerator) | Low-growing species that tolerate both immersion and drawdown/damp conditions. |
| Amphibious woody (ATw) (fluctuation tolerator) | Woody perennial species that require flooding during some stage of their life cycle, but tolerate fluctuations in surface water availability. |
| Amphibious plastic (ARp) (fluctuation responder) | Species that respond to changes in surface water availability with morphological plasticity (i.e. change growth form substantially depending on water presence/absence and depth). |

*During preliminary classification some species may be placed in the overarching categories A or T if there is insufficient information available to classify them into a more specific WPFG subcategory. Classifications may be revised and refined as additional information becomes available.

disturbance. However, it should be noted that while such increases could occur due to altered hydrology, increases in exotic and opportunistic species abundance can also occur due to a range of other types of disturbance. It is therefore important that such changes, if detected, are interpreted in conjunction with other evidence of wetland drying and are not taken as conclusive evidence of drying in the absence of other supporting information (such as direct evidence of a reduction in groundwater depth) .

In previous monitoring assessments of weedy species diversity and abundance have not always explicitly defined which species should be included in this weedy species category and why. Both exotic and native species can be considered weeds depending on location and context and the criteria for native species inclusion/exclusion in this category are somewhat subjective. In future monitoring we recommend focusing on the abundance of exotic species only, as listed in the Atlas of NSW Wildlife - Census of Australian Plant Taxa (OEH, 2013) and defined on the National Herbarium of NSW website (PlantNET, 2013). Nomenclature follows CHAH (2011) (NB: Those native species that have been listed as weedy in previous monitoring reports are terrestrial dry and damp habitat species (i.e. Tdr and Tda functional groups). Increases in the abundance of these species will be detected as an increase in Tdr and/or Tda vegetation cover at monitoring sites.

Newnes Plateau swamps occur adjacent to eucalypt forest (and/or radiata pine plantations) and waterlogging is thought to have an environmental filtering effect, limiting the establishment of eucalypt seedlings in wetland areas (Benson and Baird, 2012). Woody species encroachment has also been demonstrated to be a useful indicator of wetland drying in wetlands elsewhere (Tiner, 1999; Keddy, 2010). Increases in eucalypt and/or pine seedling abundance are recommended as a potential indicator of drying here. However, it should be noted that further work needs to be done to determine whether or not eucalypt seedling abundance (i.e. number of recently established seedlings <1m in height) actually differs between wet and dry sites.

While mature tree numbers within swamp boundaries are low, data have not yet been collected across enough swamps to determine if the abundance of tree seedlings shows a similar trend. Evidence from a pilot study, comparing eucalypt detection frequencies between two wet swamps (Bungleboorie North and Sunnyside East) and two drier swamps (West Wolgan and Narrow Swamp) indicates that frequency of eucalypt seedling detection may not be an effective indicator of site dryness, because seedling detection frequencies in the two wet swamps (BNS and SSE) were similar or higher than those in the dry swamps (WW and NSN).

## M Demonstration of relationship between the vegetation indicator variables selected for ground-based monitoring and site wetness

## Data collection

Point intercept data were collected from all existing seasonal vegetation monitoring plots in Newnes Plateau Shrub Swamps (MU50) and Newnes Plateau Hanging Swamps in Spring 2012. Species composition was recorded at points spaced every 50cm along four transects per 20 x 20m plot and along eight transects per 10 x 40m plot, summing to a combined total transect length of approx. 80m per plot.

## Classification of plots based on relative water availability

Each of the 20m x 20m monitoring plots was classified into one of two hydrology groups, 'Wet' or 'Dry'. These were allocated based on water permanence, as determined from field observations over the previous four years of seasonal vegetation monitoring surveys (McKenna pers. comm.). Plots characterised by the presence of standing water throughout the year were classified as 'Wet', while those with permanently low, or variable, water tables were classified as 'Dry'. Plots were also classified into two groups based on their location within the wetland, 'Edge' or 'Middle'. Edge plots were located in the wet/dry ecotone at the wetland/forest boundary, while middle plots were located near the midpoint, or lowest elevation of the wetland vegetation community.

## Data analysis

All species were classified into water plant functional groups (WPFG). Next, cover scores (i.e. total number of times encountered) were calculated for each species, per transect, and summed at the WPFG level to obtain a total cover score per group. Total cover was also calculated for non-vegetated area (i.e. total number of sample points where no vegetation was detected).

The data were analysed using the statistical package PRIMER v.6. A Bray-Curtis dissimilarity matrix was calculated, using WPFG cover scores to for between-transect comparisons. This dissimilarity matrix was used to produce an non-metric multi-dimensional scaling (nMDS) plot to display differences in indicator variable scores according to hydrology group (Wet/Dry) and plot position (Edge/Middle). We then averaged indicator variable scores at the plot scale (i.e. pooled all transects per plot) and used a permutational multivariate analysis of variance PERMANOVA to determine if indicator variable scores differed significantly according to plot hydrological category (Wet/Dry) or position (Edge/Middle), and if there was any interaction between these terms. Hydrological category and plot position were treated as fixed factors and the test was run with permutation of residuals under a reduced model and 999 permutations of the raw data. Where significant differences were detected between categories of plots, similarity percentage (SIMPER) analyses was performed to determine the nature and extent of these differences.

## Results

Significant differences were detected in indicator variable scores, both between “Wet” and “Dry” plots (p = 0.001) and between “Edge” and “Middle” plots (p = 0.001). There was no significant interaction between these terms (Table 1).

The main differences detected between these plot categories, as reflected in the SIMPER analysis and in Figure 1 are as follows:

Edge plots, on average, contained a higher abundance of points scored as non-vegetated, lower abundance of inundation-tolerant shrubs (Atw) and sedges and rushes (Ate) and a higher abundance of terrestrial dry (Tdr) habitat vegetation than middle plots (Figure 1, Table 2).

Wet plots, on average, contained a higher abundance of amphibious vegetation (Ate, Atw and Arp groups) and much lower average abundance scores for terrestrial dry (Tdr) and terrestrial damp (Tda) habitat vegetation, and areas scored as non-vegetated, than dry plots (Figure 1, Table 2).

## Figures and tables

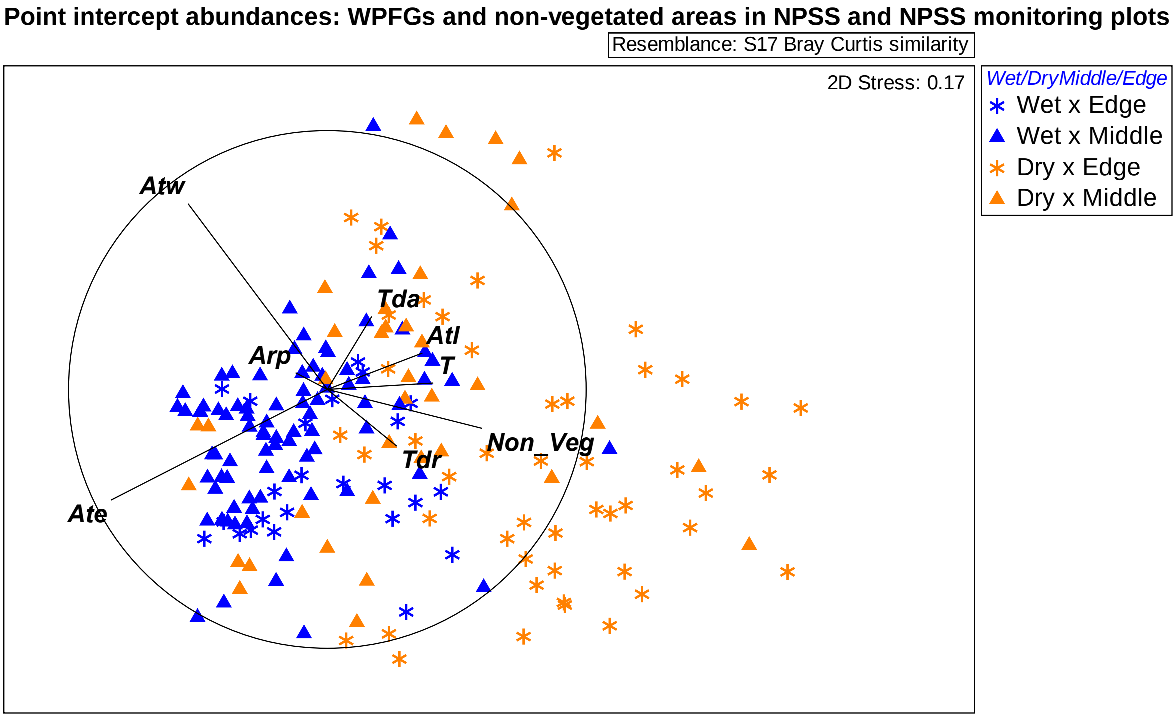


**Figure 1.** Relationship between indicator variable scores and plot class (Wet/Dry and Edge/Middle)

## Table 1. PERMANOVA output

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

***Factors***

```
Name         Abbrev.  Type   Levels
Wet/Dry      We       Fixed       2
Middle/Edge  Mi       Fixed       2
```

*PERMANOVA table of results*

```
                                                Unique
Source  df      SS      MS  Pseudo-F  P(perm)   perms
We       1  5706.6  5706.6    11.883    0.001     999
Mi       1    2561    2561    5.3329    0.001     998
WexMi    1   250.1   250.1   0.52081    0.717     999
Res     42   20169  480.22
Total   45   30106
```

*Details of the expected mean squares (EMS) for the model*

```
Source  EMS
We      1*V(Res) + 18.806*S(We)
Mi      1*V(Res) + 18.806*S(Mi)
WexMi   1*V(Res) + 9.403*S(WexMi)
Res     1*V(Res)
```

*Construction of Pseudo-F ratio(s) from mean squares*

```
Source  Numerator  Denominator  Num.df  Den.df
We      1*We       1*Res             1      42
Mi      1*Mi       1*Res             1      42
WexMi   1*WexMi    1*Res             1      42
```

*Estimates of components of variation*

```
Source    Estimate  Sq.root
S(We)       277.91   16.671
S(Mi)       110.64   10.519
S(WexMi)   -24.473   -4.947
V(Res)      480.22   21.914
```

## Table 2. SIMPER output

### *Section 1. Examines Wet/Dry groups (across all Middle/Edge groups)*

***Characteristics of plots within “Wet” group***
**Average similarity: 76.75**

```
Species  Av.Abund  Av.Sim  Sim/SD  Contrib%   Cum.%
Ate        182.89   49.05    4.03     63.92   63.92
Atw         93.11   24.09    2.57     31.39   95.30
Tda          8.61    1.44    0.88      1.87   97.17
Tdr         14.31    1.18    0.43      1.53   98.71
Atl          5.08    0.54    0.46      0.71   99.41
T            3.06    0.29    0.60      0.37   99.79
Non_Veg      1.89    0.14    0.31      0.18   99.97
Arp          1.06    0.03    0.14      0.03  100.00
```

***Characteristics of plots within “Dry” group***
**Average similarity: 64.34**

```
Species  Av.Abund  Av.Sim  Sim/SD  Contrib%   Cum.%
```

```
Ate        114.54   32.20    3.22     50.04   50.04
Atw         61.87   13.00    1.26     20.21   70.25
Tda         28.18    5.70    1.31      8.87   79.12
Tdr         23.69    5.53    1.06      8.60   87.72
T           21.06    4.34    0.92      6.75   94.47
Atl         17.62    3.09    1.03      4.80   99.26
Non_Veg      4.49    0.47    0.39      0.74  100.00
```

***<u>Comparision of groups WET  &  DRY</u>***
**Average dissimilarity = 35.71**

```
         Group WET  Group DRY
Species   Av.Abund   Av.Abund  Av.Diss  Diss/SD  Contrib%   Cum.%
Ate         182.89     114.54    14.03     1.44     39.29   39.29
Atw          93.11      61.87     8.20     1.34     22.96   62.25
Tda           8.61      28.18     4.31     1.40     12.06   74.31
T             3.06      21.06     2.93     1.23      8.21   82.53
Atl           5.08      17.62     2.63     1.20      7.38   89.90
Tdr          14.31      23.69     2.49     0.87      6.97   96.88
Non_Veg       1.89       4.49     0.93     0.63      2.59   99.47
Arp           1.06       0.04     0.19     0.34      0.53  100.00
```

***Section 2. Examines Middle/Edge groups (across all Wet/Dry groups)***

***Characteristics of plots within “Edge” group***
**Average similarity: 67.75**

```
Species  Av.Abund  Av.Sim  Sim/SD  Contrib%   Cum.%
Ate        128.91   37.09    4.05     54.74   54.74
Atw         58.39   11.24    1.37     16.59   71.33
Tdr         37.91    8.28    1.59     12.22   83.56
T           16.02    4.41    0.83      6.52   90.07
Tda         15.28    3.83    1.19      5.65   95.73
Atl         12.13    2.36    0.78      3.48   99.21
Non_Veg      3.95    0.52    0.37      0.77   99.98
Arp          0.17    0.01    0.22      0.02  100.00
```

***Characteristics of plots within “Middle” group***
**Average similarity: 74.86**

```
Species  Av.Abund  Av.Sim  Sim/SD  Contrib%   Cum.%
Ate        168.39   46.42    3.29     62.01   62.01
Atw         91.84   23.57    2.37     31.49   93.50
Tda         17.45    2.26    0.71      3.02   96.52
Atl          9.26    0.94    0.52      1.25   97.77
Tdr          7.67    0.88    0.52      1.17   98.94
T            7.55    0.61    0.46      0.82   99.76
Non_Veg      2.44    0.16    0.35      0.21   99.97
Arp          0.88    0.02    0.12      0.03  100.00
```

***Comparison of groups Edge  &  Middle***
**Average dissimilarity = 31.23**

```
         Group Edge  Group Middle
Species    Av.Abund      Av.Abund  Av.Diss  Diss/SD  Contrib%   Cum.%
Ate          128.91        168.39     9.94     1.35     31.83   31.83
Atw           58.39         91.84     8.27     1.34     26.49   58.32
Tdr           37.91          7.67     5.55     1.30     17.77   76.09
Tda           15.28         17.45     2.72     0.98      8.72   84.81
Atl           12.13          9.26     1.89     0.94      6.05   90.86
T             16.02          7.55     1.84     0.77      5.90   96.76
Non_Veg        3.95          2.44     0.86     0.63      2.75   99.51
Arp            0.17          0.88     0.15     0.33      0.49  100.00
```

# N Classification of Newnes Plateau plant species into water plant functional groups (WPFG)

This Appendix contains a list of plant species recorded previously in Newnes Plateau THPSS and details of their functional group classification, including information sources used. Where species had been classified into WPFG previously based on experimental data or on extensive field observations (Brock and Casanova 1997, Casanova and Brock 2000, Reid and Quinn 2004), we allocated species to the same groups. The remaining species were classified as per the methods of Britton and Brock (1994), Reid and Quinn (2004) and Casanova (2011), based on morphology, ecological information obtained from; scientific publications, herbarium records (i.e. AVH 2013), observations from seasonal field monitoring surveys and the results of a seed-bank germination and growth experiment conducted by CMLR in 2013 (C. Johns, unpublished data). Details of references are provided at the end of this appendix. **NB**: For some species, WPFG classifications may be updated as more information becomes available. We have flagged classifications that we consider to be borderline based on the information currently available.

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| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Acacia acicularis | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in dry sclerophyll forest, heath and woodland in sandy and clay loam soils. Occoasionally recorded at the edges of wetlands or creeklines (approx 7% of herbarium records, 154 assessed in total). |
| Acacia buxifolia | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as growing in dry sclerophyll forest, woodland and heath, often on hillslopes on sandy or gravelly areas. |
| Acacia dorothea | Shrub | Perennial | Ter | Tdr |  | F |  | AVH (2013) | Chiefly collected from scrub and dry sclerophyll forest habitats. |
| Acacia longifolia | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as growing in sclerophyll communities and coastal heath and scrub, often collected from sand on foredunes. Grows to 8m high (described as shrub or tree). |
| Acacia melanoxylon | Tree | Perennial | Ter | Tdr | Tdr/Tda | F |  | PlantNET (2013); AVH (2013) | Frequently occurs as a fringing species rather than a true wetland species. Often collected from sites on creek banks and occasionally from dry creek beds or similar. Described as widespread, particularly at higher altitudes and grows in a variety of habitats, chiefly in wet sclerophyll forest and in or near cool rainforest. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Acacia obtusifolia | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as growing in dry and wet sclerophyll forest, woodland and heath, in sandy and loam soils, mostly on sandstone but also on basalt. Only very occasionally collected from dry water courses i.e. areas that may be inundated at times. Grows to 8m high (described as tree or shrub). |
| Acacia spp. | Shrub or Tree | Perennial | Ter | T |  | F |  | PlantNET (2013) |  |
| Acacia terminalis | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as growing in dry sclerophyll forest, woodland and heath, usually on sandstone. |
| Acacia ulicifolia | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in dry sclerophyll woodland and forest, usually in sandy soil. |
| Acaena ovina | Forb | Perennial | Ter | Tdr |  | F | D | Cunningham et al (1992); PlantNET (2013); AVH (2013) | Most frequently collected from disturbed areas, including roadsides. Occasionally collected in moist drainage lines, creek beds and similar moist habitats. |
| Agrostis bettyae | Grass | Perennial | Amp | ATe | ATe/Tda | F |  | PlantNET (2013); AVH (2013); N. McCaffrey pers. obs. | Described as occurring in montane woodland, but has often been collected from areas described as damp ground or as seasonally wet areas, at the edges of wetlands or drainage lines or in areas with poor drainage. |
| Agrostis spp. | Grass | Perennial | Ter/Amp | T |  | F |  | PlantNET (2013) | Some species occur in bogs. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Allocasuarina littoralis | Tree | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in woodland or occasionally tall heath, on sandy or otherwise poor soils. Very occasionally collected from (intermittently wet?) creek beds or drainage lines. |
| Allocasuarina nana | Tree | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in heath on sandstone, especially in exposed situations such as ridges. |
| Amperea xiphoclada | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as widespread in heath, woodland and forest on low-fertility sandy soils. |
| Amyema pendulum | Mistlet oe | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Mistletoe. Described as parasitic on Eucalyptus and locally common on several Acacia species. |
| Amyema spp. | Mistlet oe | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Classification based on habitat of host spp. found in Newnes Plateau surveys. |
| Anagallis arvensis | Forb | Annual or Perennial | Ter | Tda |  | F | D | PlantNET (2013); AVH (2013) | Described as perennial or annual and widespread in pastures, disturbed sites and creek banks (PlantNET 2012). Similar habitat to Conyza bonariensis, which was classified as Tda by Reid & Quinn (2004). |
| Aristida ramosa | Grass | Perennial | Ter | Tdr |  | F | D | PlantNET (2013); AVH (2013) | Described as occurring in woodland on poor soils. Often collected from roadsides, pastures, cleared areas. |
| Aristida spp. | Grass | Annual or Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Described as frequenly ocurring in low rainfall areas and on poor soils. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Arrhenechthites mixta | Forb | Perennial | Ter | Tdr |  | E,F |  | PlantNET (2013); AVH (2013); Johns et al (In prep.) | Name change to A. mixtus. Established inUQ glasshouse experiment under free-draining conditions only. |
| Arthropodium milleflorum | Forb | Perennial | Ter | Tda | Tda/ATl | F |  | PlantNET (2013); AVH (2013) | Described as occurring in a variety of habitats (quite common in grasslands and woodlands i.e. dry to moist sites, but occasionally in boggy/swampy areas too). |
| Arthropodium minus | Forb | Perennial | Ter | Tda | Tda/Tdr | F |  | PlantNET (2013); AVH (2013) | Described as occurring in a variety of habitats. |
| Arthropodium spp. | Forb | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Described as occurring in a variety of habitats |
| Asplenium flabellifolium | Fern | Perennial | Ter | Tda |  | F |  | Cunningham et al (1992); PlantNET (2013); AVH (2013) | A trailing terrestrial species, occurring in sheltered, moist shady conditions, mainly found in rock crevices but sometimes epiphytic in rainforest. |
| Astrotricha spp. | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2012); AVH (2013) | Described habitats include wet sclerophyll forest, rainforest margins and dry sclerophyll forest. (Hydrophyte classification based on species found in following IBRA Bioregions: Sydney Basin, South Eastern Highlands, NSW Southwestern Slopes) |
| Austrodanthonia eriantha | Grass | Perennial | Ter | Tdr |  | F | D | PlantNET (2012); AVH (2013) | Described as occurring in a variety of habitats, including moderately disturbed areas e.g. roadsides and pastures. Now called Rhytidosperma erianthum. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Austrodanthonia penicillata | Grass | Perennial | Ter | T |  | F |  | PlantNET (2012); AVH (2013) | Now Rytidosperma penicillatum. Described as occurring in grassland and open woodland, often on slopes. |
| Austrodanthonia pilosa | Grass | Perennial | Ter | T |  | F |  | PlantNET (2012); AVH (2013) | Described as occurring in a variety of habitats. Now called Rhytidosperma pilosum. |
| Austrodanthonia setacea | Grass | Perennial | Ter | T |  | F |  | PlantNET (2012); AVH (2013) | Now Rhytidosperma setaceum. Occurs in a variety of habitats, including in moist areas e.g. roadside drains. |
| Austrodanthonia spp. | Grass | Perennial | Ter | Tdr |  | F |  | PlantNET (2012) | Described as occurring in a variety of habitats. Now Rhytidosperma. |
| Austrostipa pubescens | Grass | Perennial | Ter | Tdr |  | F |  | PlantNET (2012); AVH (2013) | Described as growing in woodland and heath on sandstone. |
| Austrostipa rudis | Grass | Perennial | Ter | Tdr |  | F |  | PlantNET (2012); AVH (2013) | Described as occurring in woodland. |
| Austrostipa spp. | Grass | Perennial | Ter | Tdr |  | F |  | PlantNET (2012) |  |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Baeckea linifolia | Shrub | Perennial | Amp | ATw |  | E,F |  | PlantNET (2012); AVH (2013); N. McCaffrey pers. obs.; C. Johns pers. obs; P. McKenna pers. obs. | Typically recorded in wet heath and in damp places, such as in riparian vegetation along creek banks, near waterfalls, in drainage lines or similar habitats. Observed in wetland areas subject to shallow surface inundation by UQ field staff. Seedlings established in both free-draining and waterlogged conditions in UQ glasshouse and Tolerated subsequent shallow inundation (3-5cm, ~8 weeks), maintaining growth even when completely submerged. |
| Baeckea spp. | Shrub | Perennial | Ter/Amp | T/ATw |  | F |  | PlantNET (2013) | Some species primarily occur in wet areas, while others are found in drier places. |
| Baeckea utilis | Shrub | Perennial | Amp | ATw |  | E,F |  | PlantNET (2012); AVH (2013); N. McCaffrey pers. obs.; C. Johns pers. obs; P. McKenna pers. obs. | Described as occurring in heath or sclerophyll forest, typically in wet places. Often found at the edges of swamps, creeks or drainage lines. Observed in wetland areas subject to shallow surface inundation by UQ field staff. Seedlings established in free-draining and waterlogged conditions in UQ glasshouse and Tolerated subsequent shallow inundation (3-5cm, ~8 weeks even when completely submerged. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Baloskion australe | Sedge/ Rush | Perennial | Amp | ATe |  | F |  | PlantNET (2013); AVH (2013); N. McCaffrey pers. obs. | Usually described as occurring in wet peaty, sandy or gravelly soil and in Sphagnum bogs. Sometimes found in forest and/or extending upslope from drainage lines into drier areas. Has been seen growing in a few cm of water at some Newnes Plateau wetland sites. |
| Baloskion fimbriatum | Sedge/ Rush | Perennial | Amp | ATe |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in wet and poorly drained, deep sandy soils. Frequently found at wetland edges, in the ecotone between the wet swamp edge and surrounding drier habitat vegetation. |
| Baloskion gracile | Sedge/ Rush | Perennial | Amp | ATe |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in wet and poorly drained deep, sandy or peaty soils. Also often collected from non-wetland sites. |
| Baloskion spp. | Sedge/ Rush | Perennial | Amp | ATe |  | F |  | PlantNET (2013) | Described as generally occurring in swampy, peaty areas. |
| Banksia cunninghamii | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in dry sclerophyll forest |
| Banksia ericifolia | Shrub | Perennial | Amp | ATw |  | F |  | PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.; P. McKenna pers. obs. | Described as occurring in heath, dry sclerophyll forest and woodland. Also sometimes found in swampy situations (c. 10% of AVH records from NSW & ACT). Observed growing in waterlogged soil at one Newnes Plateau wetland monitoring site. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Banksia marginata | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as occurring in dry sclerophyll forest |
| Banksia spinulosa | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as occurring in heath, dry sclerophyll forest and woodland. |
| Banksia spp. | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013) | Classified based on distribution records of other species listed in this table only. |
| Bauera spp. | Forb/Shrub | Perennial | Ter | T | | F | | PlantNET (2013) | Only three species described for this genus in NSW. Habitats range from open heath to wet areas. |
| Baumea rubiginosa | Sedge/ Rush | Perennial | Amp | ATe | | E,F | | PlantNET (2013); AVH (2013); Johns et al (In prep.) | Described as occurring in swamps and other damp areas, on sandy soils. Established inshallow water (3-5cm deep) in UQ glasshouse experiment. |
| Baumea spp. | Sedge/ Rush | Perennial | Amp | ATe | | F | | PlantNET (2013) | Described variously as occurring in permanently moist areas, in standing water, along streams and in swamps. |
| Billardiera scandens | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as common in open eucalypt forest and woodlands. |
| Blechnum ambiguum | Fern | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Described as common on wet rocks, near waterfalls, on cliff faces and in similar situations. |
| Blechnum cartilagineum | Fern | Perennial | Ter | T | | F | | PlantNET (2013); AVH (2013) | Described as widespread and hardy, occurring in open forest and rainforest. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Blechnum minus | Fern | Perennial | Amp | ATe | ATe/Tda | F | | PlantNET (2013); Romanowski (1998); AVH (2013) | Described most often as forming colonies along creek banks on wet to waterlogged soil just above the water line and in seasonally waterlogged swamps, usually in partly shaded places. |
| Blechnum nudum | Fern | Perennial | Amp | ATe | | F | | PlantNET (2013); Romanowski (1998); AVH (2013); N. McCaffrey pers. obs.; C. Johns pers. obs. | Occurs in moist to waterlogged areas including rainforest gullies, stream banks and sometimes in swamps, in forested places, often partly shaded. Has been observed in wet areas in a few cm of water on the Newnes Plateau. |
| Blechnum patersonii | Fern | Perennial | Amp | ATe | | F | | PlantNET (2013); Romanowski (1998); AVH (2013) | Described as being found often along creeks or in rock crevices, in rainforest and moist gullies. |
| Blechnum spp. | Fern | Perennial | Amp | ATe | ATe/Tda | F | | PlantNET (2013) | |
| Boronia deanei | Shrub | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013); P. McKenna pers. obs. | Described as growing in wet heath and mainly collected from around the margins of swamps. |
| Boronia microphylla | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as growing in heath and dry sclerophyll forest on sandstone. Approx. 5% of collection records from riparian or poorly drained areas. |
| Boronia spp. | Shrub | Perennial | Ter | T | | F | | PlandNET (2013) | |
| Bossiaea heterophylla | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as common on sandy soils in a variety of habitats. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Bossiaea lenticularis | Shrub | Perennial | Ter | Tda |  | E,F |  | PlantNET (2013); AVH (2013); C. Johns pers. obs | Described as occurring in dry sclerophyll forest, often in moist sites. Sometimes collected around edges of swamps. Single specimen Established infree-draining conditions in UQ glasshouse experiment. |
| Brachyloma daphnoides | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in heath, dry sclerophyll forest and woodland, usually on sandy soils. |
| Brachyscome graminea | Forb | Perennial | Ter | Tda |  | F |  | PlantNET (2013); AVH (2013) | Often described as occurring on moist or swampy ground. |
| Brachyscome scapigera | Forb | Perennial | Ter | Tda |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in sclerophyll forest, frequenly on swampy ground. |
| Brachyscome spathulata | Forb | Perennial | Ter | T |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring on heavy soils in open areas, including in woodlands, grasslands and alpine meadows. |
| Brachyscome spp. | Forb | Annual or Perennial | Ter | T |  | F |  | PlantNET (2013) |  |
| Caesia parviflora | Forb | Perennial | Ter | Tdr | Tdr/Tda | F |  | PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.; P. McKenna pers. obs. | Described as occurring in heath (including wet and dry heath), woodlands and dry sclerophyll forests on sandstone-derived soils. Sometimes observed at damp/waterlogged sites by UQ staff. |
| Caladenia spp. | Forb |  | Ter | Tdr |  | F |  | PlantNET (2013) | Generally described as occurring most commonly in dry sclerophyll forests or woodlands. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Callicoma serratifolia | Shrub or Tree | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Described as occurring mainly in rainforest and being common along creeks and rocky gullies. |
| Callistemon pityoides | Shrub | Perennial | Amp | ATw | | F | | PlantNET (2013); AVH (2013) | Described as occurring in wet places, including wet heath and riparian scrub as well as in swamps. Typically collected from boggy areas, often in peaty granitic heathland or sometimes in shallow and/or running water in open sites. |
| Calochilus spp. | Forb | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Most spp occur mainly in dry sclerophyll forest and similarly dry/terrestrial environments, but C. paludosis is also often found in swampy heaths and on damp peaty soils. Calochilus grandiflorus is also occasionally found in peaty, swampy areas. |
| Calochlaena dubia | Fern | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Decribed as widespread in tall open forest, usually on poorer soils. Often found in moist to wet areas, including lining creeks. |
| Calytrix tetragona | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as occcurring in heath, woodland and dry sclerophyll forest, particularly on skeletal and sandy soils. |
| Carex gaudichaudiana | Sedge/ Rush | Perennial | Amp | ATe | | F | | Reid & Quinn (2004); PlantNET (2013); Romanowski (1998); AVH (2013) | Described as occurring in swamps, in shallow water and on creek banks. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Carex inversa | Sedge/ Rush | Perennial | Amp | ATe |  | F |  | Cunningham et al (1992); PlantNET (2013) | Described in PlantNET as being widespread in grassland and open forest (drier sites), but according to Cunningham et al (1992), it grows in moist situations such as swamps, river flats and regularly flooded roadside drains (i.e. areas that have standing water some of the time). |
| Carex spp. | Sedge/ Rush | Perennial | Amp | ATe |  | E,F |  | Brock & Casanova (1997); Casanova & Brock (2000); PlantNET (2013); C. Johns pers. obs | Brock & Casanova may not be referring to the same Carex sp., but the UQ survey team have recorded this Carex in swampy areas only on the Newnes Plateau (i.e. subject to wetting and drying) and it should have a broadly similar life-history. |
| Cassinia aculeata | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occuring in sclerophyll forest, woodland and heath on sandy or gravelly soils. |
| Cassinia compacta | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Occurs in sclerophyll forest and wooldand on sandy and clay soils and rocky sandstone ridges. |
| Cassinia uncata | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Occurs in mallee or dry sclerophyll forest, on ridges in gravelly or silty soil. |
| Cassytha glabella | Vine | Perennial | Ter | Tda |  | F |  | PlantNET (2013); AVH (2013) | Parasitic twiner. |
| Caustis recurvata | Sedge/ Rush | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Occurs in coastal sandy heath and mountain heath. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Celmisia longifolia | Forb | Perennial | Amp | ATe |  | F |  | PlantNET (2013); AVH (2013); P. McKenna pers. obs. | Described as usually occurring in bogs or seepages. Often observed in wet swamps on the Newnes Plateau by UQ staff. |
| Celmisia spp. | Forb | Perennial | Ter | Tda |  | F |  | PlantNET (2013) |  |
| Centaurium erythraea | Forb | Annual or Biennial | Ter | Tda | Tda/Tdr | E,F | D | PlantNET (2013); AVH (2013); Johns et al (In prep.) | Described as widespread, especially in pastures. Frequently an early coloniser of floodplain areas and wetland margins after drawdown. Occurs in similar situations to *Cirsium vulgare* (classified as Tda by Brock & Casanova 1997). Established in damp free-draining conditions in UQ glasshouse experiment and did not survive subsequent immersion. |
| Centaurium spp. | Forb | Annual or Biennial | Ter | Tda | Tda/Tdr | F | D | PlantNET (2013); AVH (2013) | Described as widespread, especially in pastures and/or settled areas. |
| Centaurium tenuiflorum | Forb | Annual or Biennial | Ter | Tda | Tda/Tdr | F | D | PlantNET (2013); AVH (2013) | Described as widespread in settled areas but uncommon. Frequently an early coloniser of floodplain areas and wetland margins after drawdown. Occurs in similar situations to Cirsium vulgare (classified as Tda by Brock & Casanova 1997). |
| Centella asiatica | Forb | Perennial | Ter | Tda |  | F | D | PlantNET (2013); AVH (2013); N. McCaffrey pers. obs. | Described as growing mainly in damp places. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Centipeda minima | Forb | Annual | Amp | ATl | | E,F | | Casanova & Brock (2000); Reid & Quinn (2004); PlantNET (2013); AVH (2013) | Common in damp areas, including areas subject to flooding where it typically germinates during drawdown. |
| Centipeda spp. | Forb | Annual or Perennial | Amp | ATl | | E,F | D? | PlantNET (2013) | PlantNET describes these species as occurring in damp places or areas subject to flooding. Centipeda minima and C. cunninghamii can germinate underwater (own unpublished experimental results). |
| Characeae indeterminate | Macroalgae | | Aqu | Sr | | E,F | | Casanova (2011); AVH (2013) | |
| Chiloglottis spp. | Forb | | Ter | T | | F | | PlantNET (2013) | Described as occurring in various habitats, from damp to dry. |
| Cirsium vulgare | Forb | Biennial | Ter | Tda | Tda/Tdr | E,F | D | Brock & Casanova (1997); PlantNET (2013); AVH (2013); Johns et al (In prep.) | Classified as Tda by Brock & Casanova (1997). However, often occurs in dry locations and disturbed habitats. Established in free-draining conditions only in UQ glasshouse and did not survive subsequent inundation. |
| Clematis aristata | Vine | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Occurs in moist or sheltered sites, usually in forests. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Clematis spp. | Vine | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Mostly climbers. |
| Comesperma ericinum | Shrub | Perennial | Ter | Tda | Tdr/Tda | F | | PlantNET (2013); AVH (2013) | Described as occurring mainly in or on the edges of dry sclerophyll forest on sandstone. |
| Comesperma retusum | Shrub | Perennial | Amp | ATw | | F | | PlantNET (2013); AVH (2013); C. Johns pers. obs. | Described as mainly occurring in permanently wet places, including wet hillsides, moist soil in wet heath, in swamps and along creeklines. |
| Comesperma spp. | Shrub or Vine | Perennial | Ter/Amp | T/ATw | | F | | PlantNET (2013) | Habitats range from dry to wet, depending on species. |
| Conospermum taxifolium | Shrub | Perennial | Ter | Tda | Tda/Tdr | F | | PlantNET (2013); AVH (2013) | Described as occurring in heath and dry sclerophyll woodland, typically in dry heath on deep sand dunes, but occasionally collected in swamps (i.e. <7% of AVH records). |
| Conyza bonariensis | Forb | Annual | Ter | Tda | | E,F | D | Brock & Casanova (1997); Reid & Quinn (2004); PlantNET (2013); AVH (2013) | Common in disturbed areas. |
| Conyza spp. | Forb | Annual | Ter | Tda | | E,F | D | Brock & Casanova (1997); Reid & Quinn (2004); PlantNET (2013) | Most species found in NSW are annuals (PlantNET 2012). Classification based on distribution records of species found in Newnes Plateau sites. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Conyza sumatrensis | Forb | Annual | Ter | Tda |  | F | D | PlantNET (2013); AVH (2013) | Common in disturbed areas. |
| Coronidium scorpioides | Forb | Perennial | Ter | Tda |  | E,F | D | PlantNET (2013); AVH (2013); Johns et al (In prep.) | Described as generally growing in stringybark forest, often on disturbed sites and generally on clay-loam soils. Established inUQ glasshouse experiment under damp free-draining conditions. Established plants did not survive waterlogging or immersion (8 weeks). |
| Craspedia spp. | Forb | Annual or Perennial | Ter | T |  | F |  | PlantNET (2013) | WPFG depends on species. The species found so far in the Blue Mountains west of Sydney occur in habitats ranging from dry to wet situations such as in swamps. |
| Crepis capillaris | Forb | Perennial | Ter | T |  | F | D | PlantNET (2013); AVH (2013) | Described as a common weed of roadsides and disturbed areas. |
| Cryptandra spp. | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | The species occurring in the Blue Mountains west of Sydney generally occur in drier habitats, e.g. rocky sites in open forest. |
| Cryptostylis spp. | Forb |  | Ter | T |  | F |  | PlantNET (2013) | Some described as occurring commonly in swamp heath, others usually found in sclerophyll woodland or forest. |
| Cyathea australis | Fern | Perennial | Ter | Tda |  | F |  | PlantNET (2013); AVH (2013) | Described as widespread in rainforest or open forest in gullies or on hillsides in moist shady situations. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Cyperaceae indeterminate | Sedge/Rush | | Amp | Ate | | F | | Reid & Quinn (2004); Casanova (2011) | |
| Cyperus spp. | Sedge/ Rush | Annual or Perennial | Amp | ATe | | E,F | | Reid & Quinn (2004); Casanova (2011) | Cyperus spp classified as Ate by Brock & Casanova (1997) based on experimental data. |
| Dampiera stricta | Forb | Perennial | Ter | Tdr | | E, F | | PlantNET (2013); AVH (2013); C. Johns pers. obs. | Described as usually occurring in heath on sandy soils. Established inUQ glasshouse experiment under free-draining conditions only. |
| Darwinia fascicularis | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as occurring in heath or dry sclerophyll forest. |
| Daviesia latifolia | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as widespread in dry sclerophyll communities. |
| Daviesia spp. | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013) | Most described as occurring mainly in dry sclerophyll forest and many mainly found on sandy or skeletal soils. |
| Daviesia ulicifolia | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as mainly occurring in dry sclerophyll forest. |
| Derwentia blakelyi | Forb | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Name updated to Veronica blakelyi. Described as occurring mainly in eucalypt forest. |
| Deyeuxia brachyathera | Grass | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Described as occurring in forest and mountain gullies, especially in cool, damp places. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Deyeuxia gunniana | Grass | Perennial | Ter | Tda | Tda/ATe | F | | PlantNET (2013); AVH (2013) | Described as occurring in shady or damp areas in forest or swamps. Typically collected from areas described as damp to wet e.g. at waters edge beside creek or on moist peat, rather than in standing water. |
| Deyeuxia innominata | Grass | Perennial | Ter | Tda | Tda/ATe | F | | PlantNET (2013); AVH (2013) | Described as often growing on hillsides or slopes, usually in wet places (e.g. wet herbfield) often by creeks or in swamps. |
| Deyeuxia quadriseta | Grass | Perennial | Ter | Tda | Tda/ATe | F | | PlantNET (2013); AVH (2013) | Often found in moist to wet areas, including on floodplains, along creeks and drainage lines and in swamps, but also collected in other situations (e.g. on slopes in eucalypt woodand or in grassland areas). |
| Deyeuxia spp. | Grass | Perennial | Ter/Amp | Tda/A | | F | | PlantNET (2013) | Most species occurring in the Blue Mountains are described as growing in moist, shady areas with many found growing in swamps. |
| Dianella caerulea | Forb | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013); C. Johns pers. obs. | Described as occurring in heath, dry sclerophyll forest and rainforest. Very occasionally recorded in swampy areas (<2% of herbarium records of 157 assessed). |
| Dianella prunina | Forb | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as occurring in sclerophyll forest on sandy soils. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Dianella revoluta | Forb | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in sclerophyll forest, woodland and mallee. |
| Dianella spp. | Forb | Perennial | Ter | T |  | F |  | PlantNET (2013) | Most species occur in dry sclerophyll forest, but D. tenuissima is a moist habitat specialist. |
| Dianella tasmanica | Forb | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as growing in sclerophyll forest on shallow, often sandy soils. |
| Dichelachne inaequiglumis | Grass | Perennial | Ter | Tda | Tda/ATe | F |  | PlantNET (2013); AVH (2013) | Described as widespread in woodland on better soils. 24% (of 67) herbarium records assessed referred to specimens collected from wetlands or damp habitats (e.g. drainage lines and soaks). |
| Dichelachne micrantha | Grass | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as common in dry or wet sclerophyll forest. Just over 1% (of 205) herbarium records assessed were from specimens collected in wetland habitats. |
| Dichelachne parva | Grass | Perennial | Ter | Tda |  | F |  | PlantNET (2013); AVH (2013) | Described as growing in wet habitats in montane areas on sandy or granitic soil or in shale woodland in higher rainfall areas. Often collected from moist (rather than inundated) areas e.g. wet scleropyll forest. |
| Dichelachne spp. | Grass | Perennial | Ter/Amp | T/A |  | F |  | PlantNET (2013) | Some described as occurring in wet habitats and others described as being common in wet or dry sclerophyll forest or woodlands. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Dichondra repens | Forb | Perennial | Ter | Tda |  | F |  | Cunnningham et al (1992); PlantNET (2013); AVH (2013); C. Johns pers. obs. | Described as growing in damp shaded places on a variety of soil types. Frequently found in damp areas in Newnes Plateau wetlands by UQ survey team. |
| Dichondra sp. (Glabrous leaves) | Forb | Perennial | Ter | Tda |  | F |  | Cunnningham et al (1992); PlantNET (2013); AVH (2013); N. McCaffrey pers. obs. | This taxon referred to as *D. newengland* in a draft manuscript by the late Bob Johnson (*D. newengland* currently used as the provisional name for this taxon by the National Herbarium of New South Wales- McCaffrey pers. comm.). Often observed on damp soils or mud at Newnes Plateau wetland sites by UQ field staff. |
| Dichondra spp. | Forb | Perennial | Ter | Tda |  | F |  | PlantNET (2013) |  |
| Dillwynia phylicoides | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in dry sclerophyll forest on acidic, well-drained soils. |
| Dipodium punctatum | Forb |  | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Saprophytic orchid. Described as occurring in wet sclerophyll forest to dry sclerophyll woodland on a variety of soils. |
| Dipodium roseum | Forb |  | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Saprophytic orchid. Described as occurring in wet sclerophyll forest to dry sclerophyll woodland on a variety of soils. |
| Dittrichia graveolens | Forb | Perennial | Ter | Tda |  | F | D | Cunnningham et al (1992); PlantNET (2013); AVH (2013) | Described as common in disturbed areas, particularly areas that receive extra moisture, along rivers, creeks, roadsides and in low-lying areas. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Diuris spp. | Forb | | Ter | T | | F | | PlantNET (2013) | Orchids. Mostly described as occurring in dry sclerophyll forest, though some mainly occur in moist habitats. |
| Drosera binata | Forb | Annual or Perennial | Amp | ATe | | E,F | | PlantNET (2013); AVH (2013); N. McCaffrey pers. obs; P. McKenna pers. obs.; Johns et al (In prep.) | Described as occurring in wet sand and sandy peat in swamps, on creek banks and on seepage lines. Often observed in shallow water by UQ field staff. Established inUQ glasshouse under damp or waterlogged conditions and Tolerated subsequent shallow inundation (>8 weeks) provided emergent stems were present (otherwise senesced). |
| Drosera peltata | Forb | Annual or Perennial | Ter | Tda | | E,F | | PlantNET (2013); AVH (2013); N. McCaffrey pers. obs; P. McKenna pers. obs.; Johns et al (In prep.) | Described as widespread in moist areas. Established in UQ glasshouse under damp or waterlogged conditions. |
| Drosera pygmaea | Forb | Annual or Perennial | Ter | Tda | | | | AVH (2013); N. McCaffrey pers. obs. | Observed growing in moist areas by UQ staff but not necessarily in the presence of surface water. |
| Drosera spatulata | Forb | Annual or Perennial | Ter | Tda | | E,F | | PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.; Johns et al (In prep.) | Described as occurring in wetlands and heath. Observed growing on mud and in drier areas by UQ staff, but not in standing water. Established in UQ glasshouse under damp or waterlogged conditions |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Drosera spp. | Forb | Annual or Perennial | Ter | Tda | | F | | PlantNET (2013); C. Johns pers. obs. | *Drosera* spp that are not identified to species level in Newnes Plateau wetlands are most likely to be *D. spathulata* or *D. peltata or D. pygmaea.* |
| Echinopogon ovatus | Grass | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Described as occurring in wet sclerophyll woodland and along creeks. |
| Eleocharis spp. | Sedge/ Rush | Annual or Perennial | Amp | ATe | | E,F | | Reid & Quinn (2004); Casanova (2011); AVH (2013); Johns et al (In prep.) | Established inUQ glasshouse under waterlogged or inundated (3-5cm depth) conditions. |
| Eleocharis gracilis | Sedge/ Rush | Perennial | Amp | ATe | | F | | PlantNET (2013); AVH (2013) | Described as occurring in seasonally wet situations. |
| Emilia sonchifolia | Forb | Annual | Ter | T | | F | D | PlantNET (2013); AVH (2013) | Described as a common weed of roadsides and open areas. Few herbarium records for this state. |
| Empodisma minus | Sedge/ Rush | Perennial | Amp | ATe | | E,F | | PlantNET (2013); Romanowski (1998); Johns et al (In prep.) | Described as common in bogs, swampy places and on wet creek banks including areas that may be shallowly flooded at times, always in acid soils. Established inUQ glasshouse under damp, waterlogged or inundated (3-5cm depth) conditions. |
| Entolasia marginata | Grass | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013); N. McCaffrey pers. obs. | Described as occurring in scrub in slightly damper areas on sandy or sandstone-derived soils. Observed growing in damp areas by UQ staff but not in standing water. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Entolasia spp. | Grass | Perennial | Ter | T |  | F |  | PlantNET (2013) | Described as occurring in dry scrub or in damper areas on sandy or sandstone-derived soils. |
| Entolasia stricta | Grass | Perennial | Amp | ATw |  | E,F |  | PlantNET (2013); AVH (2013); Johns et al (In prep.) | Described as occurring in scrub in dry areas, on sandy or sandstone-derived soils, though occasionally collected from moist or swampy areas. Established in UQ glasshouse under damp, waterlogged or inundated (3-5cm depth) conditions. Plants remained healthy during surface inundation (3-5cm depth) for >8 weeks (i.e. til end of experiment). |
| Epacris microphylla | Shrub | Perennial | Amp | ATw |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in swampy heath but also in drier coastal heath and dry sclerophyll forest on sandstone and granite. |
| Epacris obtusifolia | Shrub | Perennial | Amp | ATw |  | F |  | PlantNET (2013); AVH (2013) | Described as usually occurring in swampy situations or in wet heath. |
| Epacris paludosa | Shrub | Perennial | Amp | ATw |  | E,F |  | PlantNET (2013); AVH (2013); Johns et al (In prep.) | Described as occurring in swamps, bogs and wet heath on sandstone and granite. Established in UQ glasshouse under damp free-draining or waterlogged conditions. |
| Epacris spp. | Shrub | Perennial | Ter/Amp | T/ATw |  | F |  |  |  |
| Epilobium billardierianum | Forb | Perennial | Ter | Tda |  | F |  | PlantNET (2013); AVH (2013) | Described as being widespread in moist habitats. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Eriochilus cucullatus | Forb | | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Orchid. Described as being widespread in open habitats. |
| Eucalyptus blaxlandii | Tree | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Habitat described as wet or dry sclerophyll forest on moderately fertile sandy soil in elevated sandstone country. |
| Eucalyptus dalrympleana | Tree | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Approx. 4% (of 129) herbarium records referred to specimens growing on swampy ground, with another 10% collected from riparian areas. |
| Eucalyptus dives | Tree | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as occurring on shallow soils on rises. |
| Eucalyptus fastigata | Tree | Perennial | Ter | Tda | Tdr/Tda | F | | PlantNET (2013); AVH (2013) | Described as occurring in wet sclerophyll forest in cold wet areas on fertile soils. |
| Eucalyptus mannifera | Tree | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Approx 3% (of 361) herbarium records assessed referred to specimens growing on swampy ground. |
| Eucalyptus oreades | Tree | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as sporadic but locally frequent in wet or dry sclerophyll forest, usualy on poor skeletal or sandy soils on high sloping country. |
| Eucalyptus pauciflora | Tree | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Less than 0.5% (of 465) herbarium records assessed were from specimens described as occurring in swamps. However, approximately 7% of records were from specimens growing at the edges of swamps or in riparian situations. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Eucalyptus radiata | Tree | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Approx. 10% of herbarium records indicate occurrence near creeks or swamps, but rarely actually recorded in swamps (i.e. two records, of 307). |
| Eucalyptus sieberi | Tree | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as dominant in wet or dry sclerophyll forest and woodland areas. |
| Eucalyptus sp. (seedling) | Tree | Perennial | Ter | Tdr | Tdr/Tda | F | | PlantNET (2013) | |
| Eucalyptus spp. | Tree | Perennial | Ter | Tdr | | F | | PlantNET (2013) | |
| Eucalyptus stricta | Tree | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | A small number of herbarium records were for specimens growing close to water, with one record (of 325) of a specimen occurring in a permanent bog. |
| Euchiton involucratus | Forb | Perennial | Ter | Tda | | E,F | | PlantNET (2013); Campbell et al (2014); AVH (2013); Johns et al (In prep.) | Described as occurring on moist ground. Often found in areas subject to periodic inundation (33% of herbarium records referred to occurrence in wetland areas). Established in UQ glasshouse under free-draining conditions only and did not survive subsequent inundation (8 weeks). |
| Euchiton sphaericus | Forb | Perennial | Ter | Tda | | F | | PlantNET (2013); Campbell et al (2014); AVH (2013) | Described as being widespread in various habitats. Occurs in similar situations to *Cirsium vulgare which was* classified as Tda in previous studies. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Euchiton spp. | Forb | Perennial | Ter | T |  | F |  | PlantNET (2013) | Most species described as occurring in shady or moist areas, but some are not. |
| Gahnia aspera | Sedge/ Rush | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in drier situations in rainforest, dry sclerophyll forest and woodland. |
| Gahnia filifolia | Sedge/ Rush | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as growing in open woodland on hillsides, often on drier sites, on sandy soils. Occasionally collected in swamps. |
| Gahnia melanocarpa | Sedge/ Rush | Perennial | Ter | T |  | F |  | PlantNET (2013); AVH (2013) | Described as growing in wet sclerophyll forest and rainforest. |
| Gahnia microstachya | Sedge/ Rush | Perennial | Ter | Tdr |  |  |  | PlantNET (2013); AVH (2013) | Occurs in sclerophyll forest and woodland in drier situations. |
| Gahnia sieberiana | Sedge/ Rush | Perennial | Amp | ATe |  | F |  | PlantNET (2013); Romanowski (1998); AVH (2013); P. McKenna pers. obs. | Described as growing in damp places including creek edges or areas that may flood in winter as well as on drier hillsides in woodland, usually on sand or silt. Approx. 15% (of 110) herbarium records refer to swampy habitats. |
| Gahnia spp. | Sedge/ Rush | Perennial | Ter/Amp | T/ATe |  | F |  | PlantNET (2013) |  |
| Galium gaudichaudii | Forb | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as being widespread, particularly in relatively dry sites. |

| **Scientific name** | **Life form** | **Longevity** | **Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG** | **WPFG subcategory** | **WPFG classification borderline?** | **Classified using experimental data (E) or field observations (F)** | **Described as common in disturbed areas (D)** | **References** | **Comments** |
|---|---|---|---|---|---|---|---|---|---|
| Galium propinquum | Forb | | Ter | Tdr | | F | | Cunningham et al (1992); PlantNET (2013); AVH (2013) | Little information provided about habitat. Was recorded on a mountaintop near Ardlethan, in a mallee gum community (Cunningham et al (1992)). |
| Galium spp. | Forb | Annual or Perennial | Ter | Tdr | | F | | PlantNET (2013) | |
| Genoplesium spp. | Forb | | Ter | T | | F | | PlantNET (2013) | Congeners described as occurring in habitats ranging from damp 'moss-gardens' to ridgetops in sclerophyll forest. |
| Geranium homeanum | Forb | Annual or Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Described as usually occurring in damper sites. |
| Geranium neglectum | Forb | Perennial | Ter | Tda | | E,F | | PlantNET (2013); AVH (2013); Johns *et al* (In prep.) | Described as occurring on creek banks and in swamps. Only established in free-draining pots in UQ glasshouse experiment. |
| Geranium spp. | Forb | Annual or Perennial | Ter | T | | F | | PlantNET (2013) | |
| Gleichenia dicarpa | Fern | Perennial | Amp | ATe | | F | | PlantNET (2013); Romanowski (1998); AVH (2013); N. McCaffrey pers. obs. | Described as often forming large colonies in sunny damp to waterlogged sites, including in swamps and sumplands. Observed from damp to shallowly inundated conditions by UQ field staff. |
| Glossodia major | Forb | | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as occurring in sclerophyll forest, woodland and coastal heath. |

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|---|---|---|---|---|---|---|---|---|---|
| Gnaphalium spp. | Forb | Annual or Perennial | Ter | T |  | F | D | PlantNET (2013) | Some species described as occurring on periodically inundated ground, some described as colonisers of bare ground, occurring on sites subject to periodic disturbance (whether dry or damp), others habitat unspecified. |
| Gompholobium huegelii | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as widespread in dry sclerophyll forest and heath on sandy to gravelly soils. |
| Gonocarpus micranthus | Forb |  | Amp | ATl |  | E,F |  | PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.; Johns et al (In prep.) | Described as occurring in swamps and damp places in heath or open forest. Observed multiple times in damp to shallowly inundated areas by UQ field staff. Established in damp free-draining or waterlogged conditions in UQ glasshouse experiment. Established plants maintained growth during shallow inundation (3-5cm) over 8 weeks even when completely immersed. |
| Gonocarpus oreophilus | Shrub | Perennial | Ter | Tda |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in the understory of wet scleropyll forest or rainforest. |
| Gonocarpus tetragynus | Forb | Perennial | Ter | Tda |  | E,F |  | PlantNET (2013); AVH (2013) ; Johns et al (In prep.) | Described as occurring in dry sclerophyll forest, heath and shrubstone, normally on sandstone. Established in free-draining or waterlogged conditions in UQ glasshouse and did not survive subsequent immersion (8 weeks). |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Goodenia bellidifolia | Forb | | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as occuring in heath or sclerophyll forest, often on sandstone. |
| Goodenia hederacea | Forb | | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as growing in various habitats from forest to alpine woodland and grassland. |
| Goodenia ovata | Shrub | Perennial | Ter | Tdr | | F | D | PlantNET (2013); AVH (2013) | Described as occurring in forest and woodland and sometimes in exposed rocky situations near sea. |
| Goodenia spp. | Forb | | Ter | Tdr | | F | | PlantNET (2013) | |
| Goodenia stelligera | Forb | | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Described as growing in swamps on sandstone. |
| Gratiola peruviana | Forb | Perennial | Amp | ATl | | F | | Casanova (2011); PlantNET (2013); AVH (2013) | Classified as Tda by Casanova (2011), but described as growing in shallow water in the silt and mud of swamps and stream banks by PlantNET (2013). Of 87 AVH records assessed, 100% referred to damp, riparian or aquatic habitats. |
| Grevillea acanthifolia | Shrub | Perennial | Amp | ATw | | E,F | | PlantNET (2013); AVH (2013); Johns et al (In prep.) | Described as occurring in swampy areas or wet rock shelves, sand or peat over sandstone. Often collected from riparian areas e.g. on creek banks close to water, rather than in permanently inundated areas. In UQ glasshouse germinated from free-draining damp (and occasionally waterlogged) soil and once established tolerated shallow surface inundation (8wks), forming a dense network of surface roots extending into the water column. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Grevillea laurifolia | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in open woodland or dry sclerophyll forest on ridges and slopes. Sometimes found growing in the ecotone between eucalypt forest and swamp. |
| Grevillea x gaudichaudii | Shrub | Perennial | Ter | T |  | F |  | AVH (2013); Mt Tomah Botanic Gardens website www.mounttomahbotanicgarden.com.au | Described as occurring on sandstone cliffs, rocky gullies and swampy areas. |
| Gymnoschoenus sphaerocephalus | Sedge/ Rush | Perennial | Amp | ATe |  | F |  | PlantNET (2013); Romanowski (1998); AVH (2013) | Described as occurring in permanent swamps, on seasonally wet plains, on wet slopes and along shallow ephemeral creeks. |
| Haemodorum spp. | Forb |  | Ter | T |  | F |  | PlantNET (2013) | Congeners described as occurring in habitats from dry sclerophyll forest to swamps. |
| Hakea dactyloides | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring on sandy soils in heath, dry sclerophyll forest and woodland. Occasionally occurs in or near wetlands or watercourses. |
| Hakea laevipes | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring on sandy soils in heath, dry sclerophyll forest and woodland. |
| Hakea microcarpa | Shrub | Perennial | Amp | ATe |  | F |  | PlantNET (2013); AVH (2013) | Generally found in wet situations including in heathy swamps, riparian zones and hillside soaks. |
| Haloragis heterophylla | Forb | Perennial | Ter | Tda |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in moist areas, especially around creeks and drainage lines. |

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|---|---|---|---|---|---|---|---|---|---|
| Hemarthria uncinata | Grass | Perennial | Amp | ATe | | E,F | | PlantNET (2013); Romanowski (1998); AVH (2013); Johns et al (In prep.) | Grows in swamps and damp places. Tolerant of flooding. Established in UQ glasshouse under free-draining (and occasionally waterlogged) conditions. Established plants tolerated shallow surface inundation 3-5cm (8 weeks). |
| Hibbertia acicularis | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Described as widespread in heath and dry forest on infertile sands. |
| Hibbertia cistiflora subsp. cistiflora | Shrub | Perennial | Ter | Tda | Tdr/Tda | F | | PlantNET (2013); AVH (2013) | Occurs on sandstone, in dry sclerophyll forest and heath. Sometimes found in or beside swampy areas. |
| Hibbertia empetrifolia subsp. empetrifolia | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Occurs in woodland or sclerophyll forest scrambling over other vegetation. |
| Hibbertia linearis | Shru | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Occurs in heath and dry sclerophyll forest on sands. Often found on or near coastal sand dunes. |
| Hibbertia rufa | Shrub | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Described as widespread in sedgeland or heath. Of 40 herbarium records assessed, approx. 45% referred to specimens collected from heath swamps and another 45% were collected from habitats not described as wetland. |
| Hibbertia spp. | Shrub | Perennial | Ter | T | | F | | PlantNET (2013) | |
| Hibbertia vestita | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Occurs in dry sclerophyll forest on shallow, infertile soils. |

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|---|---|---|---|---|---|---|---|---|---|
| Histiopteris incisa | Fern | Perenial | Ter | Tda |  | F |  | PlantNET (2013); N. McCaffrey pers. obs.; AVH (2013) | Described as widespread in moist, sheltered situations. Only occasionally collected in swamps (i.e. in 2 of 104 AVH records assessed). |
| Holcus lanatus | Grass | Perennial | Amp | ATe | ATe/Tda | E,F | D | Cunningham et al (1992); PlantNET (2013); AVH (2013); Johns et al (In prep.) | Described as uncommon in Western NSW, found only from a damp site. More common in wetter climates and generally regarded as a weed in pastures, irrigation land and gardens. In UQ glasshouse experiment established under damp/free-draining conditions only, but Tolerated subsequent flooding and maintained growth provided emergent stems were present. |
| Hookerochloa hookeriana | Grass | Perennial | Amp | ATe | ATe/Tda | F |  | PlantNET (2013); AVH (2013) | Occurs in open forest or grassland in moist, swampy or waterlogged places. |
| Hovea heterophylla | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Occurs in dry sclerophyll woodland; widespread and common. |
| Hovea linearis | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Occurs in sands derived from sandstone in forest and woodland habitats. |
| Hydrocotyle laxiflora | Forb | Perennial | Ter | Tda | Tda/ATl | F |  | Brock & Casanova (1997); Casanova (2011); PlantNET (2013); AVH (2013); | Brock & Casanova (1997) classified Hydrocotyle triparitarta as Atl; Casanova (2011) classified Hydrocotyle verticillata as Atl; PlantNET (2013) describes H. laxiflora as commonly growing in moist areas. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Hydrocotyle peduncularis | Forb | Perennial | Amp | ATl |  | E,F |  | Brock & Casanova (1997); Casanova (2011); PlantNET (2013); AVH (2013); Johns et al (In prep.) | Brock & Casanova (1997) classified Hydrocotyle triparitarta as Atl; Casanova (2011) classified Hydrocotyle verticillata as Atl; PlantNET (2013) describes this species as commonly growing on wet mud. Some AVH (2013) records indicate this species collected below the water line in creeks. Frequently collected from damp or wet areas (including riparian zones and swamps). Established under free-draining or waterlogged conditions in UQ glasshouse. Established plants tolerated immersion (8 weeks) by increasing petiole lengths. |
| Hydrocotyle triparitata | Forb | Perennial | Amp | ATl |  | E,F |  | Brock & Casanova (1997); Casanova (2011); PlantNET (2013); AVH (2013) | Brock & Casanova (1997) classified Hydrocotyle triparitarta as Atl; Casanova (2011) classified Hydrocotyle verticillata as Atl; PlantNET (2013) describes this species as commonly growing on wet mud. Some AVH (2013) records indicate this species collected below the water lline in creeks. Frequently collected from damp or wet areas (including riparian zones and swamps). |
| Hydrocotyle spp. | Forb | Perennial | Amp/Ter | ATl/Tda |  | E,F |  | Brock & Casanova (1997); Casanova (2011); PlantNET (2013) | Brock & Casanova (1997) classified Hydrocotyle triparitarta as Atl; Casanova (2011) classified Hydrocotyle verticillata as Atl |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Hypericum gramineum | Forb |  | Ter | Tdr |  | F | D | PlantNET (2013); AVH (2013) | Described as occurring in well-drained soils of open forest and grassland. |
| Hypericum japonicum | Forb |  | Amp | ATl |  | E,F |  | PlantNET (2013); AVH (2013); C. Kilgour pers. obs.; N. McCaffrey pers. obs.; Johns et al (In prep.) | Described as growing on damp to wet soils. Of 71 herbarium records assessed, 51% specimens were collected in wetlands, 14% were from drier sites and 35% were from damp areas adjacent to wetlands or similar habitats. Established in UQ glasshouse under free-draining, waterlogged or shallowly-inundated (3-5cm) conditions and tolerated immersion (8 weeks) by reducing leaf size and increasing internode length. |
| Hypericum spp. | Forb | Annual or Perennial | Ter/Amp | T/ATe |  | F |  | PlantNET (2013) | Various habitats from well-drained soils to 'semi-aquatic' in water along river margins. |
| Hypochaeris glabra | Forb | Annual | Ter | Tdr |  | F | D | PlantNET (2013); AVH (2013) | Common in disturbed habitats. |
| Hypochaeris radicata | Forb | Annual | Ter | Tdr |  | E,F | D | PlantNET (2013); AVH (2013); Johns et al (In prep.) | Common in disturbed habitats. Established in UQ glasshouse under free-draining conditions only and did not survive subsequent immersion (8 weeks). |
| Hypochaeris spp./Leontodon taraxacoides | Forb | Annual | Ter | Tdr |  | F | D | PlantNET (2013) | Common in disturbed habitats. (Difficult to distinguish between taxa when immature.) |
| Hypolepis muelleri | Fern | Perennial | Ter | Tda |  | F |  | PlantNET (2013) | Occurs along creeks and swamps in open forest or margins of rainforest. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Hypoxis hygrometrica | Forb | Perennial | Ter | Tdr |  | F |  | Cunningham et al (1992); PlantNET (2013) | Described as common in open grassland areas including pastures. Dies back soon after seeding. |
| Isachne globosa | Grass | Perennial | Amp | ATe |  | F |  | PlantNET (2013); Romanowski (1998) | Described as usually growing in and beside fresh water and as an aquatic or semi-aquatic perennial to ~0.7m high. |
| Isolepis cernua | Sedge/Rush |  | Amp | Ate |  | F |  | N. McCaffrey pers. obs.; AVH (2013) | Only observed growing on damp to wet soils by UQ staff (i.e. not observed in dry areas). |
| Isolepis habra | Sedge/ Rush | Perennial | Amp | ATl |  | F |  | PlantNET (2013); AVH (2013) | Occurs on damp ground or in shallow water. |
| Isolepis inundata | Sedge/ Rush | Perennial | Amp | ATe |  | E,F |  | Casanova (2011); PlantNET (2013); AVH (2013); Johns *et al* (In prep.) | Described as widespread in moist habitats. Typically collected from areas of shallow water or wet mud (AVH 2013). Profuse germination and establishment in Newnes soil seedbank glasshouse experiment under waterlogged, free-draining moist and submerged (3-5cm depth) conditions. Inundation tolerant. |
| Isolepis spp. | Sedge/ Rush | Annual or Perennial | Ter/Amp | Tda/ATe |  | F |  | PlantNET (2013) | Described as occurring in moist situations. |
| Isolepis spp./Schoenus spp. | Sedge/ Rush | Annual or Perennial | Amp | ATe |  | F |  | C. Johns pers. obs. | Typically found growing in shallow water, or on wet mud and has an emergent growth form. (Difficult to distinguish between these taxa in the field when small/immature.) |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Isopogon anemonifolius | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as widespread in dry sclerophyll forest and heath. |
| Joycea pallida | Grass | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013); C. Johns pers. obs. | Now Rhytidosperma pallidum. Described as generally occurring on upland, acid soils of low fertility. |
| Juncus bufonius | Sedge/ Rush | Annual | Amp | ATe |  | E,F | D | PlantNET(2014); Johns *et al* (In prep.) | Described as common in seasonally wet disturbed habitats. Established in UQ glasshouse under waterlogged or submerged conditions. Inundation tolerant. |
| Juncus continuus | Sedge/ Rush | Perennial | Amp | ATe |  | E,F |  | Reid & Quinn (2004); AVH (2013) | Described as common in moist places with sandy soils. |
| Juncus planifolius | Sedge/ Rush | Annual or Perennial | Amp | ATe |  | E,F |  | PlantNET (2013); Reid & Quinn (2004); AVH (2013); Johns *et al* (In prep.) | Frequent germination and establishment in Newnes soil seedbank glasshouse experiment under waterlogged, free-draining moist and submerged (3-5cm depth) conditions. Inundation tolerant. |
| Juncus spp. | Sedge/ Rush | Perennial | Amp | ATe |  | E,F |  | Reid & Quinn (2004) | Juncus spp. classified as Ate by Reid & Quinn (2004). |
| Juncus usitatus | Sedge/ Rush | Perennial | Amp | ATe |  | E,F |  | Reid & Quinn (2004), Campbell *et al* (2014) | Described as common on stream banks and in other moist areas. |
| Lachnagrostis filiformis | Grass | Annual or Perennial | Ter | Tda |  | F | D | PlantNET (2013); AVH (2013) | Described as often occurring on heavy soils or in moist areas. |

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|---|---|---|---|---|---|---|---|---|---|
| Lachnagrostis spp. | Grass | Annual or Perennial | Ter | Tda |  | F |  | PlantNET (2013); N. McCaffrey pers. obs. | Described as often occurring on heavy soils or on moist sites. |
| Lactuca serriola | Forb | Biennial | Ter | Tdr |  | F | D | PlantNET (2013) | Described as common and widespread weed of gardens, roadsides, wasteland, cultivation and degraded pastures. |
| Lagenophora stipitata | Forb | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Occurs in grassland, tall alpine herbfield, woodland and sclerophyll forest. |
| Leontodon taraxacoides | Forb | Perennial or Biennial | Ter | Tda |  | E,F | D | PlantNET (2013); AVH (2013); Johns *et al* (In prep.) | A weed of lawns and wasteland. Frequently found in damp areas. Single plant established in UQ glasshouse under waterlogged conditions (none in other treatments). |
| Lepidosperma gunnii | Sedge/ Rush | Perennial | Ter | Tda |  | F |  | PlantNET (2013); AVH (2013) | Occurs in woodland and heath, often in damper areas. |
| Lepidosperma laterale | Sedge/ Rush | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in a range of habitats, especially woodland and forest, mostly on sandy soils, often on rocky hillsides. |
| Lepidosperma limicola | Sedge/ Rush | Perennial | Amp | ATe |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in swamps. |
| Lepidosperma tortuosum | Sedge/ Rush | Perennial | Amp | ATe |  | F |  | PlantNET (2013); AVH (2013) | Occurs in mountain heath and woodland habitats. Frequently found around the edges of wetlands, as well as in higher, drier locations. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Lepidosperma spp. | Sedge/ Rush | Perennial | Ter/Amp | T/ATe | | F | | PlantNET (2013) | Congeners found in a range of habitats, from dry to swampy. |
| Leptospermum arachnoides | Shrub | Perennial | Ter | T | | F | | PlantNET (2013) | Occurs in moist heath and sclerophyll forest on shallow soils. |
| Leptospermum continentale | Shrub | Perennial | Amp | ATw | | E,F | | PlantNET (2013); AVH (2013) ; Johns *et al* (In prep.) | Occurs in forest or open sandy, swampy places. Established in UQ glasshouse under waterlogged conditions (none in other treatments). |
| Leptospermum grandifolium | Shrub | Perennial | Amp | ATw | | E,F | | PlantNET (2013); AVH (2013); C. Johns pers. obs. | Mostly collected from riparian habitats. Occurs in sandy swamps and in riparian zones along rocky streams. Established in UQ glasshouse under moist free-draining or waterlogged conditions. |
| Leptospermum obovatum | Shrub | Perennial | Amp | ATw | ATw/Tda | E,F | | PlantNET (2012); AVH (2013); Johns et al (In prep.) | Often occurs in swamps, generally toward the margins, but mostly found in riparian communities among granite or sandstone rocks along the edges of swift-flowing streams. Established in UQ glasshouse under free-draining or waterlogged conditions. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Leptospermum polygalifolium | Shrub | Perennial | Amp | ATw | ATw/Tda | E,F |  | PlantNET (2013); AVH (2013); Johns et al (In prep.) | Occurs in sandy soil or on sandstone, but also on basalt derived soils. Commonly found in riparian areas and occasionally collected in swamps, but frequently occurs in other situations. Established in UQ glasshouse under free-draining or waterlogged conditions. Tolerated subsequent inundation (3-5cm depth, 8 weeks). |
| Leptospermum sphaerocarpum | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Occurs in heath or dry sclerophyll forest on ridges or escarpments. |
| Leptospermum spp. | Shrub | Perennial | Ter/Amp | T/ATw |  | F |  | PlantNET (2013) | Various habitats. |
| Leptospermum trinervium | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Occurs in dry sclerophyll forest, heath and scrub in deep or shallow sandy soil. |
| Lepyrodia anarthria | Sedge/ Rush | Perennial | Amp | ATe |  | E,F |  | PlantNET (2013); AVH (2013); Johns et al (In prep.) | Occurs in or near swamps and in wet or damp peaty soils. Established in UQ glasshouse under free-draining or waterlogged conditions. Tolerated subsequent inundation (3-5cm depth, 8 weeks). |
| Lepyrodia scariosa | Sedge/ Rush | Perennial | Amp | ATe |  | F |  | PlantNET (2013); AVH (2013); C. Kilgour pers. obs.; N. McCaffrey pers. obs.; C. Johns pers. obs. | Occurs in moist sand or peaty soil in heath and woodland and near margins of swamps. Sometimes observed in shallowly inundated wetlands by UQ staff. |
| Lepyrodia spp. | Sedge/ Rush | Perennial | Ter/Amp | Tda/ATe |  | F |  | PlantNET (2013) | Described as occurring in moist/wet soil or in swampy areas. |

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|---|---|---|---|---|---|---|---|---|---|
| Leucopogon lanceolatus | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Often found on hillsides in wet or dry sclerophyll forest. Occasionally collected near wetland margins or along creeklines. |
| Leucopogon microphyllus | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013) | Described as widespread in heath, scrub and dry sclerophyll forest on sandy or rocky soils. |
| Lindsaea linearis | Fern | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Described as widespread in moist areas, often amongst rocks in open forest or heath or near swamps. |
| Logania albiflora | Shrub | Perennial | Ter | T | | F | | PlantNET (2013) | Occurs in wet sclerophyll forest and woodland |
| Lomandra confertifolia subsp. rubiginosa | Sedge/ Rush | Perennial | Ter | Tdr | | F | | PlantNET (2013) | Usually occurs in dry sclerophyll forest. |
| Lomandra filiformis | Sedge/ Rush | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Usually occurs in dry sclerophyll forest, on well drained sandy or rocky soils. |
| Lomandra filiformis subsp. coriacea | Sedge/ Rush | Perennial | Ter | Tdr | | F | | PlantNET (2013) | Usually occurs in dry sclerophyll forest, on well drained sandy or rocky soils. |
| Lomandra filiformis subsp. filiformis | Sedge/ Rush | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Usually occurs in dry sclerophyll forest, on well drained sandy or rocky soils. |
| Lomandra glauca | Sedge/ Rush | Perennial | Ter | Tdr | | F | | PlantNET (2013) | Occurs in heath to dry sclerophyll forest. |

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|---|---|---|---|---|---|---|---|---|---|
| Lomandra longifolia | Sedge/ Rush | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Found in a variety of habitats. Most herbarium records indicate non-wetland habitat, but approx. 3% (of 244) referred to areas that wet and dry (e.g. stream beds) and another 8% indicated damp and/or riparian zone habitats. |
| Lomandra multiflora subsp. multiflora | Sedge/ Rush | Perennial | Ter | Tdr | | F | | PlantNET (2013) | Occurs in woodland and forest. |
| Lomandra spp. | Sedge/ Rush | Perennial | Ter | T | | F | | PlantNET (2013) | Some species occur near waterways or in rainforest. |
| Lomatia myricoides | Shrub | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Often occurs along watercourses or in sclerophyll forest (approx. 50% of herbarium records riparian). |
| Lomatia myricoides x silaifolia | Shrub | Perennial | Ter | T | | F | | PlantNET (2013); AVH (2013) | Hybrid. |
| Lomatia silaifolia | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Widespread in heath, sclerophyll forest and woodland. |
| Lomatia spp. | Shrub | Perennial | Ter | T | | F | | PlantNET (2013) | Various habitats, from dry to moist areas. |
| Ludwigia spp. | Forb or Shrub | | Ter/Amp | T/A | | F | | PlantNET (2013) | Most species occur in wet or seasonally wet places, with many spreading into areas of standing water with floating stems. |

| **Scientific name** | **Life form** | **Longevity** | **Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG** | **WPFG subcategory** | **WPFG classification borderline?** | **Classified using experimental data (E) or field observations (F)** | **Described as common in disturbed areas (D)** | **References** | **Comments** |
|---|---|---|---|---|---|---|---|---|---|
| Luzula flaccida | Forb | Perennial | Ter | Tda |  | F | D | PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.; Johns *et al* (In prep.) | Described as common in moist grassy understory in eucalypt woodland, in grassy margins of wet sclerophyll forest and also disturbed sites such as road banks. Established in UQ glasshouse under free-draining or waterlogged conditions. Tolerated subsequent inundation (3-5cm depth, 8 weeks). |
| Luzula spp. | Forb |  | Ter/Amp | T/ATe |  | F |  | PlantNET (2013) | Various habitats described, from open grassy areas to swamps. |
| Lycopodiella lateralis | Clubmoss | Perennial | Ter | Tda | Tda/ATl | F |  | PlantNET (2013); AVH (2013); N. McCaffrey pers. obs. | Almost always found in moist to wet and boggy areas, e.g. slopes near streams. Observed on damp ground to mud by UQ staff but not in standing water. |
| Lycopodium deuterodensum | Clubmoss | Perennial | Ter | T |  | F |  | PlantNET (2013) | Widespread in various situations, often on sandy soils. |
| Microlaena stipoides | Grass | Perennial | Amp | Tda |  | F |  | PlantNET (2013); AVH (2013); Johns *et al* (In prep.) | Occurs in a variety of habitats including wet and dry sclerophyll forest, damp ground along creeks and in pastures and suburban lawns. Established in UQ glasshouse under free-draining or waterlogged conditions. Tolerated subsequent inundation (3-5cm depth, 8 weeks). |
| Microtis unifolia | Forb |  | Ter | Tdr |  | F |  | PlantNET (2013) | Widespread in a variety of habitats including rock outcrops in semi-arid areas. |

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|---|---|---|---|---|---|---|---|---|---|
| Mirbelia platylobioides | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Occurs in heath or eucalypt woodland on sandy soils. |
| Mirbelia rubiifolia | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Occurs in heath or eucalypt woodland on sandy soils. |
| Mirbelia spp. | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Mostly found in heath or woodland on sandy soils. |
| Mitrasacme polymorpha | Forb | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Widespread, typically on sandy soil overlying sandstone. |
| Mitrasacme serpyllifolia | Forb | Perennial | Ter | Tda |  | E,F |  | AVH (2013); C. Kilgour pers. obs.; C. Johns pers obs. ; Johns *et al* (In prep.) | Observed in damp areas but not in standing water by UQ staff. Established in UQ glasshouse under free-draining or waterlogged conditions. Established plants did not survive inundation (3-5cm depth, 8 weeks). |
| Mitrasacme spp. | Forb | Annual or Perennial | Ter | T |  | F |  | PlantNET (2013); C. Kilgour pers. obs.; C. Johns pers. obs. | Some species prefer damp habitats, while others primarily found in drier areas. |
| Monotoca scoparia | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Usually found in dry sclerophyll forest, woodland or heath on sandy soil. |

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|---|---|---|---|---|---|---|---|---|---|
| Myriophyllum pedunculatum | Forb | Perennial | Amp | ARp | ARp/ATl | E,F | | Casanova (2011); Reid & Quinn (2004); PlantNET (2013); AVH (2013) P. McKenna pers. obs.; N. McCaffry pers. obs.; C. Johns pers obs.; Johns *et al* (In prep.) | Neither reference classified this particular species but its congeners were classified as Arp. This species is also described as ranging from aquatic to fully emergent. Established in UQ glasshouse under waterlogged or submerged (3-5cm depth) conditions. Inundation tolerant. |
| Nertera granadensis | Forb | Perennial | Amp | ATl | ATl/Tda | E,F | | PlantNET (2013); AVH (2013) ; Johns *et al* (In prep.) | Occurs in bogs and wet soil or on rocks near water. Established in UQ glasshouse under free-draining or waterlogged conditions. Established plants survived immersion but leaves were yellow after 8 weeks. |
| Notochloe microdon | Grass | Perennial | Amp | ATe | | F | | PlantNET (2013); N. McCaffrey pers. obs. | Grows in moist shady areas. Observed on damp soils and in up to 5cm of standing water by UQ field staff (N. McCaffrey has only ever seen this species in the middle of swamps). |
| Notodanthonia longifolia | Grass | Perennial | Ter | T | | F | | PlantNET (2013) | Now Rhytidosperma longifolium. Grows in open forest on rocky or sandy soils, occasionally in damp places. |
| Ochrosperma oligomerum | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013) | Grows in dry sclerophyll forest and heath on sandstone ridges or outcrops. |
| Olearia erubescens | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013); C. Johns pers. obs. | Grows in dry sclerophyll forest. Occasionally recorded around edges of swamps. |

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|---|---|---|---|---|---|---|---|---|---|
| Olearia quercifolia | Shrub | Perennial | Amp | ATw | | F | | PlantNET (2013); AVH (2013); P. McKenna pers. obs.; C. Johns pers. obs.; N. McCaffrey pers. obs. | Grows in swampy or moist terrain. |
| Opercularia hispida | Forb | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Usually occurs on sandy soils, often among rocks and on creek banks. |
| Opercularia spp. | Forb or Shrub | Perennial | Ter | T | | F | | PlantNET (2013) | Some species occur on creek banks. |
| Orchidaceae indeterminate | Forb | | Ter | T | | F | | PlantNET (2013) | |
| Oxalis spp. | Forb | | Ter | Tda | | E,F | D | PlantNET (2013); Johns *et al* (In prep.) | A common weed occurring in a variety of habitats. Often found in disturbed areas. Established under waterlogged conditions in UQ glasshouse. |
| Panicum decompositum var. tenuius | Grass | Perennial | Ter | T | | F | | PlantNET (2013) | Described as widespread on good soils. |
| Panicum spp. | Grass | Annual or Perennial | Ter/Amp | Tda/ATe | | F | D: some spp. | PlantNET (2013) | Habitats vary, from standing water to cultivated areas. |
| Paspalidium spp. | Grass | Annual or Perennial | Ter | T | | F | | PlantNET (2013) | Most described as occurring in dry habitats, but some associated with river banks etc. |

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|---|---|---|---|---|---|---|---|---|---|
| Patersonia fragilis | Sedge/ Rush | Perennial | Amp | ATe | | E, F | | PlantNET (2013); AVH (2013); C. Johns pers. obs.; Johns *et al* (In prep.) | Occurs in wet heath. Established under free-draining or waterlogged conditions in UQ glasshouse. Established plants tolerated inundation (3-5cm, 8 weeks). |
| Patersonia longifolia | Sedge/ Rush | Perennial | Ter | Tdr | | F | | PlantNET (2013) | Grows in dry sclerophyll forest and heath on sandy soil. |
| Patersonia sericea | Sedge/ Rush | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Grows in dry sclerophyll forest, woodland and heath. Sometimes found in or around swampy areas. |
| Patersonia spp. | Sedge/ Rush | Perennial | Ter | T | | F | | PlantNET (2013) | Various habitats. |
| Persoonia chamaepitys | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Occurs in dry sclerophyll forest or heath on sandstone. Sometimes found at the edges of wetlands. |
| Persoonia hindii | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013); C. Johns (pers. obs.) | Occurs in sclerophyll forest to woodland. Only 15 habitat records available that could be assessed. Often observed on slopes above swamps on the Newnes Plateau by UQ staff, but not within swampy areas. |
| Persoonia laurina | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013) | Occurs in dry sclerophyll forest or heath on sandstone. |
| Persoonia levis | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); AVH (2013) | Occurs in heath to dry sclerophyll forest. |

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|---|---|---|---|---|---|---|---|---|---|
| Persoonia mollis | Shrub | Perennial | Ter | Tda |  | F |  | PlantNET (2013); AVH (2013) | Occurs in heath to wet sclerophyll forest. |
| Persoonia mollis subsp. mollis | Shrub | Perennial | Ter | T |  | F |  | PlantNET (2013); AVH (2013) | Occurs in wet to dry sclerophyll forest. |
| Persoonia myrtilloides | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Occurs in heath to dry sclerophyll forest on sandstone. |
| Persoonia myrtilloides subsp. myrtilloides | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Occurs in heath to dry sclerophyll forest on sandstone. |
| Persoonia recedens | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Occurs in dry sclerophyll forest on sandstone. |
| Persoonia spp. | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Most described as occurring in dry sclerophyll forest, woodland or heath, often on sandstone. Small number occur in wet sclerophyll forest. |
| Petrophile canescens | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in dry and wet heat and dry sclerophyll forest on deep sandy soils. |
| Petrophile pulchella | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in heath and dry sclerophyll forest on shallow sandy soils. |
| Phyllanthus hirtellus | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Common in heath and dry sclerophyll forest. |

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|---|---|---|---|---|---|---|---|---|---|
| Phyllota phylicoides | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Occurs in dry sclerophyll forest on sandstone. Occasionally collected from swampy areas (7 of 231 habitat records assessed i.e. 3%). |
| Pimelea linifolia | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Wide range of habitats. Occasionally occurs in swampy areas. |
| Pinus radiata | Tree | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Exotic plantation forestry species. |
| Platysace lanceolata | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Occurs in woodland and heath, often on sandy soil. |
| Platysace linearifolia | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Grows in dry sclerophyll forest on sandy soil. |
| Poa affinis | Grass | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Occurs in woodland on sandstone. |
| Poa labillardierei | Grass | Perennial | Ter | Tda |  | F |  | PlantNET (2013) | Occurs on river flats and moist situation, and in forests extending up open sheltered slopes |
| Poa labillardierei var. labillardierei | Grass | Perennial | Ter | Tda |  | F |  | PlantNET (2013); AVH (2013) | Occurs on river flats and moist situation, and in forests extending up open sheltered slopes |
| Poa sieberiana var. cyanophylla | Grass | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013); C.Johns pers. obs | Described as occurring in a wide range of habitats. Less than 1% of 104 herbarium records assessed, specified a periodically inundated habitat. Only observed in dry areas (i.e. above the wetland edge) in Newnes Plateau wetland vegetation surveys. |

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|---|---|---|---|---|---|---|---|---|---|
| Poa sieberiana var. sieberiana | Grass | Perennial | Ter | Tda |  | F |  | PlantNET (2013); AVH (2013) C.Johns pers. obs | Various habitats. Approx. 4% of (211) herbarium records assessed were from wetland habitats and another 6% specified other damp habitats. Frequently observed in damp areas in Newnes Plateau wetland vegetation surveys (i.e. often abundant in drainage lines / tends not to occur in drier areas). |
| Polygonum plebeium | Forb | Annual or Perennial | Ter | Tda |  |  | D | PlantNET (2013); AVH (2013) | Common on disturbed sites. Typically found around the margins of waterways and wetlands in areas which have recently undergone drawdown. |
| Polyscias sambucifolia | Shrub | Perennial | Ter | T |  | F | D | PlantNET (2013); AVH (2013) | Common on disturbed sites in wet or dry sclerophyll forest or rainforest margins. |
| Pomaderris andromedifolia subsp. andromedifolia | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Mainly occurs in open forest along escarpment. Sometimes found in riparian zones. |
| Poranthera microphylla | Forb | Annual | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Widespread in forest and woodland. |
| Prasophyllum spp. | Forb |  | Ter | T |  | F |  | PlantNET (2013) | Habitats vary; some prefer moist to wet areas, others only recorded in drier habitats. |
| Pratia spp. | Forb | Perennial or Annual | Ter/Amp | Tda/ATl |  | F |  | PlantNET (2013) | Habitats typically include wet, muddy areas e.g. swamps. |

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|---|---|---|---|---|---|---|---|---|---|
| Pratia surrepens | Forb | Perennial | Amp | ATl | | F | | PlantNET (2013); AVH (2013) | Occurs in or near swamps, in moist grassland and on mud in depressions. |
| Prunella vulgaris | Forb | Perennial | Ter | Tda | Tda/ATl | E,F | D | PlantNET (2013); AVH (2013); Johns et al (In prep.) | Widespread weed, often found in disturbed areas, particularly moist sites. Single plant established in UQ glasshouse under free-draining conditions. Survived subsequent immersion but leaves were yellow after 8 weeks. |
| Pseudanthus divaricatissimus | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013); Atlas of Living Australia (2013) | Occurs on rocky sandstone sites on sandy soils. |
| Pseuderanthemum variabile | Forb | Perennial | Ter | T | | F | | PlantNET (2013) | Occurs in a variety of coastal habitats, especially rainforest and wet sclerophyll forest. |
| Pseudognaphalium luteoalbum | Forb | Annual | Ter | Tda | | E,F | | Brock & Casanova (1997); Reid & Quinn (2004); PlantNET (2013); own unpublished experimental results | Widespread species described as occurring in most plant communities, on various soils. |
| Pteridium esculentum | Fern | Perennial | Ter | T | | F | | PlantNET (2013); AVH (2013) | Described as occurring in open forest or cleared land. |
| Pterostylis longifolia | Forb | | Ter | Tda | | F | | PlantNET (2013) | Decribed as common in moist areas of sclerophyll forest and coastal scrubs. |
| Pterostylis spp. | Forb | | Ter | T | | F | | PlantNET (2013) | Orchids. Various habitats. |

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|---|---|---|---|---|---|---|---|---|---|
| Pultenaea canescens | Shrub | Perennial | Amp | ATw | | F | | PlantNET (2013); AVH (2013) | Occurs in swamp-heath on sandstone, mostly around margins when found near wetlands, but also frequently recorded in drier habitats. |
| Pultenaea capitellata | Shrub | Perennial | Ter | T | | F | | PlantNET (2013); AVH (2013) | Described as occurring in swamp heath to dry sclerophyll forest on acidic substrates. When occurring in swamps, generally found around the higher, drier margins. |
| Pultenaea divaricata | Shrub | Perennial | Amp | ATw | | E,F | | PlantNET (2013); AVH (2013); Johns et al (In prep.) | Collection records indicate that this species has almost always been collected from areas with damp to very wet ground, usually in swamp heath (sometimes with surface water) or associated with hillside seepages (e.g. hanging swamps). Established in UQ glasshouse under waterlogged conditions. |
| Pultenaea scabra | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013) | Described as occurring in heath to dry sclerophyll forest, usually on sandy soils |
| Pultenaea spp. | Shrub | Perennial | Ter | | | F | | PlantNET (2013) | |
| Pultenaea tuberculata | Shrub | Perennial | Ter | Tdr | | F | | PlantNET (2013) | Described as occurring in dry sclerophyll forest to heath on sandstone. |
| Ranunculus spp. | Forb | Annual or Perennial | Ter/Amp | T/ATl/ATe | | F | | Reid & Quinn (2004) | Reid & Quinn (2004) classified R. inundatus as Ate and R. amphitrichus as Tda. Most species described as occurring on moist ground/wet mud. |
| Restionaceae indeterminate | Sedge/Rush | | Amp | Ate | | F | | | Classification based on own field observations. |

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|---|---|---|---|---|---|---|---|---|---|
| Rhynchosia minima | Forb |  | Ter | Tdr |  | F |  | PlantNET (2013) | Occurs in a variety of habitats, mostly on heavy soils in grassland. |
| Rhytidosporum procumbens | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Occurs in heath, scrub and sclerophyll forest. Often occurs in moister areas, including near swamps. |
| Rubus spp. | Shrub | Perennial | Ter | Tda |  | F | D | PlantNET (2013); N. McCaffrey pers. obs.; P. McKenna pers. obs. | Categorisation based on field observations of species occurring at Newnes Plateau wetland sites. |
| Rubus ulmifolius | Shrub | Perennial | Ter | Tda |  | E,F | D | PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.; P. McKenna pers. obs.; Johns et al (In prep.) | Occurs in wetter areas of southern to central eastern NSW. Established in UQ glasshouse experiment under waterlogged conditions. |
| Schoenus apogon | Sedge/ Rush | Perennial | Amp | ATe |  | F | D | Cunningham et al (1992); PlantNET (2013); Romanowski (1998); AVH (2013) | Described as occurring in seasonally wet habitats. Often occurs in the fringing zone around wetlands or on creek banks, in moist but not necessarily inundated areas. Also occurs in disturbed sites e.g. pastures, roadsides, lawns and construction sites, where conditions are damp. |
| Schoenus brevifolius | Sedge/ Rush | Perennial | Amp | ATe |  | F |  | PlantNET (2013) | Described as occurring in swamps and damp heath. |
| Schoenus imberbis | Sedge/ Rush | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Described as growing in dry sclerophyll forest and heath on sandy soils. |
| Schoenus maschalinus | Sedge/ Rush | Perennial | Amp | ATe/ATl |  | F |  | PlantNET (2013) | Occurs in damp to swampy places. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Senecio diaschides | Forb | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Described as growing in moist sites in sclerophyll forest. |
| Senecio hispidulus | Forb | | Ter | Tdr | | F | D | PlantNET (2013) | Described as growing mainly in disturbed sites. |
| Senecio linearifolius | Forb | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Described as occurring mostly in wet sclerophyll forest. Sometimes recorded in areas adjacent to wetlands or creeklines. |
| Senecio madagascariensis | Forb | Annual or Biennial | Ter | Tdr | | F | D | PlantNET (2013) | Described as a widespread opportunistic weed, especially in degraded pasture and disturbed sites. |
| Senecio minimus | Forb | Annual | Ter | Tdr | | F | D | PlantNET (2013); AVH (2013) | Described as a widespread opportunistic weed, mainly in wet sclerophyll forest. |
| Senecio prenanthoides | Forb | Perennial | Ter | Tdr | | F | | PlantNET (2013) | Described as growing in eucalypt woodland. |
| Senecio spp. | Forb | Annual, Biennial or Perennial | Ter | T | | F | D - some spp. | PlantNET (2013) | |
| Sonchus asper | Forb | Annual | Ter | Tdr | | F | D | PlantNET (2013); AVH (2013) | Described as a weed of most habitats, including pastures, cultivation, roadsides, gardens, wasteland and disturbed areas. |
| Sonchus oleraceus | Forb | Annual | Ter | Tdr | | E,F | D | Brock & Casanova (1997); Own unpublished experimental data; AVH (2013) | Brock & Casanova (1997) classified this as Tdr, but other species that commonly occur in disturbed areas on moist soil e.g. Conyza spp have been classed as Tda. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Sonchus spp. | Forb | Annual | Ter | Tdr | | E,F | D | PlantNET (2013); AVH (2013) | Brock & Casanova (1997) classified S. oleraceus as Tdr. |
| Sowerbaea juncea | Forb | Perennial | Ter | Tda | | F | | PlantNET (2013) | Described as occurring in heath on damp and intermittently water-logged soils. |
| Sphaerolobium spp. | Shrub | Perennial | Ter | Tda | | F | | PlantNET (2013) | Only two species found in NSW. Often occurs in moister habitats, including wet heath to swampy areas. |
| Sphagnum cristatum | Moss | Perennial | Amp | ATl | | F | | AVH (2013); Whinam & Chilcott (2002); N. McCaffrey pers. obs.; P. McKenna pers. obs. | Only observed by UQ staff in permanently wet areas, including bogs. |
| Sphagnum spp. | Moss | Perennial | Amp | ATl | | F | | N. McCaffrey pers. obs.; P. McKenna pers. obs. | Only observed by UQ staff in permanently wet areas, including bogs. |
| Sphaerolobium minus | Shrub | Perennial | Ter | Tda | | F | | PlantNET (2013) | Described as widespread in wet heath or sometimes forest on sandy or peaty soils. |
| Sphaerolobium vimineum | Shrub | Perennial | Ter | Tda | | F | | PlantNET (2013); C. Johns pers. obs. | Described as widespread in heath and forest, often in swampy places. Observed growing on damp ground by UQ field staff but not in inundated areas. |
| Sprengelia incarnata | Shrub | Perennial | Amp | ATw | | F | | PlantNET (2013); AVH (2013) | Described and typically collected from areas described as swampy shrubland and in heath, frequently on wet sandy and/or peaty soil. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Stackhousia monogyna | Forb | Perennial | Ter | Tdr | | F | | PlantNET (2013) | Described as growing in heath, grassland, woodland and sclerophyll forest, often on slopes, rarely in swamps. |
| Stackhousia spp. | Forb | Annual or Perennial | Ter/Amp | T/ATw | | F | | PlantNET (2013) | Habitat varies according to species. |
| Stellaria pungens | Forb | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Described as common in shady places. |
| Sticherus lobatus | Fern | Perennial | Ter | Tda | | F | | PlantNET (2013); N. McCaffrey pers. obs. | Often forms colonies in open forest or on margins of rainforest. |
| Stylidium graminifolium | Forb | Perennial | Ter | T | | F | | PlantNET (2013); AVH (2013) | Occurs in dry sclerophyll forest. |
| Stylidium lineare | Forb | Perennial | Ter | Tda | | F | | PlantNET (2013) | Occurs in heath and dry sclerophyll forest on sandstone and open poorly-drained plateau areas. |
| Stylidium productum | Forb | Perennial | Ter | T | | F | | PlantNET (2013) | Occurs in dry sclerophyll forest on sandstone. |
| Stylidium spp. | Forb | Perennial | Ter | T | | F | | PlantNET (2013) | |
| Taraxacum officinale | Forb | Perennial | Ter | Tda | | E,F | D | Brock & Casanova (1997); PlantNET (2013); AVH (2013) | Classified as Tda in previous experimental study. Described as a widespread weed of lawns, roadsides, wasteland and cultivated and pasture areas. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Telopea speciosissima | Shrub | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring on deep sandy soils with brown or yellow clay over sandstone in dry slerophyll forest. |
| Tetrarrhena spp. | Grass | Perennial | Ter/Amp | T/ATe |  | F |  | PlantNET (2013) | Habitats range from heath on sandstone, to wet heaths, peat swamps, watercourse fringes and damp tussock grasslands. |
| Thelionema caespitosum | Forb | Perennial | Ter | T |  | F |  | PlantNET (2013) | Described as widespread. |
| Thelymitra spp. | Forb |  | Ter | T |  | F |  | PlantNET (2013) | Orchids. Habitats range from open forest to wetter sites e.g. seepage areas. |
| Trachymene spp. | Forb | Annual, Biennial, Perennial or Ephemeral | Ter | T |  | F | D - some spp. | PlantNET (2013) | Habitats range from sclerophyll forest to swampy areas. |
| Tricoryne elatior | Forb | Perennial | Ter | T |  | F |  | PlantNET (2013) | Habitat ranges from sclerophyll forest, heath and woodland to swamps on sandy loam and lateritic soils. |
| Utricularia dichotoma | Forb | Perennial | Amp | ATl | ATe/ATl | E,F |  | Reid & Quinn (2004); PlantNET (2013); AVH (2013); Johns et al (In prep.) | Reid & Quinn (2004) classified Utricularia australis as Arp, but it grows in fully immersed situations whereas U. dichotoma grows in shallow water. Established in UQ glasshouse under waterlogged or submerged conditions. Inundation tolerant. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Utricularia spp. | Forb | Annual or Perennial | Amp | ATe/ARp | | E | | Reid & Quinn (2004); PlantNET (2013); AVH (2013) | Reid & Quinn (2004) did not classify this whole genus, but Utricularia australis was classified as Arp. |
| Velleia montana | Forb | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Described as occurring mainly in subalpine grassland and woodland. |
| Vellereophyton dealbatum | Forb | Annual or Biennial | Ter | Tda | | F | D | PlantNET (2013) | Occurs on disturbed moist sites. |
| Veronica plebeia | Forb | Perennial | Ter | T | | F | D | PlantNET (2013); AVH (2013) | Occurs in eucalypt forest, grassland, on rainforest margins and as a weed in lawns and gardens. |
| Veronica spp. | Forb or Shrub | Annual or Perennial | Ter/Amp | Tda/ATl | | F | D - some spp. | PlantNET (2013) | Habitats range from eucalypt forest to disturbed pasture to growing in running water along stream banks. |
| Viola betonicifolia | Forb | Perennial | Ter | T | | F | | PlantNET (2013); AVH (2013) | Described as widespread in woodland and forest. |
| Viola hederacea | Forb | Perennial | Ter | Tda | | F | | PlantNET (2013); AVH (2013) | Occurs in sheltered moist places. |
| Viola sieberiana | Forb | Perennial | Ter | Tda | | E,F | | PlantNET (2013); AVH (2013); Johns et al (In prep.) | Grows on moist ground on more exposed sites. Established in UQ glasshouse experiment under free-draining or waterlogged conditions. |
| Viola spp. | Forb | Annual, Biennial or Perennial | Ter | Tda | | F | | PlantNET (2013); C. Johns pers. obs. | This taxon observed growing in damp conditions by UQ field staff. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Wahlenbergia gracilis | Forb | Perennial | Ter | Tda |  | F |  | Cunningham et al (1992); PlantNET (2013) | Described as occurring in many situations, often in the vicinity of watercourses. |
| Wahlenbergia luteola | Forb | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Occurs in woodland grassland and along roadsides. |
| Wahlenbergia spp. | Forb | Annual or Perennial | Ter | T |  | F |  | PlantNET (2013) |  |
| Wahlenbergia stricta | Forb | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Occurs in a variety of plant communities. |
| Xanthorrhoea media | Sedge/ Rush | Perennial | Ter | Tdr |  | F |  | PlantNET (2013) | Described as occurring on sandstone, usually on drier, more exposed ridges and hillsides. |
| Xanthosia dissecta | Forb | Perennial | Ter | Tda |  | E,F |  | PlantNET (2013); AVH (2013); Johns et al (In prep) | Described as usually occurring in damp situations, in woodland, wet heath and swamp. Germinated in UQ glasshouse experiment under waterlogged conditions. |
| Xanthosia pilosa | Shrub | Perennial | Ter | T |  | F |  | PlantNET (2013); AVH (2013) | Described as occurring in heath and sclerophyll forest, occasionally along watercourses, on rocky and sandy sites. |
| Xanthosia spp. | Forb or Shrub | Perennial | Ter | T |  | F |  | PlantNET (2013) | Various habitats, from sclerophyll forest to swamps. |
| Xanthosia stellata | Forb | Perennial | Ter | Tdr |  | F |  | PlantNET (2013); AVH (2013) | Occurs in eucalypt forest on sandstone. |

| Scientific name | Life form | Longevity | Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG | WPFG subcategory | WPFG classification borderline? | Classified using experimental data (E) or field observations (F) | Described as common in disturbed areas (D) | References | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Xyris complanata | Sedge/ Rush | Perennial | Ter | Tda |  | F |  | PlantNET (2013); AVH (2013) | Often described as growing in damp or seasonally wet areas, including at the edges of swamps, but also occurs in heath on sandy soil. |
| Xyris gracilis | Sedge/ Rush | Perennial | Ter | Tda |  | F |  | PlantNET (2013); Romanowski (1998); AVH (2013) | According to AVH records, many X. gracilis specimens collected from damp or wet areas on sandy or peaty soils i.e. intermittently wet or waterlogged ground such as in hanging swamps or near the margin of a wetland. Sometimes described as occurring in a swamp. |
| Xyris spp. | Sedge/ Rush | Perennial | Ter/Amp | Tda/ATe |  | F |  | PlantNET (2013); Romanowski (1998) | Most Xyris spp. described as occurring on seasonally moist/wet ground, with only X. operculata growing regularly in permanently waterlogged soils. |
| Xyris ustulata | Sedge/ Rush | Perennial | Amp | ATe | N | F |  | AVH (2013); PlantNET (2013); Romanowski (1998) | Often seen growing in shallowly inundated areas in Newnes Plateau wetlands by UQ field staff. Typically collected from wet swampy areas (i.e. wetlands and/or seepage zones) |

Aigis Group
Springvale Colliery Extension Project
Response to Submission – The Australia Institute
24/09/2014

# SPRINGVALE COLLIERY EXTENSION PROJECT

## RESPONSE TO SUBMISSION BY THE AUSTRALIA INSTITUTE

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## 1. ***PURPOSE OF DOCUMENT***

This document addresses issues raised by The Australia Institute (TAI) in its submission to the Department of Planning and Infrastructure on the economic assessment prepared for the Springvale Colliery Extension Project by Aigis Group (AG).

The document proceeds by initially addressing general issues raised in respect of adequacy and compliance of AG's assessment. Specific issues are then addressed individually. The document concludes with a consolidation of the key points.

## 2. ***ADEQUACY AND COMPLIANCE***

At a number of junctures in its submission, TAI raises concerns in relation to the adequacy of the AG assessment, in the context of:

- Its compliance with 'state and federal guidelines' for preparation of cost benefit analyses; and
- Its failure to 'meet standards expected in the economics profession'.

Prior to addressing these issues, some general discussion of the method adopted in the economic assessment is warranted. AG and Centennial Coal (Centennial) are aware that, viewed from the strictures of current and previous economic practice surrounding consent-related economic assessments, and particularly those relating to Cost Benefit Analysis, the method employed in the submitted economic assessment is likely to be considered unorthodox.

Centennial management has determined that the company will no longer place material that might be considered commercially sensitive in the public domain, in the context of submitting consent approvals. The economic assessment is explicit in stating that Centennial will provide such material to the appropriate decision-making bodies as required for determination of the application.

Centennial has carried through a detailed program of reassessing its broader environmental impact statement processes, particularly those relating to socioeconomic impact assessment. As such, the process arrived at, while remaining cognisant of NSW Treasury and other material, is focused on more fully addressing the legislative requirements applying to assessment. In particular, as provided for in the *Environmental Planning and Assessment Regulation 2000,* assessment should be conducted *'having regard to biophysical, economic and social considerations, including the principles of ecologically sustainable development'*. In short, the focus of the economic assessment has been shifted more towards addressing, and where possible quantifying, these externalised impacts that may potentially affect the most relevant stakeholder groups.

In acknowledging that this may not meet the 'expected' orthodoxy, as is exemplified by TAI's commentary, the method adopted represents an attempt to avoid those parts of orthodox practice that largely serve to detract from the ability of 'lay' stakeholders to comprehend the analysis presented, as it relates to project impacts likely to be of greater significance to those groups. The method also seeks to not only identify, but quantify, and thus more fully recognise, the magnitude of these externalities.

In summary, the methodological critique submitted by TAI has some validity from the perspective of orthodox economics practice. However, Centennial and AG submit that such orthodoxy has not served the provision of appropriate, comprehensible information to stakeholders well. The economic assessment aims to provide this level of information. Simultaneously, it does not inhibit the ability of the decision-maker to require further information for its consideration.

Internally, this process has been described as turning the assessment focus in 180°. That is, from an internal focus on information that is of questionable relevance to stakeholders in the area of affectation, to a clearer explanation of the nature and scale of more relevant impacts, and the commitments of Centennial to address those impacts.

### *2.1 Compliance with guidelines*

AG acknowledges that the method adopted in preparing the economic assessment may be interpreted as not complying with orthodox cost-benefit analysis practice. AG has worked with Centennial Coal over several years on a project to develop a social and economic assessment method that focuses on providing more user-friendly information for stakeholders in the assessment process. In developing the present approach, reference has been had to the Department's *Guideline for economic effects and evaluation in EIA* (2002) and the *Guideline for the use of Cost Benefit Analysis in mining and coal seam gas proposals* (2012). The key point of TAI's critique on this point is that the method used in the economic assessment is not fully compliant with conventional cost benefit analysis. This is acknowledged by AG and Centennial. The content of this document will further explain the rationale for, and use of, an alternative method for economic assessment of mining projects

### *2.2 Adequacy of information presented*

The section of the TAI submission titled '*Main costs and benefits*' (pp.1-2) states that the economic assessment contains insufficient information in relation to the economics of the project for the community and decision makers. With respect to the community, Centennial has reviewed the 307 submissions in relation to this project proposal. With the exception of TAI's submission, no other submission indicated that there was inadequate information included to allow individual or group members of the community to consider the socioeconomic implications of the proposal. With respect to the information available to decision makers, Centennial acknowledges that there may be additional information required to allow consideration of the project. As is provided for in the 'Guideline *for economic effects and evaluation in EIA'* (NSW Department of Planning, 2002), the economic assessment includes an explicit undertaking to provide such information on request of the Department and or other relevant assessment bodies.

TAI's discussion on the need for this information in allowing the financial strength of the project is a valid comment. The undertaking to provide this material addresses this matter. It should also be noted that in relation to Springvale Colliery, the mine commenced production in 1992 and has operated continuously since that time. Figure 1 demonstrates volatility in thermal coal prices over a 30-year period. As noted, this volatility has not affected continuation of mining at Springvale Colliery. Centennial submits that this would amply establish the viability of continued operation of the mine.

**Figure 1: Australian thermal coal price, USD/metric ton, June 1984 – June 2014**

**Source:** http://www.indexmundi.com/commodities/?commodity=coal-australian&months=360

Centennial's extensive community consultation programs have not produced any material questioning the operational viability of Springvale or other Centennial mines operating in the area. This would appear to be supported by the lack of responses received that relate to the information presented to the community in the economic assessment.

It is relevant to point out that among the submissions received, approximately 85% of local submissions were supportive of the proposal as is substantiated in Appendix 1. For the surrounding region[1] and NSW, support was 20% and 1% respectively. This of course means that objections were approximately 15%, 80% and 99% respectively. This suggests that the community that most closely observes the impacts of, and which better understands the positive and negative aspects of the

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[1] Blue Mountains, Bathurst, Mudgee and Orange

mine's operations, appears to have a different view to the very small proportion of the State's population who reside beyond the area, but have provided comment on the application. A more detailed analysis of these data is included in Appendix 1.

In order to illustrate its point, TAI cites part of a determination by the Planning Assessment Commission in relation to the Stratford Coal Project. The intent of the excerpt is to illustrate how claims in respect of employment impacts in the economic assessment for the project have not been realised to date due to reductions in the workforce relating to economic conditions. There is no doubt that such an outcome is also possible at Springvale Colliery or any other mine in the state. However, this perspective is limited in that it relates to a particular point in time. If a longer-term view of the project was taken, it would be reasonable to acknowledge that at a point warranted by economic conditions, production and employment would be likely to return to higher levels. Exemplifying this, Springvale Colliery received consent modification in 2013 to, *inter* alia, increase both employment and production levels. If a mine is inoperative for a period of time, it follows that negative impacts also largely cease during that period. That is, the timing of benefits and costs may change, but there would be a strong likelihood that the approved resource would still be extracted at some point. Furthermore, in terms of royalty and tax income for state and federal governments, this may be considered as a positive outcome, given that higher prices in a more favourable market environment would yield higher returns to government.

## 3. *SPECIFIC ISSUES*

### *3.1 Labour, wages and opportunity cost*

The TAI submission includes some valid theoretical commentary on employment impacts. However, there is some contextual material included in the economic assessment that suggests that TAI's argument for reducing the value or contribution of employee incomes to the regional and state economies to zero cannot reasonably be sustained. In the regional context, TAI's analysis disregards Lithgow City Council's recognition of the contribution of mining incomes to the region. This is discussed in the economic assessment (pp. 26 – 28). On the strength of this material alone, TAI's argument should be considered as unsustainable.

TAI states that due to the current low unemployment rate (stated at 5.8 per cent for NSW), it is inappropriate to assume that employees cannot find alternative employment. TAI assumes that mining employees' skills are directly transferrable to 'other mining, construction and engineering projects' (p.3). In terms of equating this opportunity cost to zero in the context of the Lithgow LGA regional economy, this assumption must necessarily be based on an accompanying assumption that such other projects would either be situated within, or in relatively close proximity to the Lithgow region, or relate to workers commuting to other areas where such jobs are available. The need to consider this is demonstrated by internal employee survey output, generated in February/March 2013 and cited in the economic assessment (p. 29), noting that 76 per cent of the mine's employees reside in the Lithgow LGA. This supports an assumption, further supported by survey output, that these workers have residential and community ties to the region and as a consequence, being required to leave the area to obtain alternative employment may not be the purely economic-driven decision that may be implied from TAI's approach.

Taking regional context and current economic circumstances into consideration, there are several further limitations to TAI's assumptions:

- In addition to being 'highly skilled' as noted by TAI, a considerable proportion of the Springvale Colliery workforce possess skills that are highly specialised, and may in fact be either unsuitable for deployment in the alternative employment suggested by TAI, or result in underemployment.
- In terms of this specialisation, the production workforce at Springvale, as underground miners, possess perhaps greater levels of skill specialisation than might mining production employees more generally. These employees currently represent 85 per cent of all employment at the mine. The NSW Minerals Council identified underground mining employees as comprising 43.8% of total coal mining jobs in the State in 2012. As it cannot be assumed that these specific skills are directly transferrable to open cut mining, further opportunities within NSW are likely to be confined to less than 50% of any mining jobs available.
- The prevailing low unemployment rate cited by TAI would suggest that opportunities for comparable alternative employment would in fact likely be scarce. This is particularly likely to be the case in the mining sector. The Productivity Commission (1998, p.67) provided one measure of the relative constraints on finding alternative employment within the black coal mining industry, finding that voluntary labour turnover rates were less than half the average for all industries.
- The extent to which some proportion of employees might find alternative employment cannot be estimated with any level of certainty, as such outcomes involve individual decisions, the timing of cessation of mining, economic conditions (such as employment levels as discussed above), and a large variety of other factors. What can be firmly established is that should the mine be unable to continue operations, all employment at the mine would cease, with the resultant impacts on employee's households and the regional and extended economies. Review of all submissions made in support of the project highlights that a major concern of mine closure is the potential for population decline in the region, resulting in a broad adverse impact across the social (participation, social networking and general social capital) and financial economy (i.e. loss of / decline in spending). This is demonstrated by data provided in Appendix 1 that indicates that Springvale Colliery spent approximately $23 million with Lithgow LGA-based contractors, and around another $1.2 million with contractors based in the region. The loss of this work would clearly have significant negative impacts

in such a relatively small local and regional economy. It is not clear that this is recognised in TAI's submission, which discusses the extension of mining in the context of a new project (*'if the project did not go ahead'*) and cites federal guidelines that in part state that *'it can be expected that many of the jobs* [relating to the project] *will be filled by individuals who are currently employed but who are attracted either by the pay or by other attributes of the new positions'* (p.3). The positions referred to would be sustained, not created, as a consequence of approval. The potential extent of these impacts is illustrated in the Appendix 1.

The limitations identified above are intended to address TAI's contention that there is no direct or extended economic benefit associated with Springvale employees' incomes. As previously stated however, a case can be made out for acknowledging that only a proportion of the benefit of these incomes is expended in the local economy. Material relating to internal research conducted among Springvale employees is reported in the economic assessment (p. 29). This includes a finding that on average, employees spend 33 per cent of their incomes with local businesses. Application of this proportion to the total wages benefit objected to by TAI, would result in an adjusted wage and salary assumption of approximately **$214 million,** with the estimated economic benefits of the project decreasing to **$469 million** and **net benefit to $391 million**. Given the commentary above in relation to the more specialised production personnel at Springvale, if the proportion of these employees (85 per cent) was applied to the estimates above, the estimates would be **$135 million** (wage and salary estimate), **$432 million** (estimated economic benefits) and **$361 million (net benefit)**. It is submitted that these estimates would be conservative, as it would no longer provide for benefit associated with economic activity by these households in other parts of NSW.

### *3.2 Royalties and taxes*

The method applied by TAI for assessing royalties net of deductions appears to be incorrect. On page 4, TAI states, in part 'At $74 per tonne, royalties **before deductions** *[emphasis added]* are $5.32 per tonne'. Therefore TAI estimates royalties and then subtracts relevant deductions. Discussion with Centennial management indicates that in practice, the relevant deductions are made prior to calculating royalties. A simplified example is presented below[2].

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[2] The method adopted includes provision of $0.50 per tonne for the range of levies applying to production. This has also been used in the working for the TAI method, whereas in its submission, TAI assumes $0.05 per tonne for the research levy. A price of $100 per tonne is adopted to more clearly illustrate the net royalty realised per tonne and does not reflect any price assumptions in the economic assessment.

**BOX 1: INDUSTRY PRACTICE**

| | |
|---|---|
| Revenue: | $100 |
| Beneficiation levy: | $ 3.50 |
| Other deductions: | $ 0.50 |
| Net of deductions: | $ 96 |
| Net royalty @ 7.2% | **$ 6.91** |

**BOX 2: APPARENT TAI METHOD**

| | |
|---|---|
| Revenue: | $100 |
| Royalty @ 7.2%: | $ 7.20 |
| Beneficiation levy: | $ 3.50 |
| Other deductions: | $ 0.50 |
| Net royalty: | **$ 3.20** |

Applied to the $74 price assumption cited by TAI, the actual royalty per tonne would be **$5.04,** rather than **$1.77**[3] as estimated by TAI.

It is apparent that approved industry practice largely preserves the State's interests in terms of the net royalty income collected. Such an outcome stands to reason. The estimates included in the economic assessment include allowance for the deduction of the relevant levies according to the method exemplified in Box 1. As a consequence, TAI's estimate of royalties, and proposed reduction of these for the purposes of assessment are incorrect and should be disregarded.

In its discussion of corporate taxes, TAI assumes that the total tax on which the assessment is based is the nominal corporate tax rate of 30 per cent. However, as Centennial Coal is Thai-owned, the tax treaty with Thailand is relevant. As a consequence it is assumed that half of the corporate tax rate (15 per cent) is expatriated to Thailand, and thus the equivalent is paid in Australia. Therefore the effective tax rate is assumed as 15 per cent, which is comparable to the 'independent estimates' of 13.9 per cent suggested by TAI. In the material provided by Centennial for this project, all state and federal taxes were bundled, and are thus presented in one calculation.

### *3.3 Biodiversity offset provision and project impact controls and mitigation*

The biodiversity offset comprises part of a broader biodiversity off set strategy that is proposed in recognition of the potential for impacts on Temperate Highland Peat Swamps on Sandstone (THPSS) on the Newnes Plateau, and also in relation to clearing of native vegetation relating to site works.

Findings in the relevant specialist report on biodiversity impacts (cited in the economic assessment, Appendix 2, p. 51) are that expected impacts are likely to be negligible (within pre-mining or natural variations). Table 10 details contingent provisions for restoration of the relevant THPSS should this be required. Clearly, these actions would directly address any impacts that might eventuate.

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[3] If total other deductions were included (rather than the research levy used by TAI), the royalty per tonne using TAI's method would be **$1.32**.

The offset area contains a critically endangered ecological community (EEC). This has been assessed as being of higher ecological significance or value than the land to be cleared. Coupled with the undertakings to carry out any THPSS remediation that may be required, the proposed strategy represents a valuable contribution to the community in terms of conservation value.

In quantitative terms, it should be noted that Table 10 (‘Biodiversity’) states the nominal value of the offset land and management commitments ($2,900,000) against the estimated cost to the community of biodiversity impacts associated with land clearing and other potential project impacts ($3,500,000). As a consequence, the net ‘value’ of the offset is an economic ‘cost’ of $600,000. Part of this cost would be defrayed by the remediation commitments detailed in Table 10, should these impacts eventuate. The economic impact assessment clearly indicates that the costs and benefits associated with the offset are ‘netted off’ against each other. Reference should be had to Table 4 and footnote 10 (p. 21) and Table 10, ‘Biodiversity’ (p. 37) in the Economic Assessment. It should be noted that in the context of the assessed benefits and costs of the project, the offset may not meet conventional measures of materiality. Therefore, if the consent authority determined that this should be excluded, such exclusion would not materially impact on the net positive benefit determined in the economic assessment.

With regard to the other mitigation and project control measures that have been included as benefits, these too are ‘netted off’ against the assessed cost of impacts. The details of each of these ‘offsets’ are included in Table 10. This does not appear to have been recognised by TAI. Given the blanket discounting of all quantitative assessments of impacts proposed by TAI based on its contestation of the valuation methods contained in Table 3 of the economic assessment, this material may not have been considered.

This is a particular example of the intent of the economic assessment to invert the focus of the analysis, as discussed in the introductory remarks. TAI suggests that these commitments should be treated as costs to the business, which of course they are, in the conventional or orthodox sense in which TAI insists all assessment should be based. The alternative focus used in the economic assessment is to recognise the costs of the mine’s activities, and offset these against the benefit of the mitigation and other appropriate measures aimed at redressing the costs/impacts. This exemplifies the approach of turning the assessment method in ‘180°’; that is, rather than focusing on the internal costs and benefits of operations, turning the focus of the analysis about, onto the external costs and benefits to the community, for the purposes of providing the community with comprehensible information. Adopting this perspective, the costs of acquisition and management of the offset are incurred by company, with the benefits associated with those disbursements accruing to the community through the maintenance of conservation values and the return of the conservation lands to public ownership. Similarly, the remediation costs borne by the company in relation to mine sites or other affected areas return similar benefits to the community.

### *3.4 Environmental impacts*

TAI acknowledges that the benefits transfer method, while not ideal, can be an acceptable method for assessing impacts given constraints around generating project-specific metrics. Furthermore, the NSW Office of Environment and Heritage (OEH) Environmental Valuation Reference Inventory (EVRI) webpage specifically identifies benefits transfer as a method that '*can provide estimations for cost-benefit analyses and impact assessments, encouraging the internalisation of pollution costs and appreciation of natural capital tradeoffs*'[4]. This is the approach taken in the economic assessment, with the costs being estimated, and appropriate prevention and mitigation activities put in place to address these.

TAI notes that the method is acceptable '*particularly where the alternative is to include a zero value for environmental damage'* (p. 6, italics added); TAI then proceeds to revalue the assessed costs to a zero value, apparently justifying this on the basis of questions on the suitability of the studies used for valuation. Those questions appear not to acknowledge the recognition of limitations of the approach taken, which are included in the economic assessment (pp. 17-18), nor the explanatory material in Table 3 (pp 19-20) that explains how the studies used in the analysis were applied in the evaluation. The table also identifies that in instances where a range of values where calculated in the relevant studies, that the upper bound value was adopted for valuation, thus introducing an element of conservatism (i.e. placing a higher value) when assessing potential impacts.

In addition to the general observations made above in relation to valuations, certain issues raised by TAI (Table 2, p. 6) require individual responses. These are addressed below.

- **Noise**: TAI states that *'it is unclear how these 17 year old results have been adapted to current prices in Australian dollars'* (italics added). Footnotes 6 & 8 to Table 3 (economic assessment, pp. 19-20) state that; '*All values adjusted by three percent per annum to allow for inflation*'. Although not stated in the economic assessment, it should be added that all currency conversions required in adopting the studies used were based on exchange rates contemporaneous with each study. These data can be found on the Reserve Bank of Australia website[5]. This study was preferred on the basis that it is

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[4] http://www.environment.nsw.gov.au/publications/evri.htm

[5] http://www.rba.gov.au/statistics/historical-data.html#exchange-rates

included in EVRI[6], and was the most suitable study in respect of noise available in the inventory.

- **Subsidence, soil and water**: TAI states that how the values of this study have been applied is 'unclear'. TAI then contradicts this conclusion by contesting the valuation (derived from Table 3 of the economic assessment) on the basis that its geographic scope is inadequate. TAI also asserts that all households in NSW or Australia will be relevant for consideration, as the assessment relates to a national park. BBOP is an international partnership promoting best practice on biodiversity offsets in particular. In discussing the scope of assessment methods, BBOP (2009), stated that its approach "*focuses in particular on people living in and around the project and POTENTIAL OFFSET SITES*"; further, "*This is not to deny the importance of biodiversity losses and gains for non-local stakeholders but these global values are complex and controversial to estimate in monetary terms and arguably are addressed adequately by the direct measurement approach*" (italics added). This approach is consistent with that applied in the economic assessment. As is the case with its approach to employee incomes, TAI fails to recognise that it is the local and regional communities that will be impacted most directly, and which thus should be afforded particular attention in the assessment process.
- **Air**: As stated by TAI, this study is commonly used for such analyses. The estimation of the number of receptors is based on the air shed identified in the specialist report included in the EIS. With respect to use of the findings for the GMR, a map of that area is included in Appendix 1. For the purposes of the source study, the Lower Hunter and Illawarra regions were also included. The very close proximity of Lithgow to the GMR area itself was considered as providing a basis for adopting the measures from the report.
- **Heritage**: This study was adopted in recognition of the fact that the project area also includes items of 'historic' or 'European' heritage, in addition to Aboriginal heritage items and sites.
- **Biodiversity**: TAI's speculation that AG '*appear not to have read this source study*' is surmise. In assessing studies to be applied to valuation, AG personnel have in fact read the source study. However, in order to facilitate simpler access to the valuation method adopted for stakeholders wishing to do so, the EVRI reference is retained for use in the economic assessment. It should also be noted that AG continues to assess available studies with a view to refining those used in terms of comparability and application to Centennial sites, however retains a preference for the use of studies included in EVRI, on the basis of its association with OEH.
- **Visual**: TAI states that (a) the study used relates to the Queensland Wet Tropics World Heritage Area and (b) is use is 'completely unsuitable' in the context of this proposal. The NSW OEH National Parks and Wildlife Service webpage for the Gardens of Stone National Park notes that it is part of the

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[6] Access to the Environmental Valuation Reference Inventory (EVRI) is via the NSW Government Office of Environment and Heritage website: http://www.environment.nsw.gov.au/publications/evri.htm

> Greater Blue Mountains World Heritage Area. The study was applied on the basis that, notwithstanding the undisputed differences in biophysical characteristics, there is certainly some degree of equivalence between the two areas compared, in terms of their conservation status. The likelihood of impacts on this area is discussed subsequently.

TAI's analysis concludes that the environmental costs assessed are understated, but do not clearly state why, other than to question the selection and use of the studies adopted, in a method that they acknowledge has some validity.

## 4. CONCLUSIONS

In revaluing the economic aspects of the EIS, TAI's discounting of economic benefits in Table 2 results in an aggregate outcome that is approximately equivalent to the environmental impact valuations included in the economic assessment. The effect of this is to bring the net outcome for the 'NSW community' (p. 8) to a maximum of zero. This approach has also been taken in a number of TAI's responses to other Centennial EIS documents. TAI's analysis implies that this is the 'best-case' outcome, based on its unquantified assertion that the environmental costs of the proposal have been undervalued.

There are some significant contextual issues that this approach fails to recognise. The stated focus on the NSW community fails to recognise the importance of the *continuation of this established business* in the Lithgow regional community, and the benefits of this that extend to state and national communities. This is particularly relevant in relation to the broad assumptions applicable to the treatment of employee incomes in state or national-level economies, which are used by TAI as a basis for its arguments. The regional context is highly significant in this application and there is evidence that regional impacts may be positive. For example, Hajkowicz, Heyenga and Moffat, while not attributing causality, found that "mining is positively associated with income, housing affordability, communication access, educational attainment, and employment at Australian regional scales" (2011, p.37). This study observed 71 LGAs across Australia in which mining activity was conducted. This indicates that the state and national 'standards' applied by TAI cannot unquestioningly be applied to regional assessment. This is emphasised by the analysis of submissions detailed in Appendix 1. In recognition of the fact that total employee incomes may result in an overestimation of this value, alternative **net present values** for the project in the range of **$361 million to $384 million** have been estimated, and may be preferred by decision-makers in assessing the application.

A second major issue is TAI's assertion that potential damage to the Gardens of Stone National Park has been underestimated. Appendix 2 includes a diagram indicating the Project Application Area (PAA) for the proposed Springvale Colliery extension. Based on the scale provided, the diagram indicates that the nearest point of the PAA to the national park is in excess of five kilometres from the park boundary. The buffer provided by the distance between potential mining areas and the park itself, along with mine design and adaptive management strategies will significantly reduce this risk. The assessment of environmental impacts of the proposed operations suggests that in practicality, for many stakeholders who use the area for active and passive recreation, their experience of the area will not change. This being the case, it is submitted that the economic assessment appropriately values potential impacts on the national park, the Newnes State Forest, and, of equal importance, impacts on stakeholders, within the acknowledged constraints of the methods used.

Australian Bureau of Statistics (ABS) Census 2011 website. http://www.abs.gov.au/websitedbs/censushome.nsf/home/census?opendocument&navpos=10

Business and Biodiversity Offsets Programme (BBOP). 2009. *Biodiversity Offset Cost-Benefit Handbook*. BBOP, Washington, D.C. http://www.forest-trends.org/documents/files/doc_3094.pdf

Environmental Valuation Reference Inventory. https://www.evri.ca/Global/Splash.aspx

Forest Trends Association website: http://www.forest-trends.org/program.php?id=117

Hajkowicz SA. Heyenga S. Moffat K. (2011): The relationship between mining and socio-economic well being in Australia's regions, *Resources Policy* 36: 30-38 www.elsevier.com/locate/resourpol

Index mundi (2014): Coal, Australian thermal coal Monthly Price - US Dollars per Metric Ton. Retrieved from: http://www.indexmundi.com/commodities/?commodity=coal-australian&months=360

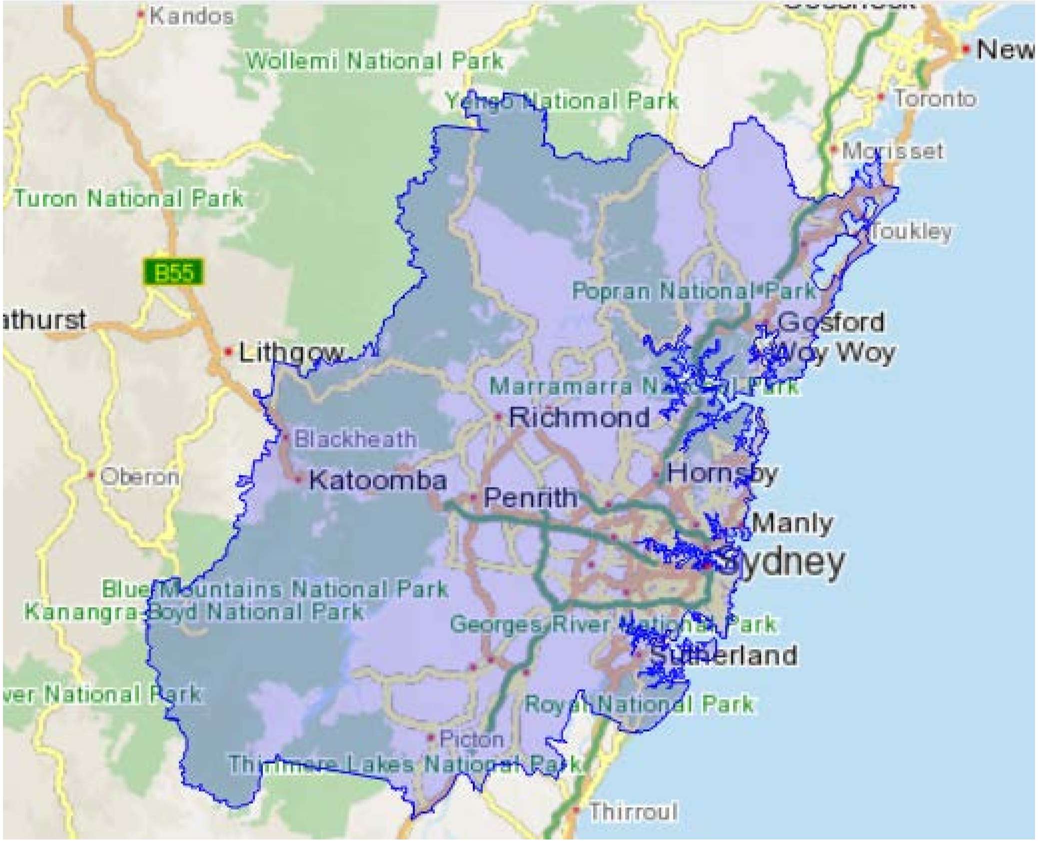
NSW Minerals Council. (2014). *NSW Mining 2012: A snapshot.* Retrieved from: http://www.nswmining.com.au/NSWMining/media/NSW-Mining/Publications/NSW-Mining-2012-A-Snapshot-FINAL.pdf

NSW Government Office of Environment & Heritage: *EVRI – Environmental value reference inventory.* http://www.environment.nsw.gov.au/publications/evri.htm

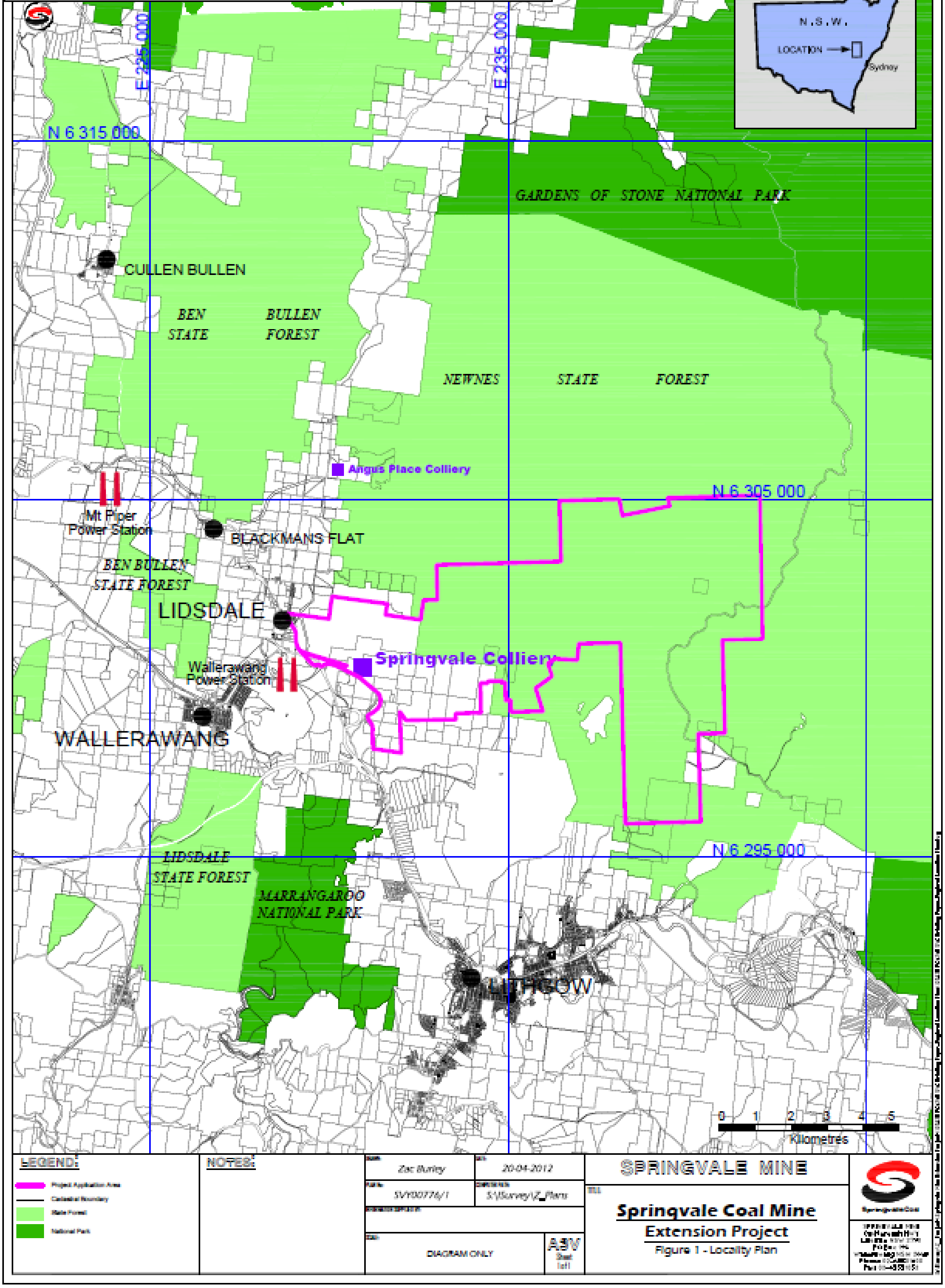
NSW Government Office of Environment & Heritage: NSW National Parks and Wildlife Service. *Gardens of Stone National Park* http://www.environment.nsw.gov.au/NationalParks/parkHome.aspx?id=N0087

Productivity Commission. (1998). *The Australian Black Coal Industry*, Inquiry Report, AusInfo, Canberra.

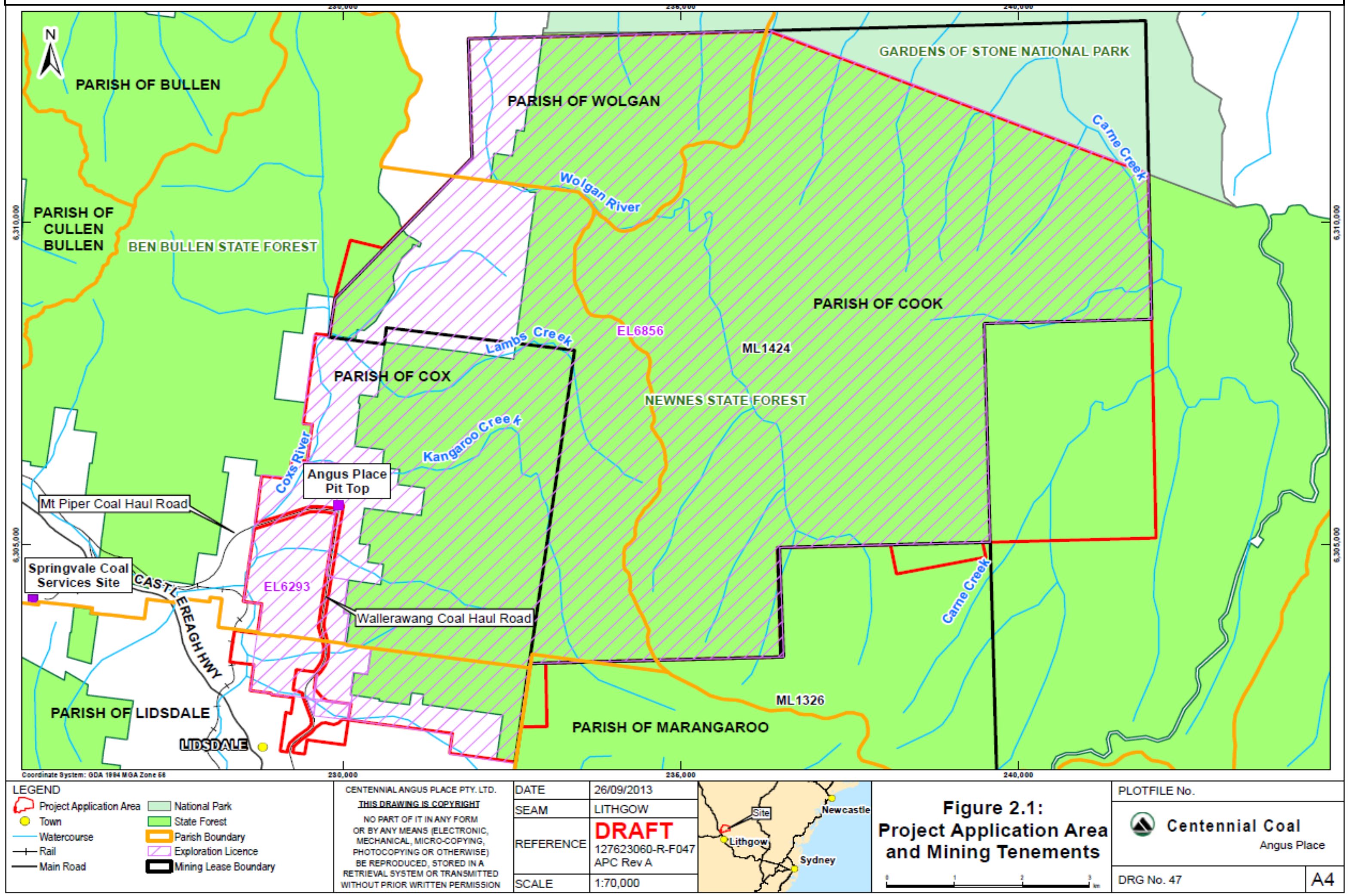
## APPENDIX 1: Map of Greater Sydney Metropolitan Region



## APPENDIX 2: Diagram of Project Application Area



## APPENDIX 2: Diagram of Project Application Area and Mining Lease Boundary



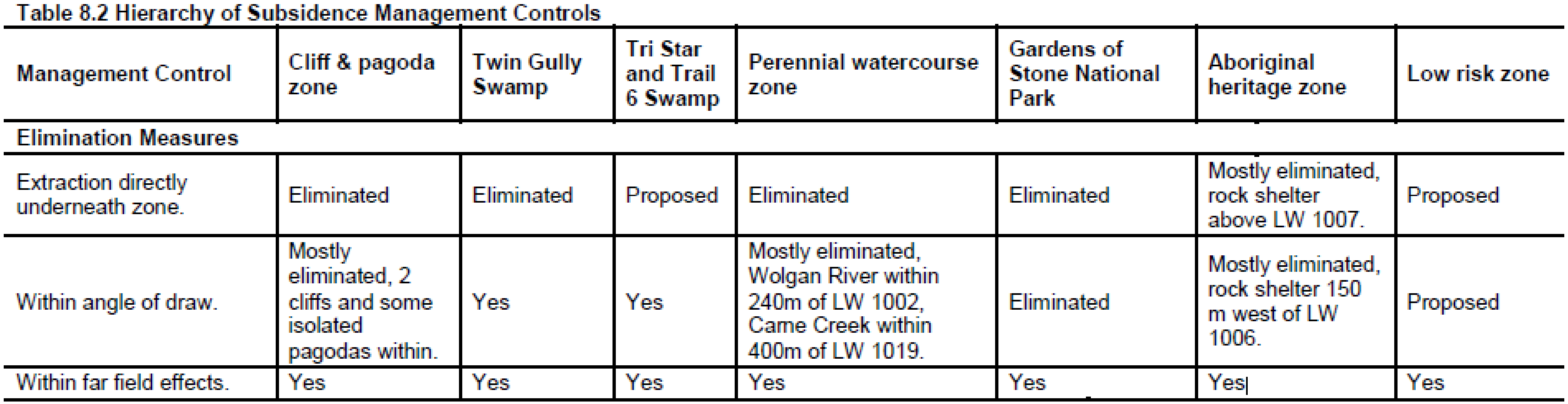


Table 8.2 Hierarchy of Subsidence Management Controls

| **Management Control** | **Cliff & pagoda zone** | **Twin Gully Swamp** | **Tri Star and Trail 6 Swamp** | **Perennial watercourse zone** | **Gardens of Stone National Park** | **Aboriginal heritage zone** | **Low risk zone** |
|---|---|---|---|---|---|---|---|
| **Elimination Measures** | | | | | | | |
| Extraction directly underneath zone. | Eliminated | Eliminated | Proposed | Eliminated | Eliminated | Mostly eliminated, rock shelter above LW 1007. | Proposed |
| Within angle of draw. | Mostly eliminated, 2 cliffs and some isolated pagodas within. | Yes | Yes | Mostly eliminated, Wolgan River within 240m of LW 1002, Came Creek within 400m of LW 1019. | Eliminated | Mostly eliminated, rock shelter 150 m west of LW 1006. | Proposed |
| Within far field effects. | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

JAMES MARSHALL & CO.

# Angus Place and Springvale Mine Extension Projects

Socio-Economic Response to Submissions Received in Support of Angus Place and Springvale Mine Extension Projects.

September 2014

# Contents

## Summary

The Angus Place and Springvale Mine Extension Projects have received a substantial number of submissions in response to the projects being placed on exhibition. On review of the submissions that were written in support of these projects, it is found that mining brings about a direct and significant social and economic benefit to local communities which would be lost should the projects be refused. A review of submissions received in support of the projects has found:

- The majority of support submissions are from the local community (Lithgow LGA) or immediate surrounding LGA's.
- The submissions outline the risks to the local community if the projects are not approved, which include:
    - The importance of ongoing secure employment.
    - Reduction in flow-on effects to other business and subsequent negative impacts.
    - The possible need for families to relocate should employment continue to decline across the sector.
    - The loss of financial and in-kind sponsorship to local community events, charities and projects.
    - The long history of mining in the LGA and also the multi-generational employment history amongst families will be lost.
    - The environmental performance of the projects is important to the workforce and that local people (including the sector workforce) access and enjoy the areas where mining is undertaken for leisure and recreation.
    - The mining sector is an important training resource for new employees and those wishing to pursue a career in the industry.
- Direct mine industry sector employment sits at 15% of Lithgow's workforce compared to 1.0% of the NSW workforce (2011 Census).
- The Lithgow Economic Development Strategy (Version 2) highlights the clear link between economic sustainability and population growth. Lithgow's current population is 20,161 (2011 census) and the projected population is forecast to be 20,650 people in 2036.
- A large proportion of Angus Place and Springvale's workforce reside in the Lithgow LGA, many of whom are long term residents and have been employed in the mining sector for many years. The workforce is more likely to own their own home and directly contribute to the social and financial economy of their community.
- For the 2013 – 2014 financial years Angus Place spent $64,923,494.15 on external contractors. Over 18% of this contribution was for contractors based in the Lithgow LGA and 80% for contractors based in other LGA's. For the

same period, Springvale spent $78,887,424.62 on external contractors. 30% of this contribution was for contractors based in the Lithgow LGA and 70% for contractors based in other LGA's.

- The financial contribution to other LGA's does not represent lost income to the Lithgow economy as it generates spending in other non-mining related sectors (i.e. accommodation, food, fuel, engagement of additional contract support services etc.). This type of expenditure would not occur if funds remained within the LGA. Therefore the indirect spend is significant.
- Case studies over the last 2 – 3 years illustrate the importance of mining to the general economy. There are many stories that recognise the link between mine related employment and the broader economy.

# 1. Introduction

Submissions written in support of both the Angus Place and Springvale Mine Extension Projects were most likely to come from people who live within the Lithgow Local Government Area (LGA) and those objecting to the projects were most likely to come from outside of the LGA. Tables 1 and 2 identify the distribution of submissions and whether they are in support, object or make comment in relation to each project.

The key themes expressed in the submissions of support, along with the number of occasions that each theme was raised are shown in Tables 3 and 4. Table 5 provides an overview of the content of the submissions in relation to the identified key themes.

**Table 1: Angus Place Summary Table: Submission Distribution (415)**

| Angus Place | Support (158) | Object (250) | Comment (8) |
|---|---|---|---|
| Local (139) | 127 | 12 | 1 |
| Regional* (102) | 22 | 79 | 1 |
| NSW (155) | 9 | 142 | 4 |
| Other State (19) | | 17 | 2 |

* Region: Blue Mountains, Bathurst, Mudgee, Orange.

**Table 2: Springvale Summary Table: Submission Distribution (307)**

| Springvale | Support (79) | Object (224) | Comment (4) |
|---|---|---|---|
| Local (73) | 62 | 11 | |
| Regional* (81) | 16 | 65 | |
| NSW (136) | 1 | 132 | 3 |
| Other State (17) | | 16 | 1 |

* Region: Blue Mountains, Bathurst, Mudgee, Orange.

**Table 3: Angus Place: Key Themes Raised in Support Submissions**

| Angus Place | Local LGA | Region* | NSW | Interstate |
|---|---|---|---|---|
| Jobs | 102 | 11 | 5 | |
| Local business | 63 | 10 | 2 | |
| Relocate | 32 | 3 | | |
| Sponsorship | 68 | 4 | 3 | |
| History | 8 | 1 | | |
| Environment | 41 | 6 | 2 | |
| Training | 2 | | | |

* Region: Blue Mountains, Bathurst, Mudgee, Orange.

**Table 4: Springvale: Key Themes Raised in Support Submissions**

| Springvale | Local LGA | Region* | NSW | Interstate |
|---|---|---|---|---|
| Jobs | 55 | 12 | | |
| Local business | 48 | 9 | | |
| Relocate | 25 | 1 | | |
| Sponsorship | 35 | 8 | | |
| History | 6 | | | |
| Environment | 27 | 2 | | |
| Training | 2 | 1 | | |

* Region: Blue Mountains, Bathurst, Mudgee, Orange.

**Table 5: Summary of Points Raised in Submission of Support (for both Angus Place and Springvale Mine Extension Projects).**

| Heading | Points Raised |
|---|---|
| Jobs | • Strong messages that jobs and job security is required.<br>• Concern about the decline in the minerals / energy sector and reduced opportunities for jobs in this area.<br>• AP and SV are long term employers and approval would allow this to continue.<br>• Jobs and job security is vital to the LGA. |
| Local business | • Indirect benefit from mining is vital to the Lithgow economy.<br>• Recognised flow on effects and adverse impact if jobs lost.<br>• Recognise that there is benefit via the engagement of local contractors.<br>• The benefit from local spending is also recognised.<br>• Loss of jobs will ‘decimate’ local business. |
| Relocate | • Given the decline in the industry families will need to relocate which will have a devastating impact on the LGA.<br>• Strong networks and social ties have been established which would be threatened if people have to relocate. |
| Sponsorship | • Support of many local charities, events and groups is recognised.<br>• Employees are also involved in these charities, events and groups so there is a strong link between the company and grass roots activities. |
| History | • Long history of mining in the area and employees also have a long history with mining and Centennial.<br>• Many employees are multi-generational. |
| Environment | • Recognise environmental performance is important.<br>• Local people recognise the value of the environment and utilise it for leisure / recreation.<br>• Not happy with outsiders opposing jobs and signing petition |

| | |
|---|---|
| | against mining<br>• Mined for many years with no adverse impact to the environment. |
| Training | • Training of new employees (traineeships and apprenticeships) is important and provides a career pathway into the industry. |

# 2. Mining Industry Sector

## 2.1 Status of Lithgow Economy

An analysis of the jobs held by the workforce in Lithgow City in 2011 shows the three most popular industry sectors were:

- Mining (1,120 people or 15.0%)
- Health Care and Social Assistance (804 people or 10.7%)
- Public Administration and Safety (715 people or 9.6%)

In combination these three industries employed 2,639 people in total or 35.3% of the total workforce. In comparison, New South Wales employed 1.0% in Mining; 11.8% in Health Care and Social Assistance; and 6.0% in Public Administration and Safety.

The major differences between the jobs held by the workforce of Lithgow City and New South Wales were:

- A *larger* percentage of people employed in Mining (15.0% compared to 1.0% in NSW).
- A *larger* percentage of people employed in Electricity, Gas, Water and Waste Services (5.0% compared to 1.1% in NSW).
- A *larger* percentage of people employed in Public Administration and Safety (9.6% compared to 6.0% in NSW).
- A *smaller* percentage of people employed in Professional, Scientific and Technical Services (2.8% compared to 8.0% in NSW).

Figure 1 Shows the Employment by Industry Sector for the Lithgow LGA (2011 Census)

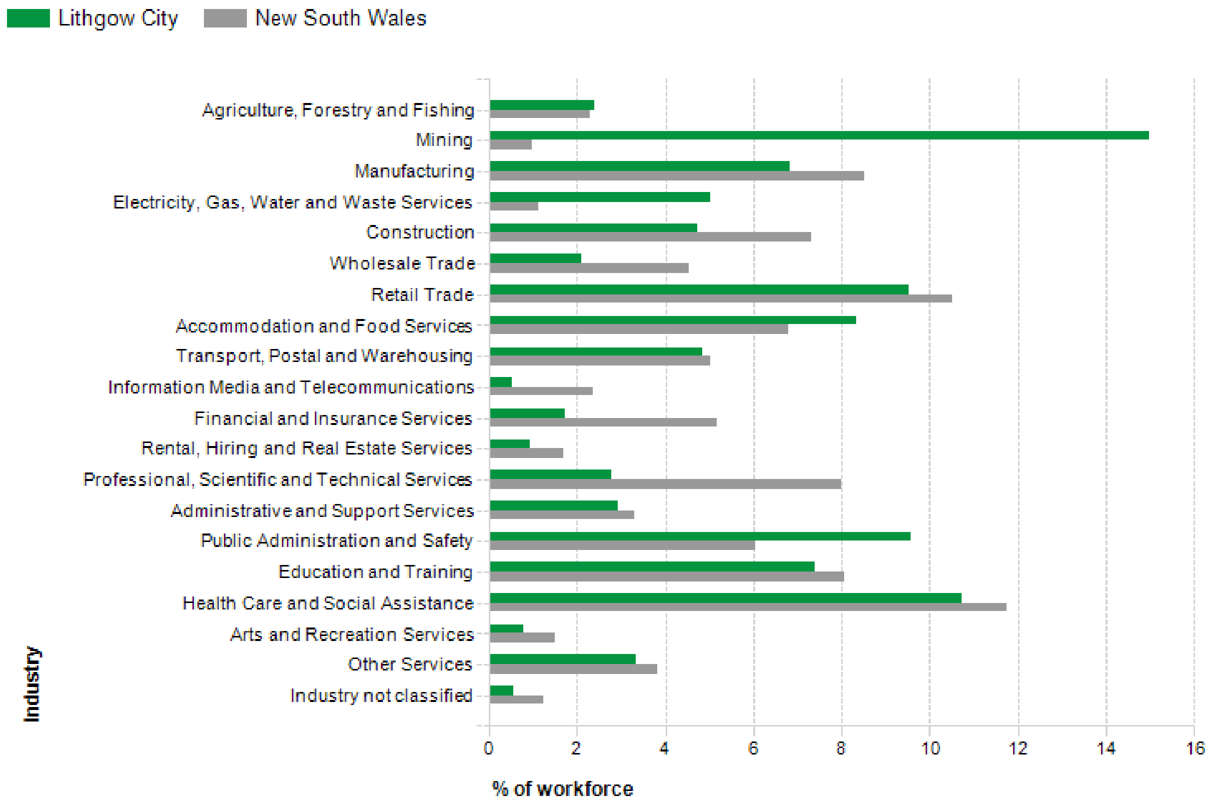

Lithgow City
New South Wales
Agriculture, Forestry and Fishing
Mining
Manufacturing
Electricity, Gas, Water and Waste Services
Construction
Wholesale Trade
Retail Trade
Accommodation and Food Services
Transport, Postal and Warehousing
Information Media and Telecommunications
Financial and Insurance Services
Rental, Hiring and Real Estate Services
Professional, Scientific and Technical Services
Administrative and Support Services
Public Administration and Safety
Education and Training
Health Care and Social Assistance
Arts and Recreation Services
Other Services
Industry not classified
Industry
0
2
4
6
8
10
12
14
16
% of workforce

**Figure 1: Employment by Industry Sector for the Lithgow LGA (2011 Census)**

The mining industry sector (including the sector sub-categories) employs a total of 1,120 people (2011 Census). Industries within the mine industry sector are identified in Table 6.

**Table 6: Employment by Mining Industry Sector.**

| Lithgow LGA | 2011 | | | 2006 | | | Change |
|---|---|---|---|---|---|---|---|
| **Industry** | **Number** | **%** | **NSW %** | **Number** | **%** | **NSW %** | **2006 - 2011** |
| Mining | 1,120 | 15.0 | 1.0 | 842 | 12.3 | 0.7 | +278 |
| **Mining Industry Sector Sub-Categories** | | | | | | | |
| Coal Mining | 1,048 | 14.0 | 0.6 | 769 | 11.2 | 0.4 | +279 |
| Oil and Gas Extraction | 0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0 |
| Metal Ore Mining | 3 | 0.0 | 0.1 | 5 | 0.1 | 0.1 | -2 |
| Non-Metallic Mineral Mining and Quarrying (nfd) | 3 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | +3 |
| Construction Material Mining | 25 | 0.3 | 0.1 | 20 | 0.3 | 0.0 | +5 |
| Other Non-Metallic Mineral Mining and Quarrying | 3 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | +3 |
| Exploration and Other Mining Support Services (nfd) | 0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0 |
| Exploration | 11 | 0.1 | 0.1 | 9 | 0.1 | 0.0 | +2 |
| Other Mining Support Services | 9 | 0.1 | 0.0 | 16 | 0.2 | 0.0 | -7 |
| Mining (nfd) | 18 | 0.2 | 0.1 | 23 | 0.3 | 0.1 | -5 |

(Source: 2011 Census Data. Id Profile)

### 2.2 Emerging Groups

The largest changes in the jobs held by the workforce between 2006 and 2011 in Lithgow City were for those employed in:

- Mining (+278 people)
- Health Care and Social Assistance (+123 people)
- Public Administration and Safety (+85 people).

These changes are significant in the context of an LGA which is experiencing very low population growth. Figure 2 shows the changes in the industry sectors between 2006 and 2011.

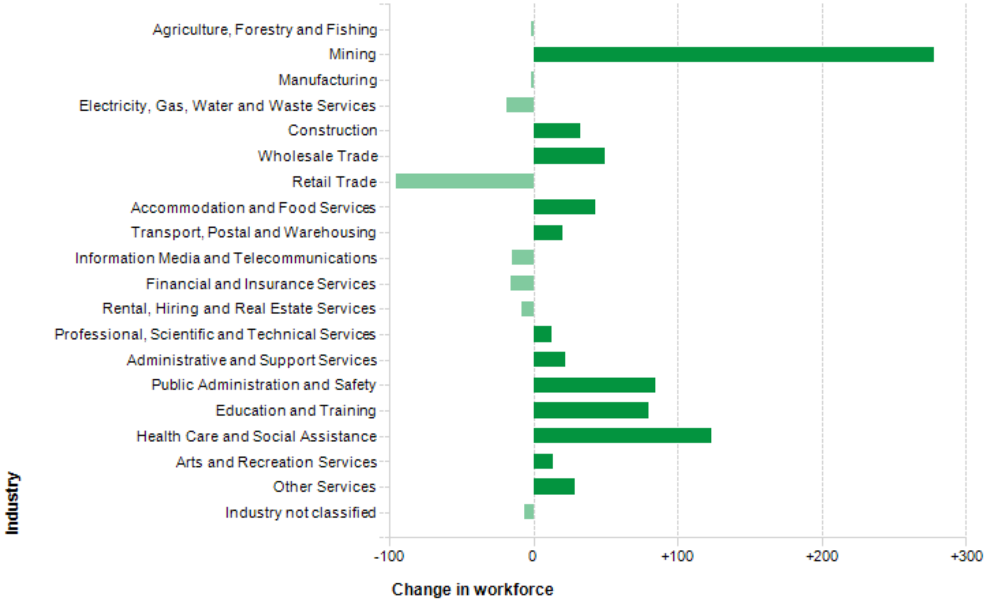


**Figure 2: Change in Employment by Industry Sector 2006 – 2011 (Lithgow LGA)**

# 3. Social Benefits of Staying in the Community

## 3.1 Overview

There are many social benefits of long term business and industry investment in any community, in particular Lithgow. Long term secure employment means that residents are more likely to purchase their home and participate in the social and financial economy of the area where they live. If there are no jobs in the industry sector, within their community, people will potentially relocate and the social and economic contribution that they make will be lost. Population stability and growth require secure employment and adequate hard infrastructure (roads, water supply etc.) and soft infrastructure (social activities, health care, education etc.). Investment in both hard and soft infrastructure requires population mass (ie demand) and growth (sustainability).

## 3.2 The Lithgow Economic Development Strategy

In support of the above, the Lithgow Economic Development Strategy (EDS) 2010-14: Version 2, states that “… growth in population is a critically important component in economic development. Such growth or decline in population figures has a direct impact on levels of total private and public expenditure in a community. Population growth provides the underlying basis for growth in labour resources, improvements in skill levels, and development of investment and capital within an area”.

The EDS goes on to say, “… population growth generates opportunities for business development and public investment, brings into the community new knowledge and expertise, and creates opportunities for innovation and business development. By contrast, if there is no significant increase in population numbers over time, then the population can become an 'ageing' one. The population will begin to stagnate and consequently varying economic demand levels eventually decline, new skills are slow to develop, innovation and enterprise have limited prospects, fewer people are attracted to in-migrate, and the rate of household and community dependency increases as fewer workers have to support an increasing number of non-workers. This is exacerbated by the out-migration of younger people seeking higher education and employment elsewhere".

These concerns are also reflected in the submissions in support of the Angus Place and Springvale Mine Extension Projects. There is an acute awareness that, given the lack of certainty in the mine industry sector, residents of the area will possibly relocate, resulting in a further decline in the socio-economic profile of the area which is a principle challenge facing the Lithgow LGA.

There are social and extended economic benefits that emerge when people stay in the Lithgow community. In summary these include:

- Investment in housing (i.e. purchasing rather than renting suggesting a stable population).
- Long term planning for the future through access to education, growth in families etc.
- Participation in social activities and maintenance of social ties.
- Long term planning / investment by other businesses that rely on the mine industry sector (directly or indirectly).
- Stability and potential investment growth in other sectors such as retail.

### 3.3 Population Forecast

Lithgow's current population is 20,161 (2011 census) and the projected population is forecast to be 20,650 people in 2036 (preliminary 2013 projections for Lithgow: Department of Planning and Environment). Further, in relation to the EDS, the median age will increase from the current 42 years to an expected 51 years by 2036.

### 3.4 Principle Challenges

Without population growth, the Lithgow LGA faces some significant challenges; some of those possibly exacerbated by the loss / decline of the mine industry sector are outlined below.

- It is predicted that the Lithgow Local Government Area will be the 46th oldest in NSW by 2022 (currently 88th). "Premature ageing" caused by migration related loss of young people and/or migration gain in older age groups, combined with general population ageing, means that the Lithgow Local Government Area will age at a significantly higher rate than the populations of NSW, Greater Sydney and the balance of NSW.

- Those renting directly from a Housing Authority in 2006 totalled 23.3% dwellings which compares to 18% in the Central West and 14.9% of dwellings in Australia at the same time.
- 2008 figures from the NSW Department of Health and Ageing, predict that Lithgow's population is expected to progressively decline annually by 0.06% after 2017.
- Social Disadvantage figures from the 2004 Index of Disadvantage (Jesuit Social Services) indicated that Lithgow was one of the most disadvantaged areas in NSW with the Lithgow 2790 postcode ranking within the top 10-15% of most disadvantaged areas.
- Socio-economic indices from ABS also list Lithgow as being within the lowest rankings of economic, educational and occupational disadvantage when compared to the rest of NSW. Lithgow also ranks poorly when compared to neighbouring Local Government Areas.

# 4. Economic Contribution

## 4.1 Workforce Contribution

As previously outlined the socio-economic contribution that mine related employment is significant. Surveys of Angus Place and Springvale employees, undertaken in February 2013 illustrate this.

Over 81% of Angus Place Colliery employees live in the Lithgow Local Government Area and 62% of these employees live in the major townships of Lithgow, Wallerawang and Portland. For Springvale nearly 76% of employees live in the Lithgow Local Government Area and nearly 80% of these employees live in the major townships of Lithgow, Wallerawang and Portland.

The survey indicates that employees are more likely to own their own home and have worked in the industry for over 10 years. The majority of employees are married with children and have lived in the Lithgow area most of their life.

Employees and their families also participate in local activities such as sport. Over 70% of those surveyed participating in some type of activity which includes, for example, volunteering their time to coach junior sports, membership in service organisations such as the rural fire service, volunteer in school canteens and participate in P & C meetings. Employee's children attend local kindergartens and schools, attend the local gyms, participate in athletics, swimming, dancing, basketball, water skiing etc. Involvement in these activities is usually in the immediate area where they live but also includes regional participation.

Living in the local area also means that there is a positive contribution into the local economy via direct spending in the communities where the workforce lives. Other than mortgage costs, food and household expenditure (groceries, household supplies, gardening, cleaning and repairs) are the highest expenditure items.

A survey of **Angus Place** employees undertaken in February 2013, found that the flow-on effects within the community where the employee lived are significant. These are summarised as follows:

- over 81% of Angus Place employees live in the Lithgow Local Government Area and 62% of these employees live in Lithgow, Wallerawang and Portland;
- 45% of those surveyed have been employed in the mining industry for over 10 years;
- 37% are from families that have worked in the industry for two or more generations;
- 79% own their own home;
- on average, each employee surveyed spends 33.5% of their total weekly income in their local residential community;
- over 40% of mine employee's partners participated in some type of work.

For **Springvale:**

- Nearly 76% of employees live in the Lithgow Local Government Area and nearly 80% of these employees live in the major townships of Lithgow, Wallerawang and Portland.
- 70% of those surveyed have been employed in the industry for over 10 years;
- 47% are have worked in the industry for two or more generations;
- 88% own their own home;
- on average, each employee surveyed spends 33.0% of their weekly income in their local residential community;
- over 40% of mine employees partners work and most participate in some regular weekly sport or social activities.

For both **Angus Place and Springvale:**

- most employees and their families participate in some local regular sport or social activities;
- the majority of employee's children, who do not currently attend school, participated in sporting activities in their local community;
- employees have strong connections to their local communities demonstrated via shopping in the communities where they live, coaching junior sport, participating in social activities, supporting local fundraising activities;
- employees are members of the local bush fire brigade and SES, and members of local clubs; and
- employees are aware of and utilise the natural assets throughout the area such as state forests and national parks for family outings.

It is evident that Angus Place and Springvale employees have a strong economic and social interaction with the local surrounding community. The continued mine related employment generated by these projects will potentially maintain a relatively stable population base demonstrated by the long term housing tenure of some employees in the LGA.

This will mean that services and infrastructure will remain viable as they will benefit from the above mentioned flow on effects over the extended life of the Project. It is not expected that the ongoing operation of the Project will create any additional demand for services and infrastructure.

## 4.2 Contractor Contribution

For the 2013 / 2014 financial year, Angus Place expended $64,923,494.15 on external contractors and for the same period Springvale expended $77,887,424.62. The allocation per LGA is summarised in Tables 7 and 8.

**Table 7: Contractor Payments Angus Place July 2013 to June 2014.**

| LGA | Invoiced Amount | % of Total |
|---|---|---|
| Lithgow | $11,857,981.71 | 18.26% |
| Bathurst | $908,873.29 | 1.40% |
| Oberon | $175,953.50 | 0.27% |
| Other | $51,980,721.65 | 80.06% |
| **TOTAL** | **$64,923,494.15** | **100%** |

**Table 8: Contractor Payments Springvale July 2013 to June 2014**

| LGA | Invoiced Amount | % of Total |
|---|---|---|
| Lithgow | $22,758,454.60 | 30.0% |
| Bathurst | $1,136,137.70 | 1.0% |
| Oberon | $96,520.00 | 0.0% |
| Other | $52,896312.32 | 69.0% |
| **TOTAL** | **$76,887,424.62** | **100%** |

With reference to contractor payments:

- Angus Place and Springvale make a significant financial contribution to the LGA and Region (totalling $142,810,918.77 in the 2013 / 14 financial year).
- The contribution is not limited to the mining industry sector alone and includes:
    - Engineering
    - Printing services
    - Security
    - Health and Safety
    - Environmental Science and Research
    - Mine technology
    - Drilling
    - Surveying
    - Earth moving.

- The contribution outside of the LGA does not represent escape expenditure. While difficult to accurately quantify, it is safe to assume that many external contractors will direct money back into the Lithgow economy via:
    - Accommodation
    - Food
    - Fuel
    - Engagement of additional contract support services.

This type of expenditure would not occur if funds remained within the LGA; meaning that the indirect financial flow on effect is again significant.

## 4.3 Case Studies

Through the preparation of numerous social impact assessments over the past three years, James Marshall & Co. has spoken to many individuals, families and businesses in regards to the contribution that the mining industry makes to the Lithgow community.

These themes are repeated in the employee survey referred to in 4.1 above (i.e. reinforce the positive contribution that people make) and also in the submissions in support of both the Angus Place and Springvale Mine Extension Projects (i.e. state what will be lost to the community if the projects are not approved). Themes include:

- Businesses often state that most of their income comes from people who work in the mines (or their families).
- When preparing for the employee survey a group of miners told a story about how they collected money over a couple of shifts in response to an article in the paper regarding the hospital requiring a piece of equipment.
- Second and third generation miners who would like their children to also work in the industry and the extension of these projects means that this is a possibility.
- People who work in the mines access the Newnes Plateau for recreation and leisure and also value the preservation of the environment.
- There is a strong connection to the area and its people.

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# Centennial Springvale Colliery Pty Ltd

# Subsurface Fracture Zone Assessment above the Proposed Springvale and Angus Place Mine Extension Project Area Longwalls

## DgS Report No. SPV-003/7b

**Date: 10th September 2014**

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Ditton Geotechnical Services Pty Ltd

10th September, 2014

Peter Corbett
Technical Services Manager
Centennial Coal Springvale Pty Ltd
PO Box 198
WALLERAWANG NSW 2845

Report No. SPV-003/7b

Dear Peter,

**Subject: Subsurface Fracture Zone Assessment above the Proposed Springvale and Angus Place Mine Extension Project Area Longwalls**

This report has been prepared in accordance with the brief for the above projects.

Please contact the undersigned if you have any questions regarding this matter.

For and on behalf of
**Ditton Geotechnical Services Pty Ltd**

Steven Ditton
Principal Engineer

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**Figures:**

Figures 1 to 10

**Attachment:**

Attachment A - Subsurface Fracture Model Review and Pi-Term Model Development Details

## 1.0 Introduction

This report provides subsurface fracture zone height predictions for the proposed longwalls in the Springvale and Angus Place Mine Extension Project Areas.

The longwalls included in this study are:

- Springvale Mine LWs 415 to 423
- Springvale Mine Extension Area LWs 424 to 432 and 501 to 503
- Angus Place Mine Extension Area LWs 1001 to 1019

The predictions have been based on the Geometry and Geology Pi-Term models presented in **DgS, 2014** and the interpreted sub-surface fracture zones above Springvale Mine's LWs 409, 411 and 412. The Geometry Pi-Term models refer to panel void width (W'), cover depth (H) and mining height (T), whereas the Geology Pi-Term model includes an additional term, the effective strata unit thickness (t'), which is the average thickness of the bending or shearing beam in the B-Zone (i.e. the dilated zone above the Continuous Fracture Zone or A-Zone).

The purpose of the review was to (i) calibrate the Geology Pi-Term model with the measured subsurface fracturing zones, and (ii) assess the likely A and B-Zone fracture zone heights above the proposed project area panels.

The original assessment of the subsurface fracture zone assessment due to LWs 411 and 412 and the geological structure beneath East Wolgan Creek (**DgS, 2013**) has been superseded by the updated Pi-Term models and borehole data used in this study.

## 2.0 Method

The subsurface fracture heights above the proposed longwall mining areas have been estimated based on:

- A review of the overburden geology above completed and future mining areas.
- The observed strata responses measured with borehole extensometer and vibrating wire piezometers installed above Springvale LWs 409, 411 and 412.
- Water table monitoring in stand pipe piezometers on the ridges above Angus Place LW 950 and Springvale LWs 411, 415 and 420.
- The results of sub-surface fracture (micro-seismic event) monitoring above LW413.
- Calibration of the Geology 'Pi-Term' Model to the measured heights of continuous subsurface fracturing (A Zone Horizon) and discontinuous fracturing and strata dilation (B-Zone Horizon).
- Comparison of measured sub-surface fracture zones with the Geometry Pi-term model predictions.

A summary of the Pi-Term models is presented in **Section 5** with development details in **Attachment A**.

## 3.0 Mining Geometry

The geometry of the completed Springvale Mine longwalls and proposed new project area longwall layouts are summarised in **Table 1**. The mining layouts with cover depth contours are presented in **Figures 1a** to **1c**.

**Table 1 - Completed and Proposed Longwall Panel Geometry**

| Mine | LW No. | Panel Width W' (m) | Cover Depth, H (m) | Mining Height T (m) | W/H | MG Chain Pillar Width $W_{cp}$ |
|---|---|---|---|---|---|---|
| Springvale Mine | 1,401-408 | 255, 265 | 385 | 2.7, 2.95 | 0.75 - 0.85 | 40 |
| | 409 | 265 | 385 | 3.25 | 0.69 | 40 |
| | 410 | 315 | 370 | 3.25 | 0.85 | 40 |
| | 411 | 315 | 290 - 368 | 3.25 | 0.86 - 1.08 | 42 |
| | 412 | 315 | 400 | 3.25 | 0.79 | 43 |
| | 413 | 315 | 400 | 3.25 | 0.79 | 43 |
| | 414 - 415 | 315 | 412 | 3.25 | 0.76 | 43 - 47 |
| | 416 - 423 | 261 | 340 - 420 | 3.25 | 0.63 - 0.78 | 58 |
| Springvale Mine Extension Project Area | 424 - 431 | 261 | 290 - 415 | 3.25 | 0.63 - 0.90 | 58 |
| | 432 | 229 | 270 - 405 | 3.25 | 0.57 - 0.85 | 58 |
| | 501 | 261 | 180 - 325 | 3.25 | 0.80 - 1.45 | - |
| | 502 | 243 | 180 - 305 | 3.25 | 0.80 - 1.35 | 35.2 |
| | 503 | 236 | 245 - 310 | 3.25 | 0.76 - 0.96 | - |
| Angus Place Mine Extension Project Area | 1001 - 1003 | 293 | 350 - 410 | 3.25 | 0.71 - 0.83 | 55 |
| | 1004 - 1006 | 261 | 280 - 430 | 3.25 | 0.61 - 0.93 | 55 |
| | 1007 - 1015 | 360 | 270 - 440 | 3.25 | 0.82 - 1.33 | 55 |
| | 1016 - 1017 | 261 | 305 - 355 | 3.25 | 0.74 - 0.86 | 55 |
| | 1018 - 1019 | 360 | 320 - 420 | 3.25 | 0.86 - 1.13 | 55 |

Shaded - Completed LWs.

The completed panels to-date had 'sub-critical' to 'critical' geometries with W/H ranging from 0.69 to 1.08. The proposed longwalls in the proposed mine extension areas will have 'sub-critical' to 'super-critical' mining geometries, with W/H values ranging from 0.57 to 1.45. *Note: It has been previously assessed in* ***DgS, 2010*** *that the transition point between 'sub-critical' and 'critical' panels occurs at W/H of 0.9 and between 'critical' and 'super-critical' behaviour at W/H of 1.4.*

In the future mining areas adjacent to shrub swamps, the mine design has been specifically designed for sub-critical panel geometries. The width to depth ratios for these proposed longwalls vary between 0.6 and 0.9, but are typically within the range of 0.65 and 0.75 and therefore, are less than those for the previously extracted longwalls at Angus Place and Springvale Collieries.

The effect of the apparent increases in panel 'criticality' and panel geometry on the subsurface fracture height zones is discussed further in **Section 6.0**.

# 4.0 Site Conditions

## 4.1 Surface Conditions

### 4.1.1 Completed Longwalls

The completed longwall panels at the Springvale Mine (LW1, 401 to 415) have been extracted below the Newnes State Forest and Plateau, which is vegetated by eucalypt tree species and sensitive shrub swamps. The terrain is gently to moderately undulated with ground slopes generally < 15° with some bedrock exposures along the creek beds. Slopes with gradients > 18° exist in the northern ends of valleys adjacent to East Wolgan and Narrow Swamps.

Several tributaries or ephemeral drainage gullies and shrub swamps associated with the Wolgan River (including West Wolgan, and East Wolgan Creek) have been undermined by Springvale and Angus Place Colliery longwalls.

There were no sensitive features such as sandstone cliff lines > 20 m high, rock formations (pagodas) > 5 m high or Aboriginal Heritage Sites within an angle of draw distance of 26.5° (0.5 times the cover depth) of the previous panels with > 20 m high cliffs adjacent to the north side of the Wolgan River near the starting ends of LWs 411 and 412; see **Figure 2a**.

### 4.1.2 Proposed Mine Extension Project Area Longwalls

The proposed longwall panels (Springvale 416 to 423, Springvale Mine Extension Project Area LWs 424 to 432 & 501 to 503 and Angus Place Mine Extension Project Area LWs 1001 to 1019) will also be extracted below the Newnes State Forest and Plateau. The terrain is gently to moderately undulating with ground slopes < 15°. There are several tributaries or ephemeral drainage gullies and shrub swamps associated with the Wolgan River (including Sunny Side East, Carne West and Carne East Creeks) that drain the plateaux to the east and west.

There are several sensitive landscape features such as sandstone cliff lines > 20 m high, rock formations (pagodas) > 5 m high and steep slopes > 18° within the Springvale and Angus Place Mine Extension Project Areas. The proposed longwalls have been set back from these features by an angle of draw distance of 26.5° (0.5 times the cover depth); see **Figures 2b** and **2c**.

## 4.2 Subsurface Conditions

### 4.2.1 Springvale Mine LWs 409 to 412

Lithological and geophysical logging of the overburden above Springvale Mine's LW 409, 411 and 412 has been summarised in **Table 2** and **Figure 3a**.

**Table 2 - Springvale Mine's Overburden Stratigraphy**

| **Strata Unit** | **Depth to base of Unit z (m)** | **Height above Mine Roof y (m)** | **Formation Thickness t (m)** | **Lithology** | **UCS (MPa)** |
|---|---|---|---|---|---|
| Burralow Formation | 60 - 79 | 306 - 318 | 60 - 79 | Interbedded Sandstone & Claystone (weathered) | 2 - 10 |
| Banks Wall Sandstone | 156 - 164 | 221 - 222 | 85 - 96 | Sandstone, massive | 30 - 50 |
| Mount York Claystone | 171 - 188 | 198 - 207 | 23 - 27 | Claystone, variable thickness | 30 - 70 |
| Burra Moko-Head Sandstone | 210 - 225 | 160 - 168 | 27 - 37 | Sandstone, massive | 30 - 90 |
| Upper Caley Formation | 234 - 264 | 121 - 144 | 24 - 39 | Sandstone | 30 - 70 |
| Lower Caley Formation | 261 - 274 | 111 - 117 | 18 - 27 | Siltstone: Sandstone | 30 - 70 |
| Katoomba & Middle River Seams | 285 - 292 | 87 - 93 | 24 - 24 | Coal/shale | 10 - 20 |
| Denman Formation | 373 - 379 | 5 - 6 | 88 - 103 | Sandstone: Siltstone | 20 - 50 |
| Lidsdale/Lithgow Seam | 376 - 383 | 0 | 3.9 - 3 | Coal | 10 - 20 |

Shaded - strong sandstone units.

### 4.2.2 Proposed Mine Extension Project Areas

Based on the cross sections through the proposed Mine Extension Project Areas provided by Palaris, it is assessed that the geology is similar to the current mining conditions (see **Section 7**).

### 4.2.3 Subsidence Reduction Potential of Massive Sandstone Units

The Subsidence Reduction Potential (SRP) of an overburden is related to the presence of strong, thickly bedded strata and refers to the potential reduction in subsidence due to the overburden being able to either 'bridge' across an extracted longwall panel or have a greater bulking volume when it collapses into the panel void (if close enough to seam level). The term was defined in an **ACARP, 2003** study into this phenomenon and is common in NSW Coalfields were massive sandstone and conglomerate stratigraphy exists.

The overburden above the Springvale and Angus Place Mine Extension Project Areas has massive sandstone units, such as the Banks Wall and Burra-Moko Head Sandstone Units, that have the capacity to span over the proposed longwall panels and reduce subsidence (i.e. ‘High’ to ‘Moderate’ SRP). Longwall panels in other coalfields with similar geometries that do not have massive strata present, tend to have higher subsidence and lower SRP (i.e. ‘Low’ SRP).

A comprehensive review of the measured subsidence and predictions for LWs 1 and 401 to 415 is presented in **DgS, 2012**. The spanning capability of the sandstone units above the current mining area is further demonstrated in the following sub-sections.

#### 4.2.4 Geological Structure

A review of the subsidence results for all of the extracted longwalls at Springvale show significant increases in subsidence (and impact) above the six wider longwalls (LWs 410 to 415) compared to the first ten 265 m wide longwalls (LWs 1 and 401 to 409). The increases are attributed to mining geometry changes and the influence of geological structure (Wolgan and Deanes Creek Lineaments). The interaction of subsidence with rapidly varying topography (plateau and valley formations) has also influenced tilt and strain above all panel geometries.

**Palaris, 2013** and **DgS, 2011** has established that there are four types (Type 1 to 4) of geological structure within the Springvale Mining Lease that appear to have had some to no effect on subsidence measurement. A summary of each structure type and its effect on subsidence development is presented below:

- Interpretation work indicates several Major Type 1 faults associated with the Wolgan, Deanes Creek and Kangaroo Creek lineaments. These lineaments (and associated faults) extend over strike lengths of several kilometres, and are associated with variable topography (ranging from incised valleys to plateau areas). Subsidence monitoring indicates that there have been localised subsidence, tilt and compressive strain increases associated with incised valleys. Where Type 1 fault zones are associated with plateau topography, subsidence increases have not been measured.

- Type 2 faulting is similar to Type 1, however, it is not as persistent as Type 1 structure with only limited surface expression (e.g. single sided valleys or steep slopes). Subsidence increase potential above Type 2 Structure is unknown at this stage as they have not yet been undermined by any Springvale longwalls.

- Minor Type 3 faulting commonly exists at seam level but show no surface expression across the mining area (e.g. mildly undulating terrain and plateau areas). Subsidence monitoring indicates that there have been no subsidence effect increases above the Type 3 structure areas.

- Type 4 structures are basement structures only, which, despite being common, do not have structural features associated with these at the Lithgow Seam level or have expression at the surface. No surface subsidence changes have occurred above Type 4 structure.

The location of the geological structure above the current and proposed Springvale and Angus Place Mine Extension Project Areas are shown in **Figures 3b** to **3d**.

The influence of geological structure on height of fracturing development (and future predictions) has been assessed from the extensometer and piezometer data for LWs 409 to 412 collected to-date and is presented in **Section 5**.

### 4.2.5 Surface and Subsurface Groundwater Aquifers

The groundwater regime has been assessed in **CSIRO, 2007** above LWs 409 to 412 and indicates that the following sub-surface aquifers (AQ1-5) exist above the proposed workings (in ascending order):

- AQ1 - The Lidsdale Seam
- AQ2 - Sandstone, coal and siltstones of the Farmers Creek Formation (includes the Gap Sandstone Member, Middle River and Katoomba Coal Seams)
- AQ3 - Conglomeratic Sandstone in Narrabeen Group's Burra-Moko Head Formation
- AQ4 - Conglomeratic Sandstone in lower Narrabeen Group's Banks Wall Sandstone
- AQ5 - Conglomeratic Sandstone in upper Narrabeen Group's Banks Wall Sandstone

Aquifers AQ1 to AQ4 are defined as confined aquifers with the AQ5 defined as an unconfined aquifer. The Mount York Claystone forms a semi-impermeable aquitard between the AQ4 and AQ5 aquifers, and is approximately 200 m above the Lithgow Seam. There are currently no privately owned groundwater extraction bores in the project areas.

## 4.3 Subsurface Monitoring Results

The strata and groundwater response to longwall mining at Springvale and Angus Place have been measured with the following devices:

- Two borehole extensometer No.s SPR40 (LW411) and SPR52 (LW412) to measure strata dilation and vertical strain. *Note: A third borehole exto (SPR65) was installed above LW413a; however, it malfunctioned during mining.*
- Four vibrating wire (VW) piezometer No.s SPR32, 39 and 48 above the chain pillars between LWs 411 and 412 and central panel VW piezometer SPR31 above LW409.

The devices consisted of 4 to 8 VW piezometers to measure changes to groundwater pressure heads in the overburden for each longwall.

- Six screened standpipe piezometers (known as the Ridge Piezometers No.s RNW, REN, SSE, RSS and RCW) to measure changes to water table levels before and after mining impacts.

- Micro-seismic event monitoring was undertaken by CSIRO in 2010 at the southern end of LW413b in five boreholes on a 400 m grid spacing. The geophones were located at depths from 100 m to 415 m (refer to **CSIRO, 2011** for details).

The locations of the extensometer and piezometric monitoring points above the completed Angus Place and Springvale Mine longwalls are shown in **Figure 1a**.

### 4.3.1 Borehole Extensometer data for LWs 411 and 412

Two multi-anchor borehole extensometers, SPR40 and SPR52, were installed above LWs 411 and 412 respectively prior to mining.

Several reviews of the extensometer data have been completed in **Aurecon, 2009**, **CSIRO, 2007** and **CSIRO, 2008**. All of the reviews have identified three distinct zones of sub-surface fracturing that indicate continuous fracturing between strata units (A-Zone), discontinuous fracturing and strata dilation (B-Zone) and a deformed elastic Zone (C-Zone).

The EWS and M subsidence monitoring lines are the closest lines to the extensometers and indicate the surface above LW411 and 412 has been subsided by 1.25 and 1.33 m respectively.

The strata displacement (relative to the surface), dilation and vertical strains measured between the anchors in SPR40 and SPR52 are summarised in **Tables 3A** and **3B** respectively and shown together graphically in **Figures 4a** to **4c** (SPR40) and **Figures 4d** to **4f** (SPR 52).

## Table 3A - Extensometer Data Summary for SPR40

| Anchor No. | Depth z (m) | Height above LWs y (m) | Mid-Height $y_m$ (m) | Anchor RL (AHD) | Anchor Displacement Relative to Surface (mm) | | Strata Dilation (mm) | | Vertical Strain (mm/m) | | HoF Zone* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 7/01/2008 (LW411) | 27/03/2009 (LW412) | 411 | 412 | 411 | 412 | |
| Surface | 0 | 368 | - | 1129 | - | - | - | - | - | - | D |
| 20 | 40 | 328 | | 1089 | 0 | 0 | - | - | - | - | C |
| 19 | 51 | 317 | 322.5 | 1078 | 9 | 9 | 9 | 9 | 1 | 1 | C |
| 18 | 62 | 306 | 311.5 | 1067 | 51 | 51 | 41 | 42 | 4 | 4 | C |
| 17 | 73 | 295 | 300.5 | 1056 | 56 | 51 | 5 | 0 | 0 | 0 | C |
| 16 | 84 | 284 | 289.5 | 1045 | 23 | 105 | -32 | 54 | -3 | 5 | B |
| 15 | 95 | 273 | 278.5 | 1034 | 112 | 95 | 89 | -10 | 8 | -1 | B |
| 14 | 106 | 262 | 267.5 | 1023 | 87 | 60 | -26 | -35 | -2 | -3 | B |
| 13 | 118 | 250 | 256 | 1011 | 220 | 174 | 134 | 115 | 11 | 10 | B |
| 12 | 129 | 239 | 244.5 | 1000 | 417 | 362 | 197 | 187 | 18 | 17 | B |
| 11 | 140 | 228 | 233.5 | 989 | 516 | 461 | 99 | 100 | 9 | 9 | B |
| 10 | 151 | 217 | 222.5 | 978 | 543 | 500 | 26 | 39 | 2 | 4 | B |
| 9 | 170 | 198 | 207.5 | 959 | 745 | 699 | 202 | 199 | 11 | 10 | B |
| 8 | 200 | 168 | 183 | 929 | 1044 | 990 | 300 | 291 | 10 | 10 | B |
| *7a* | *234* | *139* | *153.5* | *895* | *1454* | *1400* | *410* | *410* | *12* | *12* | *B* |
| 7 | 268 | 100 | 119.5 | 861 | 2842 | 2841 | 1388 | 1441 | 41 | 42 | A |
| 6 | 280 | 88 | 94 | 849 | 2848 | 2847 | 6 | 6 | 0 | 0 | A |
| 5 | 294 | 74 | 81 | 835 | 2863 | 2861 | 15 | 14 | 1 | 1 | A |
| 4 | 310 | 58 | 66 | 819 | 2842 | 2840 | -21 | -21 | -1 | -1 | A |
| 3 | 339 | 29 | 43.5 | 790 | 2725 | 2653 | -117 | -187 | -4 | -6 | A |
| 2 | 353 | 15 | 22 | 776 | 2848 | 2847 | 123 | 194 | 9 | 14 | A |
| 1 | 365 | 3 | 9 | 764 | 3000 | 3000 | 152 | 153 | 13 | 13 | A |

shading - Interpreted subsurface fracture zone; * - Height of Fracturing Zone definitions in **Attachment A**; *italics* - interpolated result based on borehole data for SPR40.

The measured heights of fracturing for the A-Zone and B-horizons in SPR40 were estimated to be 139 m and 288 m above the longwalls. The horizons were based on the anchor displacements in SPR40 and the response of piezometric data in SPR39 (see **Section 4.3.7**).

Reference to the lithology log for SPR39 indicates that the A-Zone horizon is coincident with the base of Caley Formation Sandstone unit, which together with the overlying Burra-Moko Head Sandstone Formation is approximately 51 m thick.

The anchors in the A-Zone were displaced vertically by 2842 to 3000 mm by the collapsing strata, and represents ~90% of the mining height. The maximum vertical strain between the anchors was 42 mm/m with goaf consolidation resulting in the development of several zones of compressive strain after subsidence was fully developed.

The strata in the B-Zone were displaced between 60 and 1454 mm, or 2% to 45% of the mining height. The strata were dilated between 39 and 410 mm with vertical strains from 4 to 17 mm/m.

The strata in the C-Zone were displaced between 9 and 54 mm, or 0.3% to 1.7% of the mining height. The strata were dilated between 0 mm and 52 mm with vertical strains between 0 and 4 mm/m.

**Table 3B - Extensometer Data Summary for SPR 52**

| Anchor No. | Depth z (m) | Height above LWs y (m) | Mid-Height $y_m$ (m) | Anchor RL (AHD) | Anchor Displacement Relative to Surface (mm) | | Strata Dilation (mm) | | Vertical Strain (mm/m) | | HoF Zone* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | LW412 (19/06/09) | LW413 (13/04/11) | 412 | 413 | 412 | 413 | |
| Surface | 0 | 400 | - | 1165.2 | - | - | - | - | - | - | D |
| 20 | 20 | 380 | 390 | 1145.2 | 3 | 3 | - | - | - | - | C |
| 19 | 40 | 360 | 370 | 1125.2 | 23 | 23 | 20 | 20 | 1 | 1 | C |
| 18 | 55 | 345 | 352.5 | 1110.2 | 30 | 30 | 7 | 7 | 0 | 0 | C |
| 17 | 62 | 338 | 341.5 | 1103.2 | 63 | 63 | 33 | 33 | 5 | 5 | C |
| 16 | 65 | 335 | 336.5 | 1100.2 | 47 | 47 | -16 | -16 | -5 | -5 | C |
| 15 | 75 | 325 | 330 | 1090.2 | 61 | 80 | 14 | 33 | 1 | 3 | C |
| 14 | 85 | 315 | 320 | 1080.2 | 102 | 102 | 41 | 22 | 4 | 2 | C |
| 13 | 100 | 300 | 307.5 | 1065.2 | 130 | 130 | 28 | 28 | 2 | 2 | C |
| 12 | 120 | 280 | 290 | 1045.2 | 293 | 293 | 163 | 163 | 8 | 8 | B |
| 11 | 140 | 260 | 270 | 1025.2 | 431 | 431 | 138 | 138 | 7 | 7 | B |
| 10 | 160 | 240 | 250 | 1005.2 | 516 | 516 | 85 | 85 | 4 | 4 | B |
| 9 | 180 | 220 | 230 | 985.2 | 1021 | 1021 | 505 | 505 | 25 | 25 | B |
| 8 | 220 | 180 | 200 | 945.2 | 1023 | 1023 | 2 | 2 | 0.1 | 0.1 | B |
| 7 | 255 | 145 | 162.5 | 910.2 | 1255 | 1255 | 232 | 232 | 7 | 7 | B |
| 6 | 292 | 108 | 126.5 | 873.2 | 2826 | 2826 | 1571 | 1571 | 42 | 42 | A |
| 5 | 330 | 70 | 89 | 835.2 | 3000 | 3000 | 174 | 174 | 5 | 5 | A |
| 4 | 362 | 38 | 54 | 803.2 | 3000 | 3000 | 0 | 0 | 0 | 0 | A |
| 3 | 380 | 20 | 29 | 785.2 | 3000 | 3000 | 0 | 0 | 0 | 0 | A |
| 2 | 384 | 16 | 18 | 781.2 | 3000 | 3000 | 0 | 0 | 0 | 0 | A |
| 1 | 394 | 6 | 11 | 771.2 | 3000 | 3000 | 0 | 0 | 0 | 0 | A |

shading - Interpreted subsurface fracture zone;* - Height of Fracturing Zone definitions in **Attachment A**; *italics* - interpolated result based on borehole data for SPR40.

The measured heights of fracturing for the A-Zone and B-horizons in SPR52 were estimated to be 145 m and 300 m above the longwalls. The horizons were based on the anchor displacements in SPR52 and the response of piezometric data in SPR31 and SPR48 (see **Section 4.3.7**).

Reference to the lithology log for SPR32 indicates that the A-Zone horizon is coincident with the base of Caley Formation Sandstone unit, which together with the overlying Burra-Moko Head Sandstone Formation is approximately 55 m thick.

The anchors in the A-Zone were displaced vertically by 2826 to 3000 mm by the collapsing strata, and represents ~90% of the mining height. The maximum vertical strain between the anchors was 42 mm/m after subsidence had fully developed.

The strata in the B-Zone were displaced between 293 and 1255 m, or 9% to 39% of the mining height. The strata were dilated between 2 and 505 mm with vertical strains ranging from 4 to 25 mm/m.

The strata in the C-Zone were displaced between 3 and 130 mm, or 0.1% to 4% of the mining height. The strata were dilated between 7 and 33 mm with vertical strains between 0 and 5 mm/m.

### 4.3.2 Piezometric Response to LW409

Eight Vibrating Wire Piezometers (VWPs) were installed in Borehole SPR31, which was located in the middle of LW409. The effects of undermining on the groundwater regime is presented in **Figure 5a** and summarised in **Table 4A**.

**Table 4A - Summary of Piezometer Pressure Head Changes in SPR31 above LW409**

| Piezo # | Piezo Depth z (m) | Piezo Height above LWs y (m) | Piezo RL (AHD) | Pressure Head (m) | | | HoF Zone* |
|---|---|---|---|---|---|---|---|
| | | | | Pre-Mining | Post-Mining | Change | |
| Surface | 0 | 385 | 1168.2 | | | | |
| 8 | 90 | 295 | 1078.2 | 8 | 10 | 2 | C |
| 7 | 173 | 212 | 995.2 | 91 | 58 | -33 | B |
| 6 | 293 | 92 | 875.2 | 213 | 64 | -149 | A |
| 5 | 305 | 80 | 863.2 | 227 | 74 | -153 | A |
| 4 | 360 | 25 | 808.2 | 283 | 73 | -210 | A |
| 3 | 380 | 5 | 788.2 | 302 | 61 | -248 | A |
| 2 | 384 | 1 | 784.2 | 309 | 59 | -250 | A |
| 1 | 393 | -8 | 778.2 | 321 | 35 | -286 | A |

* - Height of Fracturing Zone definitions in **Attachment A.**

The results indicate groundwater pressure head drops in the A Zone ranging from 149 m to 286 m during the relatively short monitoring period between 2nd and 5th December, 2003. The top two piezos were considered to be located in the B-Zone and C-Zones with pressure head changes of -33 m and +2 m respectively. As there were no extensometer data to correlate the piezometer response to the interpreted fracture zones, the results presented should be viewed with caution at this stage until more recent readings can be obtained.

### 4.3.3 Piezometric Response to LW411 and 412 (SPR39)

Nine Vibrating Wire Piezometers (VWPs) were installed in Borehole SPR39, which was located above the chain pillars between LW411 and 412. The effects of undermining on the groundwater regime is presented in **Figure 5b** and summarised in **Table 4B**.

Emergency mine water discharges (EMWDs) were released along East Wolgan Creek during the period from March 2008 through to February 2009. The response of the piezometers in borehole SPR39 to mining effects and EMWDs in 2009 have enabled the heights of fracturing zones to be confidently defined. The depth of fault dilation due to interaction with LW411 and 412 subsidence deformations was also able to be determined from the piezometer responses.

The piezometer and EMWD flow data has been previously presented in **Aurecon, 2009**.

**Table 4B - Summary of Piezometer Pressure Head Changes in SPR39 between LW411 & 412**

| Piezo # | Piezo Depth z (m) | Piezo Height above LWs y (m) | Piezo RL (AHD) | Pressure Head (m) Pre-Mining | Total Pressure Head Change (m) | | HoF Zone* |
|---|---|---|---|---|---|---|---|
| | | | | | LW411 | LW412 (EMWDs) | |
| Surface | 0 | 378 | 1135 | - | - | | D |
| 9 | 50 | 328 | 1085.6 | -0.84 | -1.3 | -1.3 | C |
| 8 | 80 | 298 | 1055.6 | 36.75 | -36.0 | -39.5 | B |
| 7 | 140 | 238 | 995.6 | 50.31 | -46.5 | **-38.4** | B |
| 6 | 155 | 223 | 980.6 | 58.71 | -51.4 | **-44.6** | B |
| 5 | 240 | 138 | 895.6 | 63.72 | -52.3 | **-18.9** | B |
| 4 | 270 | 108 | 865.6 | 33.27 | -25.9 | *-28.6* | A |
| 3 | 340 | 38 | 795.6 | 33.38 | *-30.3* | *-30.3* | A |
| 2 | 374 | 4 | 761.5 | 15.90 | *-17.5* | *-17.5* | A |
| 1 | 380 | -2 | 755.9 | 8.60 | *-8.2* | *-8.2* | A |

* - Height of Fracturing Zone definitions in **Attachment A**;
*italics* - reading prior to loss of instrument due to bedding shear or excessive strata dilation.
**bold** - pressure head partially recovered during EMWDs.

Piezo's 5-8 (SPR39) demonstrates that the water is being stored in the dilated strata and not draining into the A-Zone. These four piezos also clearly indicate that the groundwater in the Banks Wall and Burra Moko-Head Units (B / C Zones) are connected by a network of jointing, however, compressive strains due to natural or voussoir arching above panels also appear to have reduced the vertical rock mass permeability between dilated bedding partings and the recovery rates of groundwater levels in the upper strata.

The increase in pressure head above Piezos 5-8 during the EWMDs is the strongest evidence that surface waters were being stored in the B and C-Zones and then compressed by strata consolidation (see exto data in **Section 4.3.1**). Drops in pressure are coincident with dilation in the sagging strata as 411 and 412 passed beneath the instruments. The lag time of ~ 1 week between discharge dates and piezo response also indicates the pooling of groundwater higher up in the strata has increased the pressure at the piezos below the point of groundwater entry only.

Piezo's 5-7 (SPR39) also indicate that it is very unlikely that the fault dilation has extended to depths > 240 m due to the pressure head increases observed. It is considered that the fault is probably open near the surface and has allowed water to move deeper into the strata than it normally would have. **Aurecon, 2009** has estimated that the discharge waters may have reached a depth of 80 m below the creek, which coincides with Piezo No. 8.

### 4.3.4 Piezometric Response to LW411 and 412 (SPR32)

Four Vibrating Wire Piezometers (VWPs) were installed in Borehole SPR32, which was also located above the chain pillars between LW411 and 412 and 690 m south of SPR39. The effects of undermining on the groundwater regime after the mining of both panels is presented in **Figure 5c** and summarised in **Table 4C**.

**Table 4C - Summary of Piezometer Pressure Head Changes in SPR32 between LW411 & 412**

| Piezo # | Piezo Depth z (m) | Piezo Height above LWs y (m) | Piezo RL (AHD) | Pressure Head (m) Pre-Mining | Pressure Head (m) Post-Mining | Total Pressure Head Change (m) | HoF Zone* |
|---|---|---|---|---|---|---|---|
| Surface | 0 | 395 | 1162.6 | - | - | - | D |
| 1 | 30 | 365 | 1132.6 | 2.5 | -1.8 | -4.3 | C |
| 2 | 170 | 225 | 992.6 | 85.7 | 21.1 | *-64.6* | A |
| 3 | 320 | 75 | 842.6 | 103.5 | 45.2 | *-58.3* | A |
| 4 | 344 | 51 | 818.6 | 132.0 | 74.3 | *-57.7* | A |

*italics* - last reading before instrument sheared off by strata movements.

The results indicate groundwater pressure head drops ranging from 4.3 m to 64.6 m during the monitoring period between August 2004 and March 2009. The bottom three piezos were sheared off by strata displacements and considered to be in the A Zone. The interpreted zones are correlated with the exto data in **Section 4.3.7**.

### 4.3.5 Piezometric Response to LW412 and 413 (SPR48)

Eight Vibrating Wire Piezometers (VWPs) were installed in Borehole SPR48, which was located above the chain pillars between LW412 and 413 and adjacent to SPR52. The effects of undermining on the groundwater regime after the mining of both panels is presented in **Figure 5d** and summarised in **Table 4D**.

**Table 4D - Summary of Piezometer Pressure Head Changes in SPR48 between LW412 & 413**

| Piezo # | Piezo Depth z (m) | Piezo Height above LWs y (m) | Piezo RL (AHD) | Pressure Head (m) Pre-Mining | Pressure Head (m) Post-Mining | Total Pressure Head Change (m) | HoF Zone* |
|---|---|---|---|---|---|---|---|
| Surface | 0 | 395 | 1167 | - | - | - | D |
| 8 | 30 | 365 | 1137 | 2.5 | 0.0 | -2.4 | C |
| 7 | 50 | 345 | 1117 | 3.4 | 2.2 | -1.2 | C |
| 6 | 70 | 325 | 1097 | 17.1 | 13.5 | -3.6 | C |
| 5 | 90 | 305 | 1077 | 14.8 | 7.2 | -7.6 | B |
| 4 | 110 | 285 | 1057 | 34.2 | 12.3 | -21.8 | B |
| 3 | 140 | 255 | 1027 | 58.1 | 14.0 | *-44.2* | B |
| 2 | 170 | 225 | 997 | 39.8 | 10.2 | *-29.6* | B |
| 1 | 200 | 195 | 967 | 36.3 | 7.5 | *-28.8* | B |

*italics* - last reading before instrument sheared off by strata movements.

The results indicate groundwater pressure head drops ranging from 1.2 m to 3.6 m in the C-Zone and from 7.6 m to 44.2 m in the B-Zone during the monitoring period between March 2008 and May 2009. The bottom three piezos were sheared off by strata displacements, but still considered to be in the B-Zone based on extensometer results (SPR52). The interpreted zones are correlated with the exto data in **Section 4.3.7**.

### 4.3.6 Standpipe (Ridge) Piezometers

Five standpipe piezometers to 70 m depth were installed above Angus Place and Springvale Mines. The locations of the piezometers are shown on **Figure 1a**.

The purpose of the standpipes were to monitor the water table during mining. The results are summarised in **Table 4E** and **Figure 5e**.

**Table 4E - Summary of Ridge Piezometers and Mining Geometry**

| Piezometer No. | LW | Surface RL | Piezo Depth (m) | Maximum Observed Post-Mining Depth to Water Table (m) | Date | Latest Observed Post-Mining Depth to Water Table (m) | Date |
|---|---|---|---|---|---|---|---|
| RNW | 950 | 1158 | 57 | 56.05 | 27/09/10 | 51.90 | 22/7/13 |
| REN | 950 | 1151 | 56 | 55.05 | 07/08/11 | 51.13 | 22/7/13 |
| RSE | 412 | 1150 | 51 | 50.50 | 27/05/13 | 50.30 | 22/7/13 |
| RSS | 415 | 1157 | 36 | 32.38 | 29/05/07 | 27.60 | 22/7/13 |
| RCW | 420 | 1098 | 32 | 27.41 | 29/05/07 | 24.67 | 22/7/13 |

The results indicate that the groundwater table during the monitoring period has responded to the change in cumulative rainfall deficit and had not been affected by longwall mining up to the last readings.

### 4.3.7 Interpreted Sub-Surface Fracture Zone Summary

The borehole and extensometer results have been compared with mining geometry and overburden lithology at the Springvale Mine in **Figures 6a** (LW409), **6b** (LWs 411 and 412) and **6c** (LWs 412 and 413).

The predicted mean and Upper 95% Confidence Limits for the A and B-Zone have been determined using the Geometry and Geology Pi-Term Models and have been estimated for comparison with the interpreted fracture zones. The comparison summary and prediction methodology is described in **Section 5**.

### 4.3.8 Micro-Seismic Data

Microseismic monitoring data for Springvale Mine's LW413 was undertaken in five boreholes with eight triaxial geophones (**CSIRO, 2011**). The depth of cover was 410 m and the panel width was 315 m to give a *sub-critical* W/H of 0.77.

More than 100,000 micro-seismic events were recorded that ranged from strong shear wave events (indicating structural feature slip or rock mass shear failures in compression) to weaker ones (indicating tensile failures and bedding slip). The majority of events occurred between 70 m and 120 m above the Lithgow Seam as shown in **Figure 7**.

It was assessed that the majority of strong events were due to the crushing of the Katoomba Seam coal under abutment loading conditions and movements on domain boundaries or lineaments. Strong shearing events or compression failures also occurred in the Caley Formation sandstone and siltstone beds. The frequency of strong events peaked at 35 between 85 m and 90 m above the seam with >10 events occurring within the above mentioned boundary limits.

The results correlate well with the interpreted heights of the A-Zone, which ranged from 139 m to 145 m above LWs 411 and 412. The previous assessment that the upper Caley Formation sandstone and Burra-Moko Head Sandstone are spanning across the A-Zone (and therefore within the B-Zone) appears to be correct. It is also noted that the thickness of the sandstone units immediately above the A-Zone is approximately 55 m thick.

A lower frequency of seismic events (between 1 and 10/5m distance) occurred up to the Mount York Claystone at a distance of 200 m above the Lithgow Seam. It is considered that these events are associated with bedding shear and dilating strata movements. Only one event was recorded in the Banks Wall Sandstone at a distance of 343 m above the Lithgow Seam.

# 5.0 Height of Fracturing Prediction Models

## 5.1 DgS, 2014 Geometry Pi-Term Model

The model was developed in 2013-14 in response to several Planning and Assessment Committees (PACs) reports and general industry concerns in regards to large apparent differences between established prediction methods that use only one parameter in a particular coalfield (e.g. the mining height v. panel void width models).

The Geometry Pi-term model considers the influence of the panel width, cover depth and mining height on the height of continuous fracturing above a longwall panel. A dimensionally consistent product and power rule has been derived using non-linear regression analysis of measured cases in the NSW Coalfields. The model considers the key mining geometries and indirectly includes the influence of a wide range of geological conditions; see **Attachment A**.

The Pi-terms have been derived (by experiment) using Buckingham's Pi-Term theorem and refer to the dimensionless ratios of key independent variables with a repeating variable of influence (the panel width) as follows:

$$\underline{\text{Mean } A/W' = 2.215\,(H/W')^{0.271}(T/W')^{0.372}} \qquad R^2 = 0.61 \text{ \& rmse} = 0.12W'(21\%)$$

$$\underline{\text{U95\%CL } A/W' = \text{Mean } A/W' + a}$$

where $a = 0.16$, $0.16 - 0.086(W/H-0.7)$ and $0.1$ for sub-critical, critical & supercritical panels

$H$ = cover depth = maximum potential goaf load height.

$W'$ = effective panel width = minimum of $W$ and $1.4H$.

$T$ = mining height.

Re-arranging the above equation in terms of A gives:

$$\underline{A = 2.215W'^{0.357}H^{0.271}T^{0.372}} \qquad +/- \; aW'$$

*Note: The dimensions & powers on both sides of the equation are consistent.*

For estimating the height of the dilated B-Zone using the Geometry Pi-Term Model:

$$\underline{\text{Mean } B/W' = 1.621\,(H/W')^{0.55}(T/W')^{0.175}} \qquad R^2 = 0.86 \text{ \& rsme} = 0.12W'(13\%)$$

$$\underline{\text{U95\% } B/W' = \text{Mean } B/W' + b}$$

where $b = 0.16$, $0.16 - 0.086(W/H - 0.7)$ and $0.1$ for sub-critical, critical & supercritical panels.

Re-arranging the above equation gives $\underline{B = 1.621\,W'^{0.275}H^{0.55}T^{0.175}}$ $+/- \; bW'$

## 5.2 DgS, 2014 Geology Pi-Term Model

Further to the Geometry Model, the Pi-term Geology model also considers the influence of the effective strata unit thickness (t') on the A-Zone fracture height development. The effective strata unit thickness refers to the thickness of the beam in the B-Zone that spans the continuous fracture zones above a longwall panel. Using a product and power rule and non-linear regression analysis of measured cases, the range of 'effective beam thicknesses' for a given mining geometry was derived for the NSW Coalfields; see *Figure A42e in* **Attachment A**.

The pi-terms have also been derived (by experiment) using Buckingham's Pi-term theorem and refer to the dimensionless ratios of key independent variables with a repeating variable of influence (the panel width) as follows:

$$\underline{\text{Mean } A/W' = 1.52\,(H/W')^{0.535}(T/W')^{0.464}(t'/W')^{-0.4}} \qquad R^2 = 0.8 \;\&\; \text{rmse} = 0.09W'(15\%)$$

$$\underline{\text{U95\%CL } A/W' = \text{Mean } A/W' + a}$$

where $a = 0.15$, $0.15 - 0.12(W/H-0.7)$ and $0.1$ for subcritical, critical and supercritical panels.

H = cover depth = maximum potential goaf load height.

W' = effective panel width = minimum of W and 1.4H.

T = mining height.

t' = effective strata unit thickness in the strata above the A-Zone (see *Section A11.4.4* in **Attachment A**) at Springvale and Angus Place Collieries = 42 m, which has been back-analyzed from the measured heights of fracturing and borehole stratigraphy.

Re-arranging the above equation gives $\underline{A = 1.52W'^{0.4}H^{0.535}T^{0.464}t'^{\,-0.4}}$ +/- aW'

For estimating the height of the dilated B-Zone using the Geology Pi-Term Model:

$$\underline{\text{Mean } B/W' = 1.873\,(H/W')^{0.635}(T/W')^{0.257}(t'/W')^{-0.097}} \qquad R^2 = 0.86 \;\&\; \text{rmse} = 0.13W'(15\%)$$

$$\underline{\text{U95\% } B/W' = \text{Mean } B/W' + b}$$

where $b = 0.15$, $0.15 - 0.12(W/H - 0.7)$ and $0.1$ for subcritical, critical & supercritical panels.

Re-arranging the above equation gives $\underline{B = 1.873\,W'^{0.205}H^{0.635}T^{0.257}t'^{\,-0.097}}$ +/- bW'

## 5.3 Difference between Geometry and Geology Pi-Term Models

It is considered that the Geology Pi-term model is superior to the Geometry Pi-term model as it may be calibrated to local height of A-Zone fracture height measurements.

The Geology Pi-term model is calibrated to the measured values by adjusting the effective strata thickness until the predicted mean values for the model match the measured values above known mining geometry. The U95%CL values then provide an additional factor of safety to allow for natural variation within the database.

The Geometry Pi-Term model uses only the proposed mining geometry and cannot be calibrated to geology data directly. The effect of geological conditions across the database will therefore be 'averaged' and may therefore result in the predictions at a particular site being more or less conservative.

Overall, both the models are likely to provide conservative predictions if massive strata is present in the overburden with the capability to span the goaf and 'truncate' the A-Zone heights. As discussed earlier, it is assessed that the Springvale and Angus Place Mine extension Project Areas have several massive sandstone strata units (Upper Caley, Burra Moko-Head and Banks Wall Sandstone) above the Katoomba Seam that could span the continuous fracture zones above the proposed 260 m to 315 m wide panels.

Further details of A-Zone and B-Zone height prediction model development are provided in **Attachment A**.

## 6.0 Calibration and Validation of Pi-Term Models

The subsurface fracture zone predictions above LWs 409, 411 and 412 are summarised in **Tables 6A** (Geology Pi-Term Model) and **6B** (Geometry Pi-Term Model) with measured values derived from the borehole extensometer and VWP data.

**Table 6A - Measured v. Predicted Height of Fracturing Review Summary for Springvale Mine's LW 409, 411 & 413 based on the Geology Pi-Term Model**

| Panel | Panel Width W (m) | Cover Depth | Mining Height T (m) | Effective Strata Thickness t' | Predicted A-Zone Horizon above Mine Workings Roof* (m) | Measured A-Zone Horizon above Mine Workings Roof (m) | Predicted B-Zone Horizon above Mine Workings Roof* (m) | Measured B-Zone Horizon above Mine Workings Roof (m) |
|---|---|---|---|---|---|---|---|---|
| 409 | 265 | 385 | 3.25 | 42 | 133 - 172 | **133** | 243 - 296 | **254** |
| 411 | 315 | 368 | 3.25 | 42 | 139 - 182 | **139** | 244 - 300 | **288** |
| 412 | 315 | 400 | 3.25 | 42 | 145 - 190 | **145** | 258 - 377 | **300** |

* - Predictions based on Pi-Term model are mean and U95%CL values (i.e. mean + 1.65 standard deviations). The standard deviations are < 25% mean values.
**Bold** - measured values plot between predicted range.

**Table 6B - Measured v. Predicted Height of Fracturing Review Summary for Springvale Mine's LW 409, 411 & 413 based on the Geometry Pi-Term Model**

| Panel | Panel Width W (m) | Cover Depth | Mining Height T (m) | Predicted A-Zone Horizon above Mine Workings Roof* (m) | Measured A-Zone Horizon above Mine Workings Roof (m) | Predicted B-Zone Horizon above Mine Workings Roof* (m) | Measured B-Zone Horizon above Mine Workings Roof (m) |
|---|---|---|---|---|---|---|---|
| 409 | 265 | 385 | 3.25 | 120 - 162 | **133** | 243 - 296 | **254** |
| 411 | 315 | 368 | 3.25 | 126 - 172 | **139** | 244 - 300 | **288** |
| 412 | 315 | 400 | 3.25 | 129 - 177 | **145** | 258 - 377 | **300** |

* - Predictions based on Pi-Term model are mean and U95%CL values (i.e. mean + 1.65 standard deviations). The standard deviations are < 25% mean values.
**Bold** - measured values plot between predicted range.

The results indicate that the Geology Pi-term model, which has the mean or expected values calibrated to measured values at Springvale, predicts a 10% to 12% higher range of A and B-Zone fracturing than the Geometry Pi-term model. The reason for this is that the Geometry model includes the geological effects of all coalfields/sites within the database and is likely to be biased towards the average conditions across the database. It is recommended that the Geology model results be adopted for future area predictions for the Springvale and Angus Place Mine Extension Project Areas.

The Geology Pi-term model predictions have been plotted with the measured results in **Figures 6a** to **6c**.

## 7.0 Predicted Sub-surface Fracture Zones for Proposed Mining Areas

### 7.1 Springvale Mine's LWs 415 to 423

The predicted A-Zone and B-Zone fracture heights above the proposed Springvale longwalls LW415 to 423 and Ridge Piezometers (RNW, REN, RSE, RSS & RCW) are summarised in **Tables 7A**.

**Table 7A - Predicted Height of Fracturing Summary for Springvale Mine's LW 415 to 423 based on Geology and Geometry Pi-Term Models**

| Panel | Panel Width W (m) | Cover Depth H (m) | Mining Height T (m) | Effective Strata Thickness t' (m) | Predicted Geology Model A-Zone Horizon above Mine Workings Roof* (m) | | Predicted Geometry Model A-Zone Horizon above Mine Workings Roof* (m) | | Predicted Geology Model B-Zone Horizon above Mine Workings Roof* (m) | | Predicted Geometry Model B-Zone Horizon above Mine Workings Roof* (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | mean | U95% | mean | U95% | mean | U95% | mean | U95% |
| 415 | 315 | 400 | 3.25 | 42 | 145 | 190 | 136 | 184 | 258 | 303 | 262 | 310 |
| | 315 | 420 | 3.25 | 42 | 149 | 195 | 138 | 187 | 266 | 312 | 269 | 318 |
| 416 - 423 | 265 | 340 | 3.25 | 42 | 124 | 162 | 122 | 163 | 224 | 263 | 228 | 269 |
| | 265 | 350 | 3.25 | 42 | 126 | 165 | 123 | 164 | 228 | 267 | 232 | 273 |
| | 265 | 360 | 3.25 | 42 | 128 | 167 | 124 | 166 | 233 | 272 | 235 | 277 |
| | 265 | 380 | 3.25 | 42 | 132 | 171 | 126 | 168 | 241 | 280 | 242 | 285 |
| | 265 | 400 | 3.25 | 42 | 135 | 175 | 128 | 170 | 249 | 288 | 249 | 292 |
| | 265 | 420 | 3.25 | 42 | 139 | 179 | 129 | 172 | 257 | 296 | 256 | 299 |
| RNW (LW950) | 293 | 368 | 3.25 | 42 | 135 | 177 | 129 | 174 | 241 | 283 | 245 | 289 |
| REN (LW950) | 293 | 372 | 3.25 | 42 | 136 | 178 | 130 | 174 | 242 | 285 | 246 | 291 |
| RSE (LW411) | 315 | 360 | 3.25 | 42 | 137 | 180 | 132 | 178 | 241 | 284 | 247 | 293 |
| RSS (LW415) | 315 | 413 | 3.25 | 42 | 148 | 193 | 137 | 186 | 263 | 309 | 266 | 315 |
| RCW (LW420) | 260 | 380 | 3.25 | 42 | 131 | 170 | 125 | 167 | 240 | 279 | 241 | 283 |

* - Predictions are mean - U95%CL values; shaded - Preferred predictions.

The predictions for the A-Zone Heights are shown graphically in **Figures 8a** to **8c**.

The predictions indicate that the A-Zone is likely to occur up to the Upper Caley Sandstone with the B-Zone developing in the Burra-Moko Head and Banks Walls Sandstone. The Upper 95%CL A and B-Zones are contained within the above units.

### 7.2 Springvale Mine Extension Area LWs 424 to 432 and 501 to 503

The predicted A-Zone and B-Zone fracture heights above the proposed Springvale Mine Extension Area LWs 424 to 432 and 501 to 503 are summarised in **Tables 7B**.

## Table 7B - Predicted Height of Fracturing Summary for the Springvale Mine Extension Area LWs 424 to 432 and 501 to 503 based on Geology and Geometry Pi-Term Models

| Panel | Panel Width W (m) | Cover Depth H (m) | Mining Height T (m) | Effective Strata Thickness t' (m) | Predicted Geology Model A-Zone Horizon above Mine Workings Roof* (m) | | Predicted Geometry Model A-Zone Horizon above Mine Workings Roof* (m) | | Predicted Geology Model B-Zone Horizon above Mine Workings Roof* (m) | | Predicted Geometry Model B-Zone Horizon above Mine Workings Roof* (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | mean | U95% | mean | U95% | mean | U95% | mean | U95% |
| 424 - 431 | 260.9 | 290 | 3.25 | 42 | 113 | 149 | 116 | 154 | 202 | 238 | 208 | 245 |
| | 260.9 | 310 | 3.25 | 42 | 117 | 154 | 118 | 157 | 211 | 247 | 216 | 254 |
| | 260.9 | 330 | 3.25 | 42 | 121 | 159 | 121 | 160 | 219 | 257 | 223 | 263 |
| | 260.9 | 350 | 3.25 | 42 | 125 | 164 | 122 | 163 | 228 | 266 | 231 | 271 |
| | 260.9 | 370 | 3.25 | 42 | 129 | 168 | 124 | 166 | 236 | 275 | 238 | 280 |
| | 260.9 | 390 | 3.25 | 42 | 133 | 172 | 126 | 168 | 244 | 283 | 245 | 287 |
| | 260.9 | 410 | 3.25 | 42 | 136 | 175 | 128 | 170 | 252 | 291 | 252 | 293 |
| | 260.9 | 415 | 3.25 | 42 | 137 | 176 | 128 | 170 | 254 | 293 | 253 | 295 |
| 432 | 229 | 270 | 3.25 | 42 | 103 | 135 | 109 | 143 | 188 | 220 | 193 | 227 |
| | 229 | 290 | 3.25 | 42 | 107 | 140 | 111 | 146 | 197 | 230 | 201 | 236 |
| | 229 | 310 | 3.25 | 42 | 111 | 145 | 113 | 149 | 205 | 239 | 208 | 244 |
| | 229 | 330 | 3.25 | 42 | 115 | 150 | 115 | 152 | 214 | 248 | 216 | 252 |
| | 229 | 350 | 3.25 | 42 | 119 | 153 | 117 | 154 | 222 | 256 | 223 | 259 |
| | 229 | 370 | 3.25 | 42 | 122 | 157 | 119 | 155 | 230 | 264 | 230 | 266 |
| | 229 | 390 | 3.25 | 42 | 126 | 160 | 120 | 157 | 238 | 272 | 236 | 273 |
| | 229 | 405 | 3.25 | 42 | 129 | 163 | 122 | 158 | 243 | 278 | 241 | 278 |
| 501 | 260.9 | 180 | 3.25 | 42 | 87 | 112 | 101 | 126 | 148 | 173 | 159 | 184 |
| | 260.9 | 200 | 3.25 | 42 | 93 | 121 | 105 | 134 | 160 | 188 | 170 | 198 |
| | 260.9 | 220 | 3.25 | 42 | 98 | 128 | 108 | 139 | 170 | 200 | 179 | 210 |
| | 260.9 | 240 | 3.25 | 42 | 102 | 134 | 111 | 144 | 179 | 211 | 188 | 221 |
| | 260.9 | 260 | 3.25 | 42 | 107 | 140 | 113 | 148 | 189 | 222 | 196 | 231 |
| | 260.9 | 280 | 3.25 | 42 | 111 | 146 | 115 | 152 | 198 | 232 | 204 | 241 |
| | 260.9 | 300 | 3.25 | 42 | 115 | 151 | 117 | 155 | 207 | 243 | 212 | 250 |
| | 260.9 | 325 | 3.25 | 42 | 120 | 158 | 120 | 159 | 217 | 255 | 222 | 261 |
| 502-503 | 243.4 | 180 | 3.25 | 42 | 85 | 111 | 100 | 125 | 147 | 172 | 157 | 182 |
| | 243.4 | 200 | 3.25 | 42 | 90 | 118 | 103 | 131 | 157 | 185 | 166 | 195 |
| | 243.4 | 220 | 3.25 | 42 | 95 | 124 | 105 | 136 | 167 | 197 | 175 | 206 |
| | 243.4 | 240 | 3.25 | 42 | 100 | 131 | 108 | 140 | 177 | 208 | 184 | 216 |
| | 243.4 | 260 | 3.25 | 42 | 104 | 136 | 110 | 144 | 186 | 218 | 192 | 226 |
| | 243.4 | 280 | 3.25 | 42 | 108 | 142 | 112 | 148 | 195 | 228 | 200 | 236 |
| | 243.4 | 300 | 3.25 | 42 | 112 | 147 | 115 | 151 | 204 | 238 | 208 | 245 |
| | 243.4 | 310 | 3.25 | 42 | 114 | 149 | 116 | 153 | 208 | 243 | 212 | 249 |

* - Predictions are mean - U95%CL values; shaded - Preferred predictions.

The predictions for the A-Zone Heights are shown graphically in **Figure 9a** to **9e**.

The predictions indicate that the A-Zone is likely to occur up to the Upper Caley Sandstone with the B-Zone developing in the Burra-Moko Head and Banks Walls Sandstone. The Upper 95%CL A and B-Zones are contained within the above units.

## 7.3 Angus Place Mine Extension Area LWs 1001 to 1019

The predicted A-Zone and B-Zone fracture heights above the proposed Angus Place Mine Extension Area longwalls 1001 to 1019 are summarised in **Tables 7C**.

**Table 7C - Predicted Height of Fracturing Summary for Angus Place Mine Extension Area LWs 415 to 423 based on Geology and Geometry Pi-Term Models**

| Panel | Panel Width W (m) | Cover Depth H (m) | Mining Height T (m) | Effective Strata Thickness t' | Predicted Geology Model A-Zone Horizon above Mine Workings Roof* (m) | | Predicted Geometry Model A-Zone Horizon above Mine Workings Roof* (m) | | Predicted Geology Model B-Zone Horizon above Mine Workings Roof* (m) | | Predicted Geometry Model B-Zone Horizon above Mine Workings Roof* (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | mean | U95% | mean | U95% | mean | U95% | mean | U95% |
| 1001 - 1003 | 293 | 350 | 3.25 | 42 | 131 | 172 | 128 | 171 | 233 | 274 | 238 | 282 |
| | 293 | 370 | 3.25 | 42 | 135 | 177 | 130 | 174 | 242 | 284 | 246 | 290 |
| | 293 | 390 | 3.25 | 42 | 139 | 182 | 131 | 177 | 250 | 293 | 253 | 298 |
| | 293 | 410 | 3.25 | 42 | 143 | 186 | 133 | 180 | 258 | 302 | 260 | 306 |
| | 293 | 430 | 3.25 | 42 | 146 | 190 | 135 | 182 | 266 | 310 | 267 | 314 |
| 1004 - 1006, 1016, 1017 | 261 | 280 | 3.25 | 42 | 111 | 146 | 115 | 152 | 198 | 233 | 204 | 241 |
| | 261 | 310 | 3.25 | 42 | 117 | 154 | 118 | 157 | 211 | 247 | 216 | 254 |
| | 261 | 330 | 3.25 | 42 | 121 | 159 | 121 | 160 | 219 | 257 | 223 | 263 |
| | 261 | 350 | 3.25 | 42 | 125 | 164 | 122 | 163 | 228 | 266 | 231 | 272 |
| | 261 | 370 | 3.25 | 42 | 129 | 168 | 124 | 166 | 236 | 275 | 238 | 280 |
| | 261 | 390 | 3.25 | 42 | 133 | 172 | 126 | 168 | 244 | 283 | 245 | 287 |
| | 261 | 410 | 3.25 | 42 | 136 | 175 | 128 | 170 | 252 | 291 | 252 | 294 |
| | 261 | 430 | 3.25 | 42 | 140 | 179 | 129 | 171 | 260 | 299 | 258 | 300 |
| 1007-1015 | 360 | 270 | 3.25 | 42 | 124 | 162 | 128 | 166 | 206 | 244 | 219 | 257 |
| | 360 | 290 | 3.25 | 42 | 129 | 169 | 130 | 172 | 216 | 256 | 227 | 268 |
| | 360 | 310 | 3.25 | 42 | 133 | 176 | 133 | 176 | 225 | 267 | 236 | 279 |
| | 360 | 330 | 3.25 | 42 | 138 | 182 | 135 | 181 | 234 | 278 | 244 | 290 |
| | 360 | 350 | 3.25 | 42 | 142 | 188 | 137 | 185 | 243 | 289 | 252 | 300 |
| | 360 | 370 | 3.25 | 42 | 147 | 194 | 139 | 189 | 252 | 299 | 260 | 309 |
| | 360 | 390 | 3.25 | 42 | 151 | 199 | 141 | 192 | 261 | 309 | 267 | 318 |
| | 360 | 420 | 3.25 | 42 | 157 | 207 | 144 | 197 | 273 | 323 | 279 | 331 |

* - Predictions are mean - U95%CL values.

The predictions for the A-Zone Heights are shown graphically in **Figure 10a** to **10d**.

The predictions indicate that the A-Zone is likely to occur up to the Upper Caley Sandstone with the B-Zone developing in the Burra-Moko Head and Banks Walls Sandstone. The Upper 95%CL A and B-Zones are contained within the above units.

## 8.0 Conclusions and Recommendations

Based on subsurface monitoring of strata displacements, groundwater pressures and microseismic activity, the continuous HoF (A-Zone) has ranged from 133 m to 145 m height above Springvale Mine's LW 409 and 411 to 413 (0.33W to 0.46W; 0.36H to 0.38H; and 41T to 45T). The development of the A-Zone has stopped at a sandstone unit approximately 55 m thick comprising the Upper Caley Sandstone and the Burra-Moko Head Sandstone.

Strata dilation and discontinuous fracturing (the B-Zone) has developed up into the Banks Wall Sandstone for distances ranging from 254 m to 300 m (0.91W to 0.96W; 0.66H to 0.78H; and 78T to 92T). The development of significant pressure head in the B-Zone indicate that the hydraulic connections between the A and B Zones are likely to be limited by compression arching across joints in the rock mass.

The piezometers in Borehole SPR39 also indicate that the Wolgan River Lineament fault dilation that occurred above LW411 has allowed Emergency Mine Water Discharges along East Wolgan Creek to penetrate into the strata to depths between 80 m and 140 m. It is noted by **Aurecon, 2009** that the water pooled within the B-Zone and allowed piezometric pressures to almost recover to pre-mining values. Despite the fault allowing surface waters to move deeper into the strata than they normally would have, the B-Zone has not been ‘connected’ directly to the A-Zone because of it.

Two sub-surface fracture height models (known as the Geometry and Geology Pi-Term models) have been developed by DgS over the past 12 to 18 months from a broad database of 34 case histories within the NSW Coalfields and two from the Bowen Basin in Queensland. The models include the panel width, cover depth, mining height and in the case of effective strata unit thickness to estimate heights of continuous (A-Zone) and Discontinuous fracturing (B-Zone) horizons.

The Geology Pi-Term model has been calibrated to the measured heights of fracturing using back analysis techniques to determine an effective B-Zone strata unit thickness of 42 m. The t’ value correlates well to (i) the 55 m thick sandstone noted in the bore logs above the measured A-Zone heights between 139 m and 145 m and (ii) the minimum inferred beam thickness range of 32 m to 40 m indicated by subsidence data (i.e. twice the Horizontal Strain to Curvature Ratio = the bending beam thickness).

The Geometry only Pi-Term model predicts similar outcomes to the Geology Pi-term model (+/-12%). It is considered the Geology model results are likely to be more reliable of the two models, as it has been calibrated to local strata conditions.

The predicted sub-surface fracture height outcomes for each of the proposed mining layouts based on the Geology Pi-Term Model is summarised below:

Springvale Mine's LWs 415 to 423

- predicted expected (mean) and credible worst-case (U95%CL) heights of continuous fracturing (i.e. the A-Zone) above the 315 m wide longwall panel (LW415) range between 145 m and 195 m (0.46W to 0.61W; 0.36H to 0.46H; and 45T to 60T).

- predicted expected (mean) and credible worst-case (U95%CL) heights of continuous fracturing (i.e. the A-Zone) above the 265 m wide longwall panels range between 124 m and 179 m (0.47W to 0.68W; 0.33H to 0.48H; and 38T to 55T).

- predicted credible worst-case (U95%CL) heights of discontinuous fracturing (i.e. the B-Zone) above all the 315 m wide longwall panels range between 258 m and 312 m (0.62W to 0.99W; 0.65H to 0.74H; and 79T to 96T).

- predicted credible worst-case (U95%CL) heights of discontinuous fracturing (i.e. the B-Zone) above all the 265 m wide longwall panels range between 224 m and 296 m (0.84W to 1.12W; 0.61H to 0.70H; and 69T to 91T).

Springvale Mine Extension Area LWs 424 to 432 and LWs 501 to 503

- predicted expected (mean) and credible worst-case (U95%CL) heights of continuous fracturing (i.e. the A-Zone) above the 229 m to 261 m wide longwall panels range between 85 m and 176 m (0.35W to 0.67W; 0.33H to 0.42H; and 26T to 54T).

- predicted credible worst-case (U95%CL) heights of discontinuous fracturing (i.e. the B-Zone) above all the 229 m to 261 m wide longwall panels range between 147 m and 293 m (0.60W to 1.1W; 0.71H to 0.82H; and 45T to 90T).

Angus Place Mine Extension Area LWs 1001 to 1019

- predicted expected (mean) and credible worst-case (U95%CL) heights of continuous fracturing (i.e. the A-Zone) above the 261 m wide longwall panels range between 111 m and 179 m (0.42W to 0.69W; 0.32H to 0.52H; and 34T to 55T).

- predicted expected (mean) and credible worst-case (U95%CL) heights of continuous fracturing (i.e. the A-Zone) above the 293 m wide longwall panels range between 131 m and 190 m (0.44W to 0.65W; 0.33H to 0.49H; and 40T to 58T).

- predicted expected (mean) and credible worst-case (U95%CL) heights of continuous fracturing (i.e. the A-Zone) above the 360 m wide longwall panels range between 124 m and 207 m (0.34W to 0.58W; 0.37H to 0.6H; and 38T to 64T).

- predicted credible worst-case (U95%CL) heights of discontinuous fracturing (i.e. the B-Zone) above all the 261 m wide longwall panels range between 198 m and 299 m (0.75W to 1.14W; 0.57H to 0.83H; and 61T to 92T).

- predicted credible worst-case (U95%CL) heights of discontinuous fracturing (i.e. the B-Zone) above all the 293 m wide longwall panels range between 233 m and 310 m (0.79W to 0.94W; 0.78H to 0.85H; and 72T to 95T).

- predicted credible worst-case (U95%CL) heights of discontinuous fracturing (i.e. the B-Zone) above all the 360 m wide longwall panels range between 206 m and 323 m (0.57W to 0.90W; 0.65H to 0.90H; and 63T to 99T).

The predictions for the future mining areas indicate that the A-Zone is likely to occur up to the Upper Caley Sandstone and possibly the Burro-Moko Head Sandstone. The Upper 95%CL A and B-Zones are also contained within the above units.

Except for the proposed Springvale Mine Extension Area LWs 501 to 503, the U95% CL for the B-Zone will develop into the Banks Walls Sandstone and is likely to be below the Burralow Formation. The B-Zone above the LWs 501 to 503 may intersect with the Surface Cracking Zone (D-Zone). It is understood however, that there are now surface water or shrub swamp features of significance above these panels.

It is recommended that a subsurface fracturing monitoring program that includes borehole extensometers and groundwater piezometers during the extraction of the panels be implemented with a view to monitor groundwater and surface alluvium response for after single seam and multi-seam mining conditions.

It is understood that the mine also intends to complete an investigation drilling program to establish the existence of the B-Zone. Camera inspections and geophysics logging of dry and wet holes may allow the bedding separation and or shear zones to be detected and allow the measurement of the effective beam thickness development in the B-Zone.

## 9.0 References

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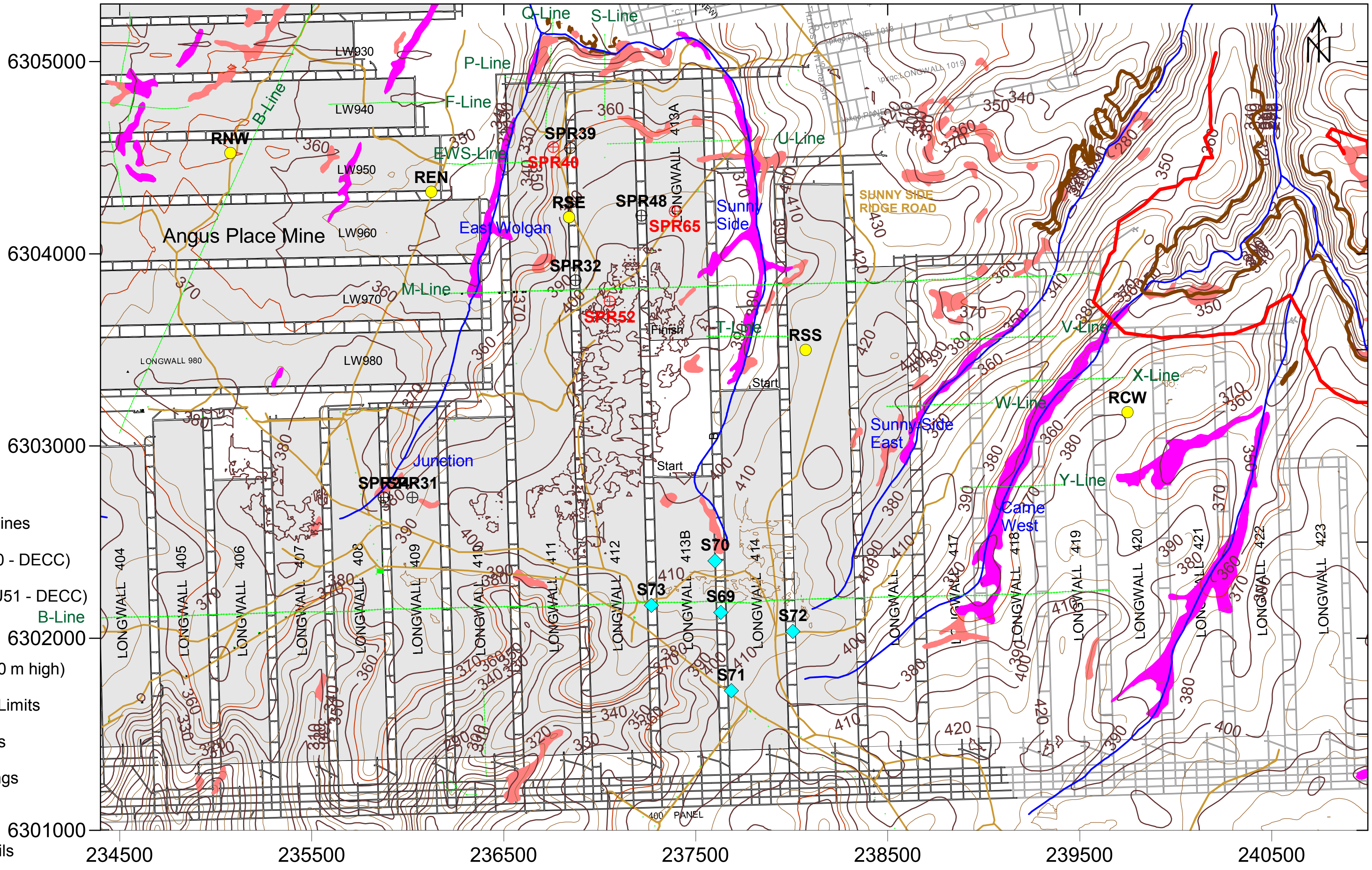
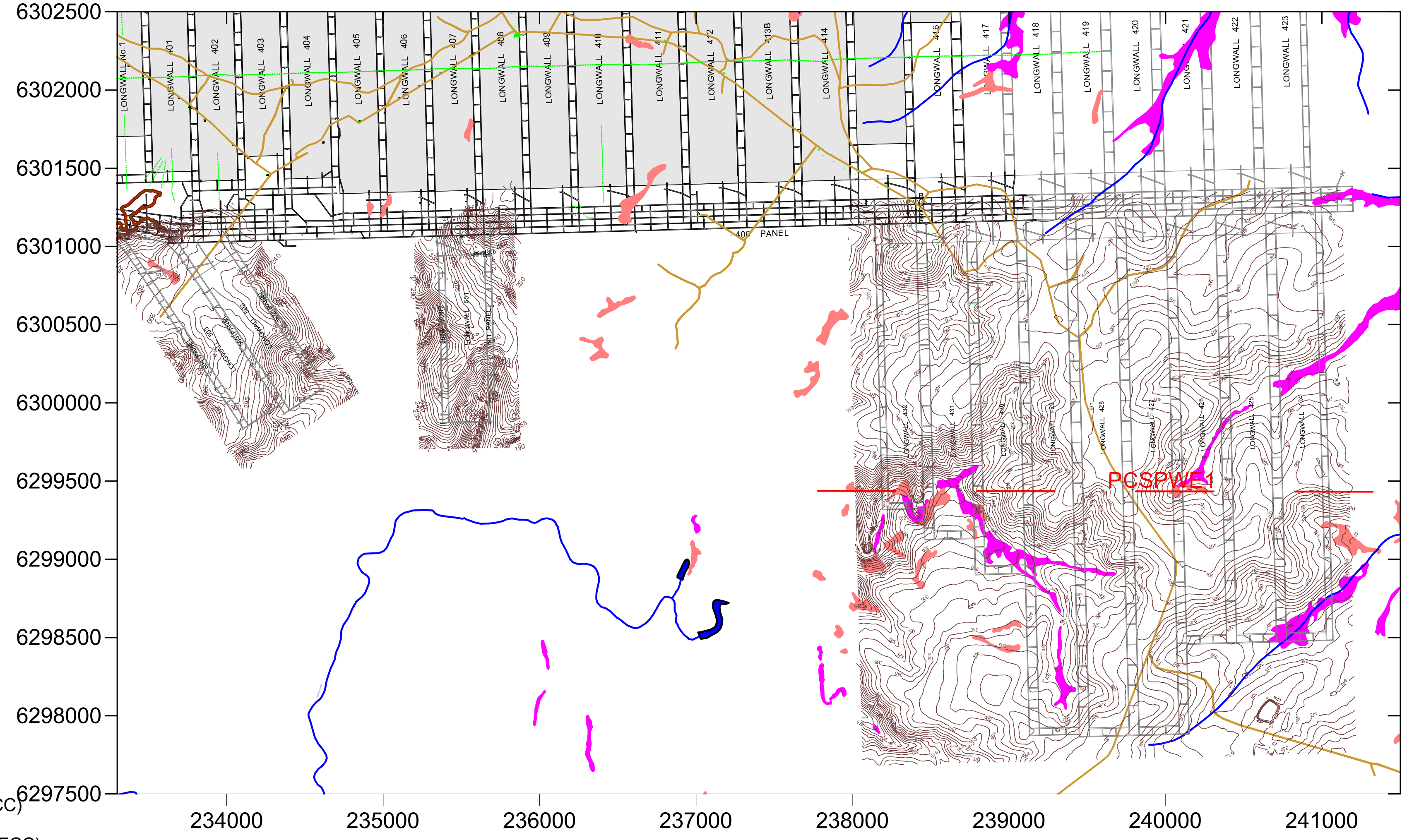


Key

- Cover Depth (m)
- Existing Subsidence Lines
- Shrub Swamps (MU50 - DECC)
- Hanging Swamps (MU51 - DECC)
- Creeks
- Rock Formations (5-20 m high)
- Design Cliff Set Back Limits
- Existing mine workings
- Proposed mine workings
- ▭ Extracted longwall
- NSW Forests Fire Trails
- ⊕ Borehole Extensometer
- ⊕ Vibrating Wire Piezometer
- ● Standpipe Piezometer
- ◆ Microseismic Geophones

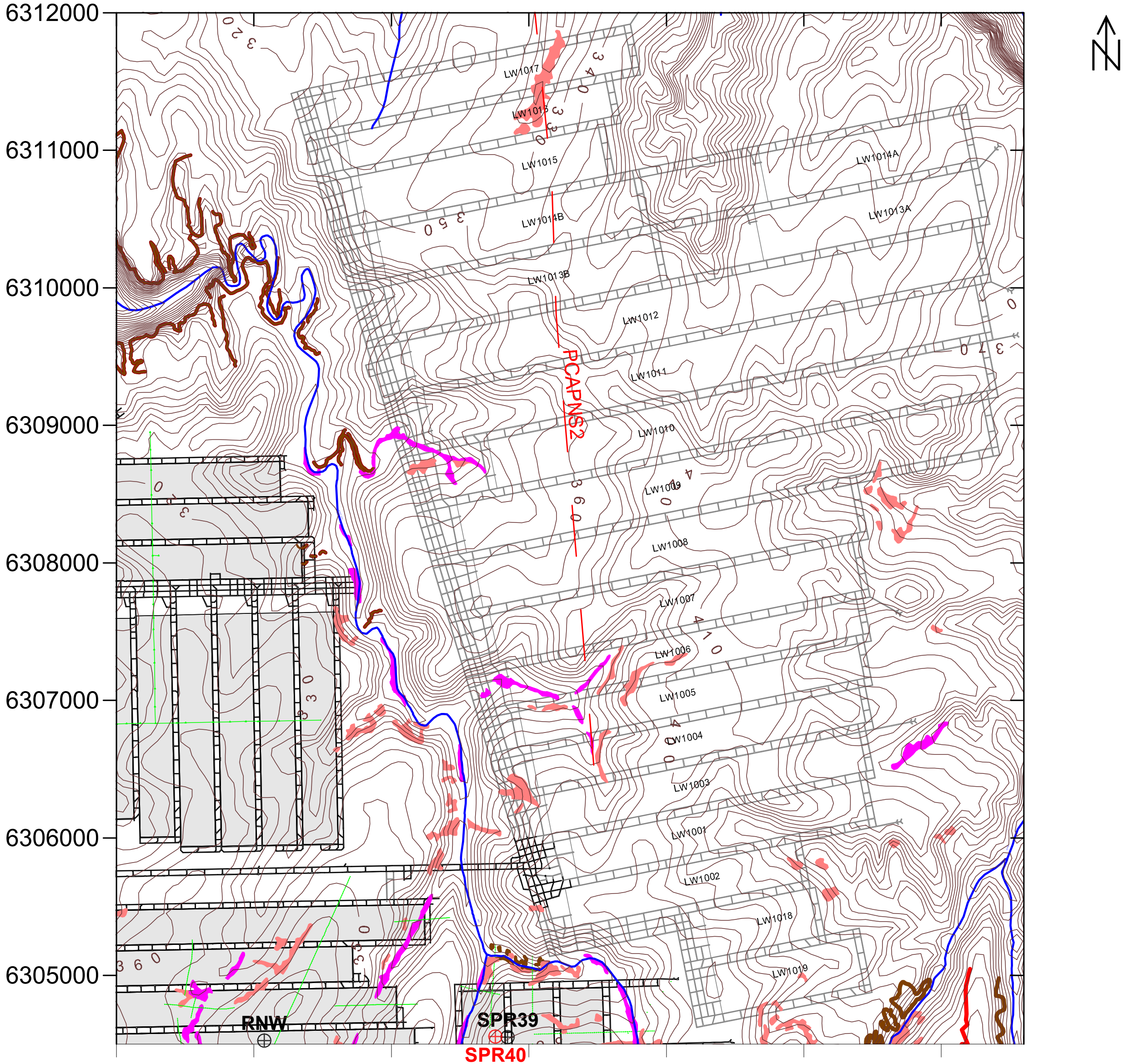
| | | | |
|---|---|---|---|
| DgS | Engineer: S.Ditton | Client: | Centennial Springvale<br>SPV-003/7b |
| | Drawn: S.Ditton | | |
| | Date: 17.08.14 | Title: | Cover Depth Contours and Borehole Monitoring Locations above the Springvale Mine Longwalls 404 to 423 |
| | Ditton Geotechnical Services Pty Ltd | Scale: | 1:30,000 |
| | | Figure No: | 1a |



Key

- Cover Depth (m)
- Existing Subsidence Lines
- Shrub Swamps (MU50 - DECC)
- Hanging Swamps (MU51 - DECC)
- Creeks
- Rock Formations (5-20 m high)
- Existing mine workings
- Proposed mine workings
- ▭ Extracted longwall
- NSW Forests Fire Trails
- Stratigraphy Cross Section

| | | | | |
|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Centennial Springvale<br>SPV-003/7b |
| | Drawn: | S.Ditton | | |
| | Date: | 17.08.14 | Title: | Cover Depth Contours above the Proposed Springvale Mine Extension Project Area Longwalls 424 to 432 & 501 to 503 |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | 1:40,000 |
| | | | Figure No: | 1b |



Key

| | |
|---|---|
| — | Cover Depth (m) |
| — | Existing Subsidence Lines |
| ⬟ | Shrub Swamps (MU50 - DECC) |
| ⬟ | Hanging Swamps (MU51 - DECC) |
| ~ | Creeks |
| ~ | Rock Formations (5-20 m high) |
| — | Existing mine workings |
| — | Proposed mine workings |
| ▭ | Extracted longwall |
| — | NSW Forests Fire Trails |
| ⊕ | Borehole Extensometer or Piezometer |
| - - | Stratigraphy Cross Section |

DgS

| | | | |
|---|---|---|---|
| Engineer: | S.Ditton | Client: | Centennial Springvale<br>SPV-003/7b |
| Drawn: | S.Ditton | | |
| Date: | 17.08.14 | Title: | Cover Depth Contours and Proposed Mining Layout in the Angus Place Extended Project Area |

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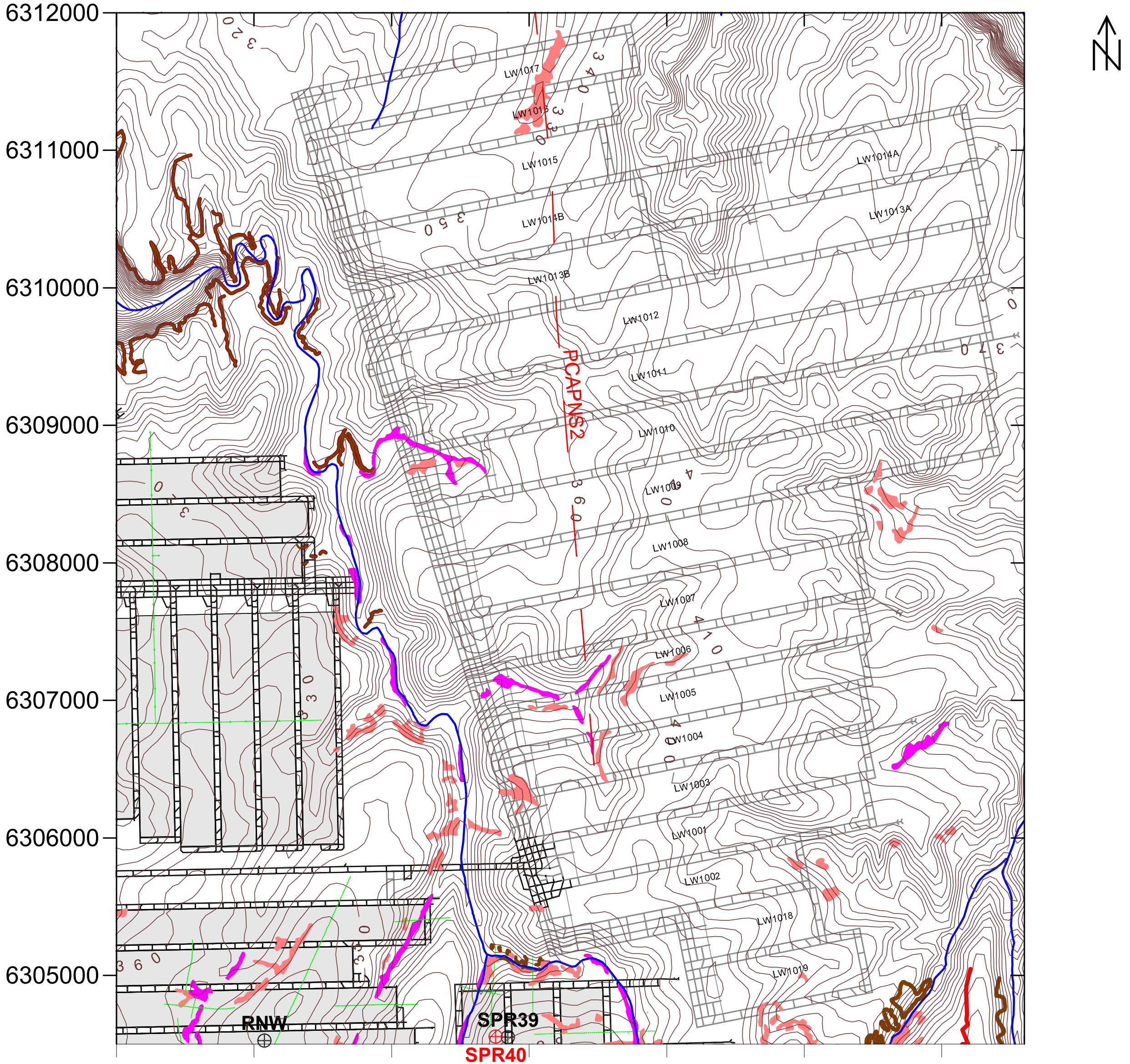
Scale: 1:50,000

Figure No: 1c



Key

- Cover Depth (m)
- Existing Subsidence Lines
- Shrub Swamps (MU50 - DECC)
- Hanging Swamps (MU51 - DECC)
- Creeks
- Rock Formations (5-20 m high)
- Existing mine workings
- Proposed mine workings
- Extracted longwall
- NSW Forests Fire Trails
- ⊕ Borehole Extensometer or Piezometer
- Stratigraphy Cross Section

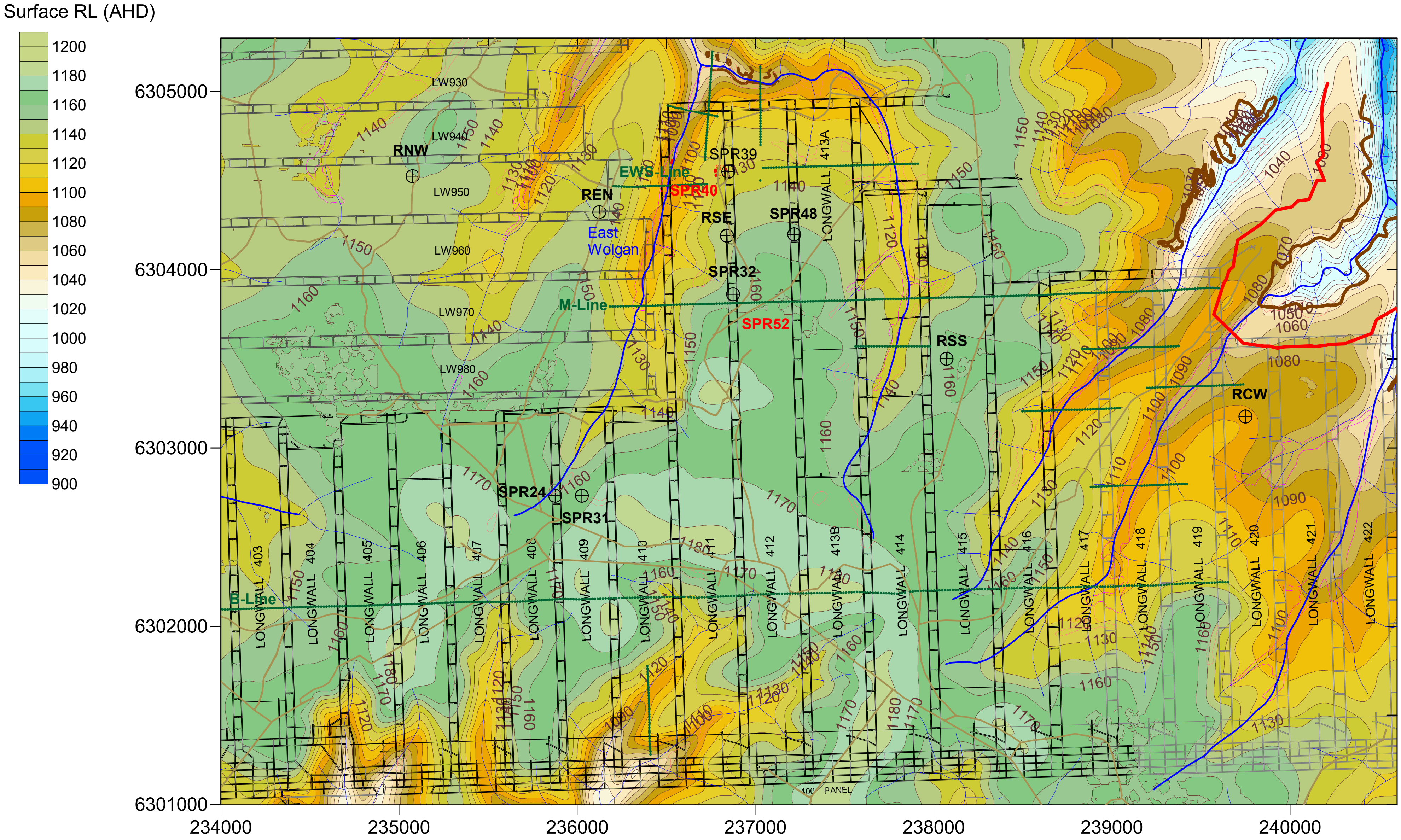
**DgS**

| | | | |
|---|---|---|---|
| Engineer: | S.Ditton | Client: | Centennial Springvale<br>SPV-003/7b |
| Drawn: | S.Ditton | | |
| Date: | 17.08.14 | Title: | Cover Depth Contours and Proposed Angus Place Mine Extension Project Area Longwalls 1001 to 1019 |

Ditton Geotechnical Services Pty Ltd

Scale: 1:50,000

Figure No: 1c

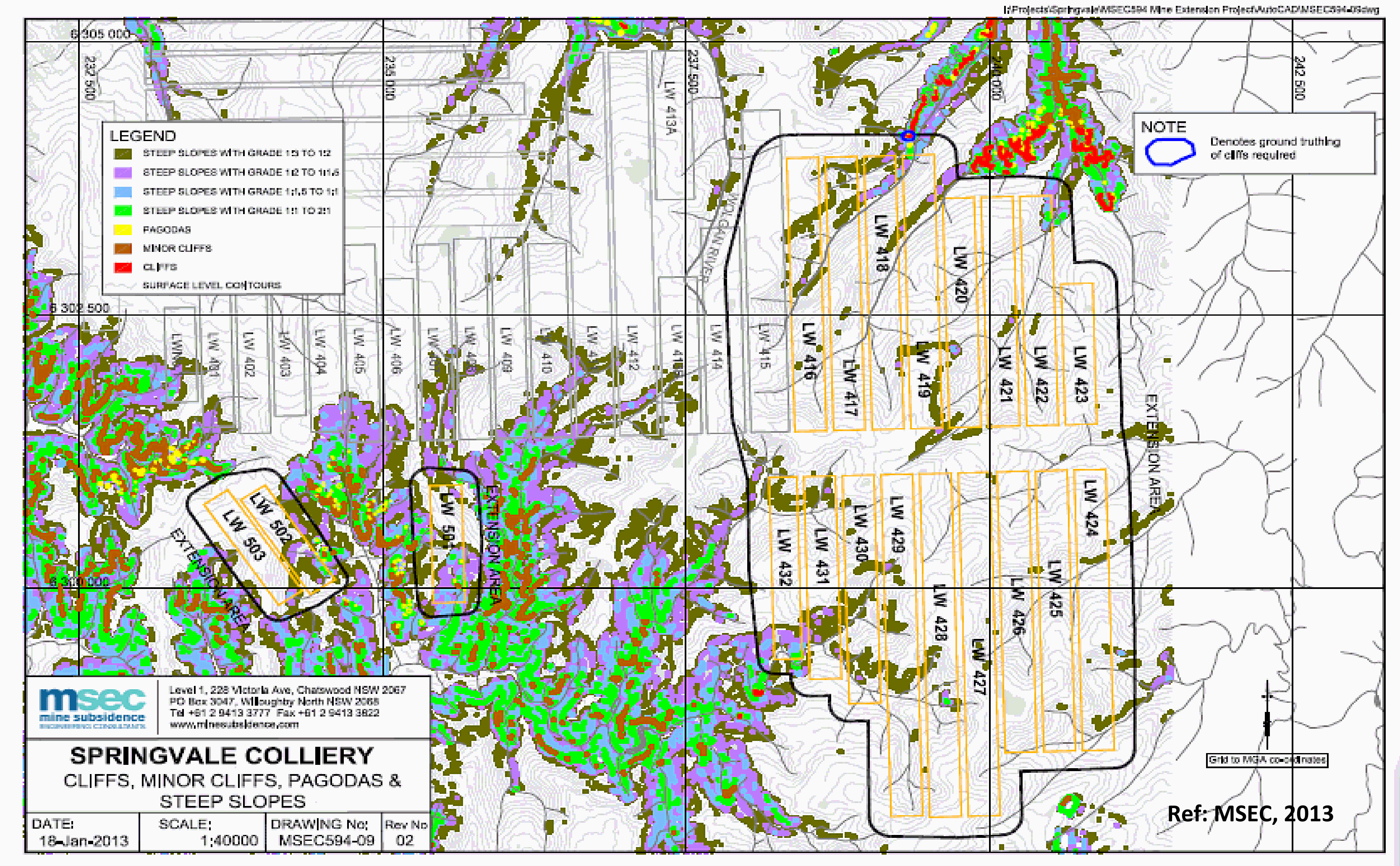


Key

● Borehole Extensometer

⊕ Borehole VW Piezometer/
Screened Well (Stand Pipe)

| | | | | |
|---|---|---|---|---|
| DgS<br>Ditton Geotechnical Services Pty Ltd | Engineer: | S.Ditton | Client: | Centennial Springvale<br>SPV-003/7b |
| | Drawn: | S.Ditton | Title: | Surface Level Contours and Borehole Extensometers / Piezometers Locations above the Existing Springvale and Angus Place Longwall Mines |
| | Date: | 17.08.14 | Scale: | 1:30,000 |
| | | | Figure No: | 2a |



Ref: MSEC, 2013

DgS

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| | | | |
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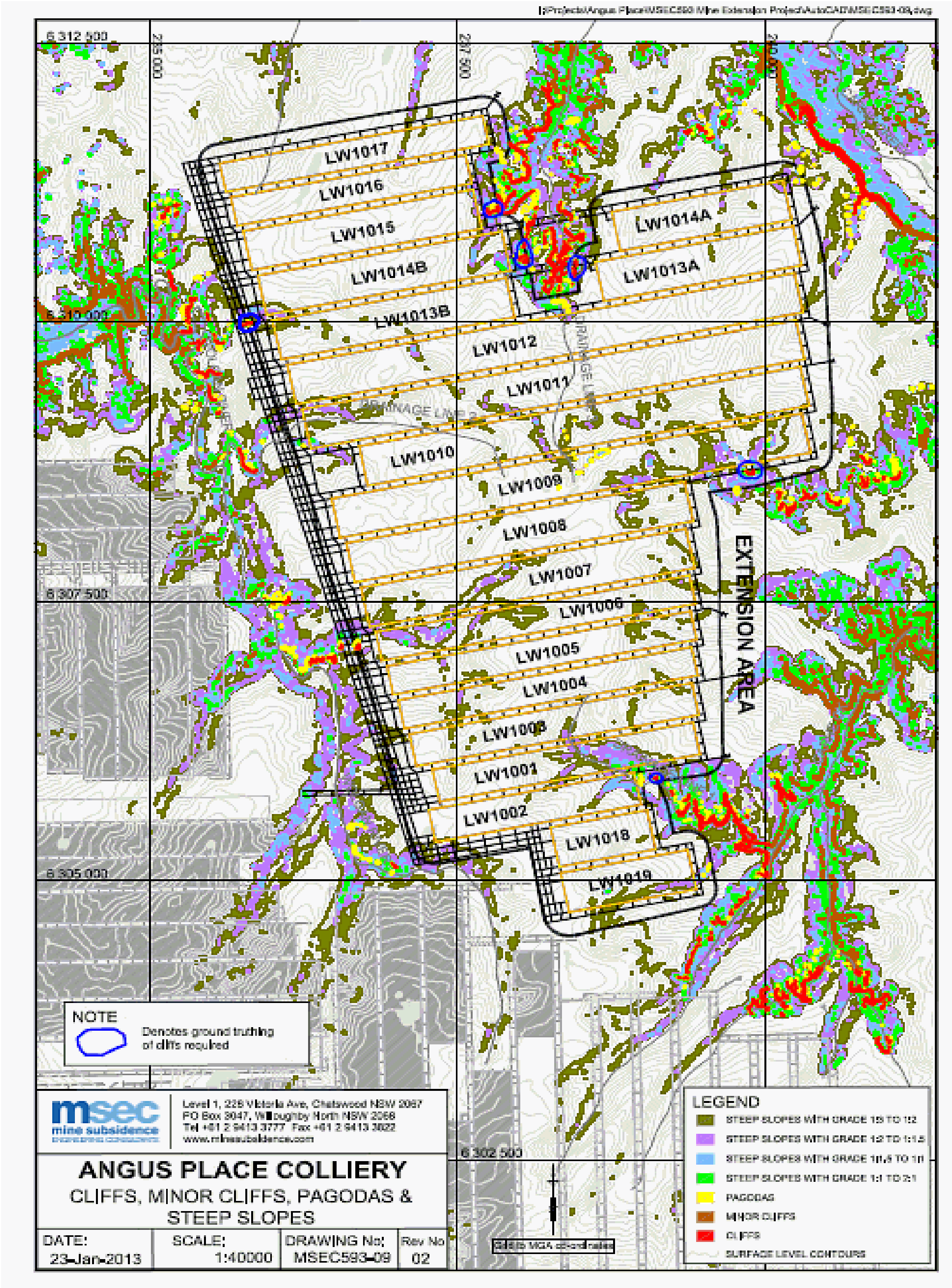
| Drawn: | S.Ditton | | |
| Date: | 15.10.13 | Title: | Surface features and Level Contours above the Proposed Springvale Mine Extension Area LWs 416 to 432 |
| | | Scale: | NTS |
| | | Figure No: | 2b |



**Ref: MSEC, 2013**

| | | | | | | |
|---|---|---|---|---|---|---|
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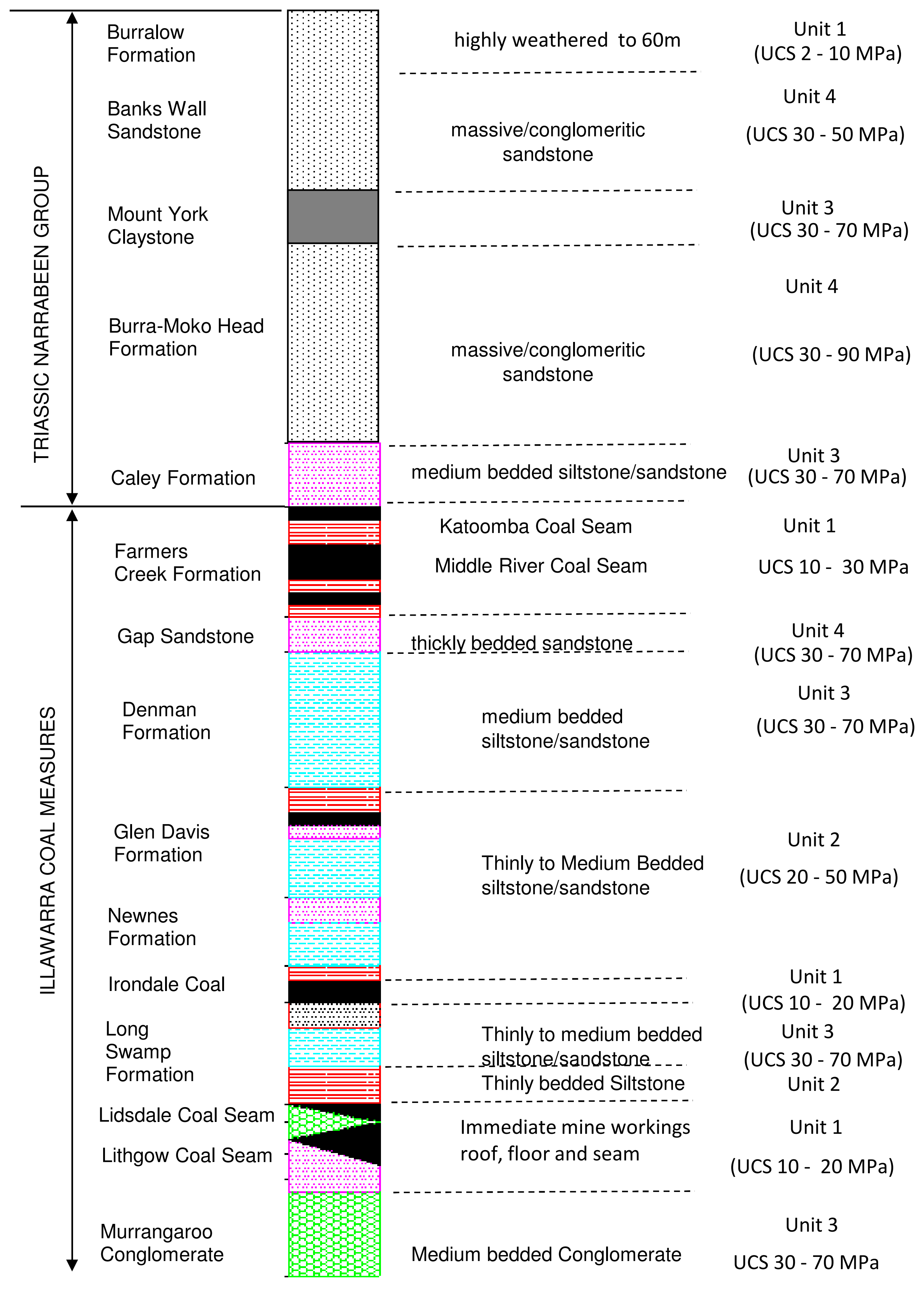
| | Drawn: | S.Ditton | | SPV-003/7b | | |
| | Date: | 28.08.14 | Title: | Surface Features & Level Contours above the Proposed Angus Place Mine Extension Area | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | 2c |



| | | | | | |
|---|---|---|---|---|---|
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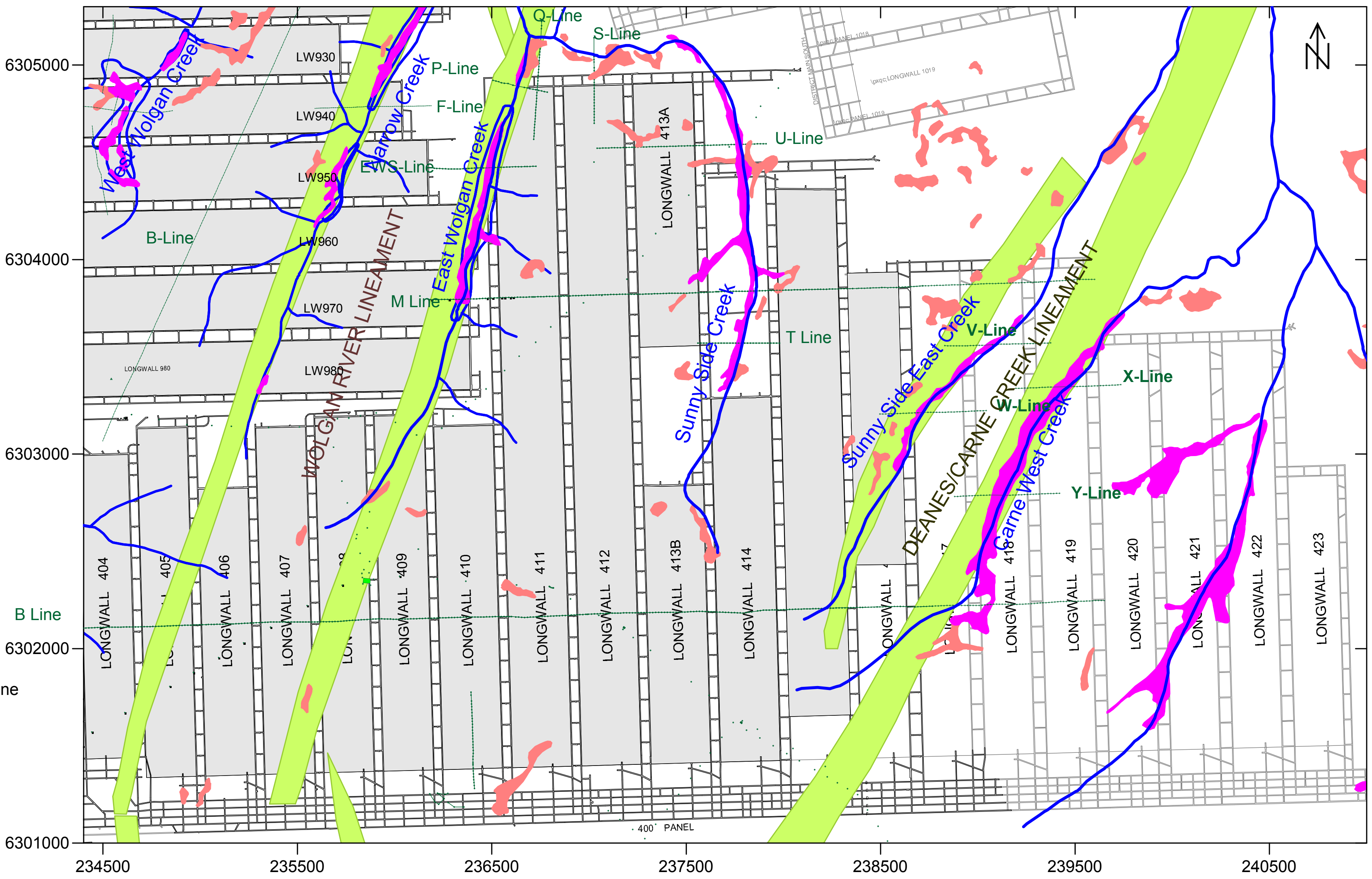
| Drawn: | S.Ditton | | | | |
| Date: | 22.08.14 | Title: | Typical Overburden Stratigraphy above the Project Areas | | |
| Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | 3a |



Key:

| | |
|---|---|
| ▰ | Type 1 Structure Zone (see Palaris, 2013) |
| — | Watercourses |
| ⬟ | Shrub Swamps (MU50 - DECC) |
| ▼ | Hanging Swamps (MU51 - DECC) |
| — | Cliff lines (>20 m high) |
| — | Rock Formations (5 - 20 m) |
| ▨ | Extracted Longwall Blocks |
| ☐ | Proposed Longwalls |
| — | Installed Subsidence Lines |

DgS

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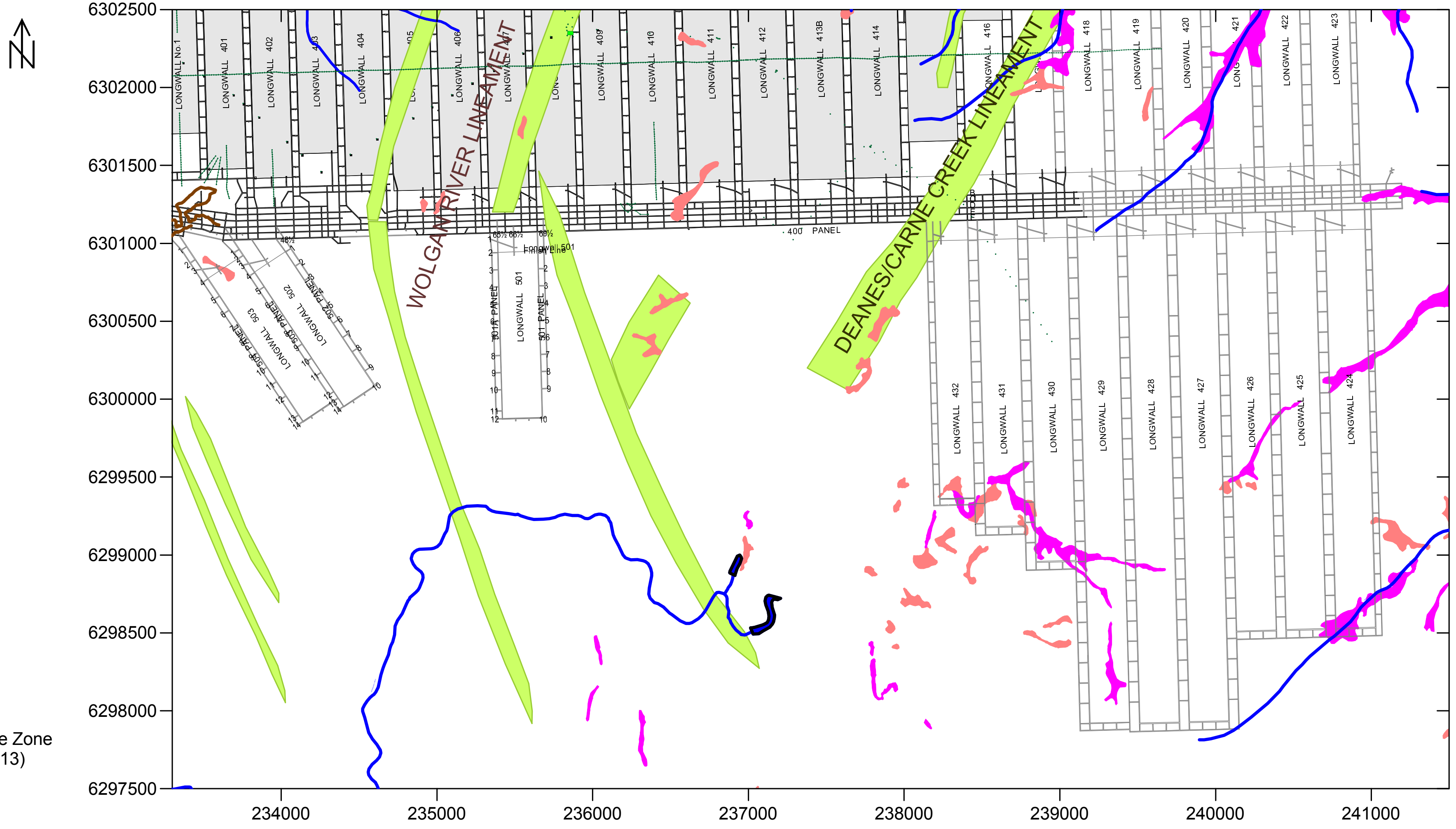
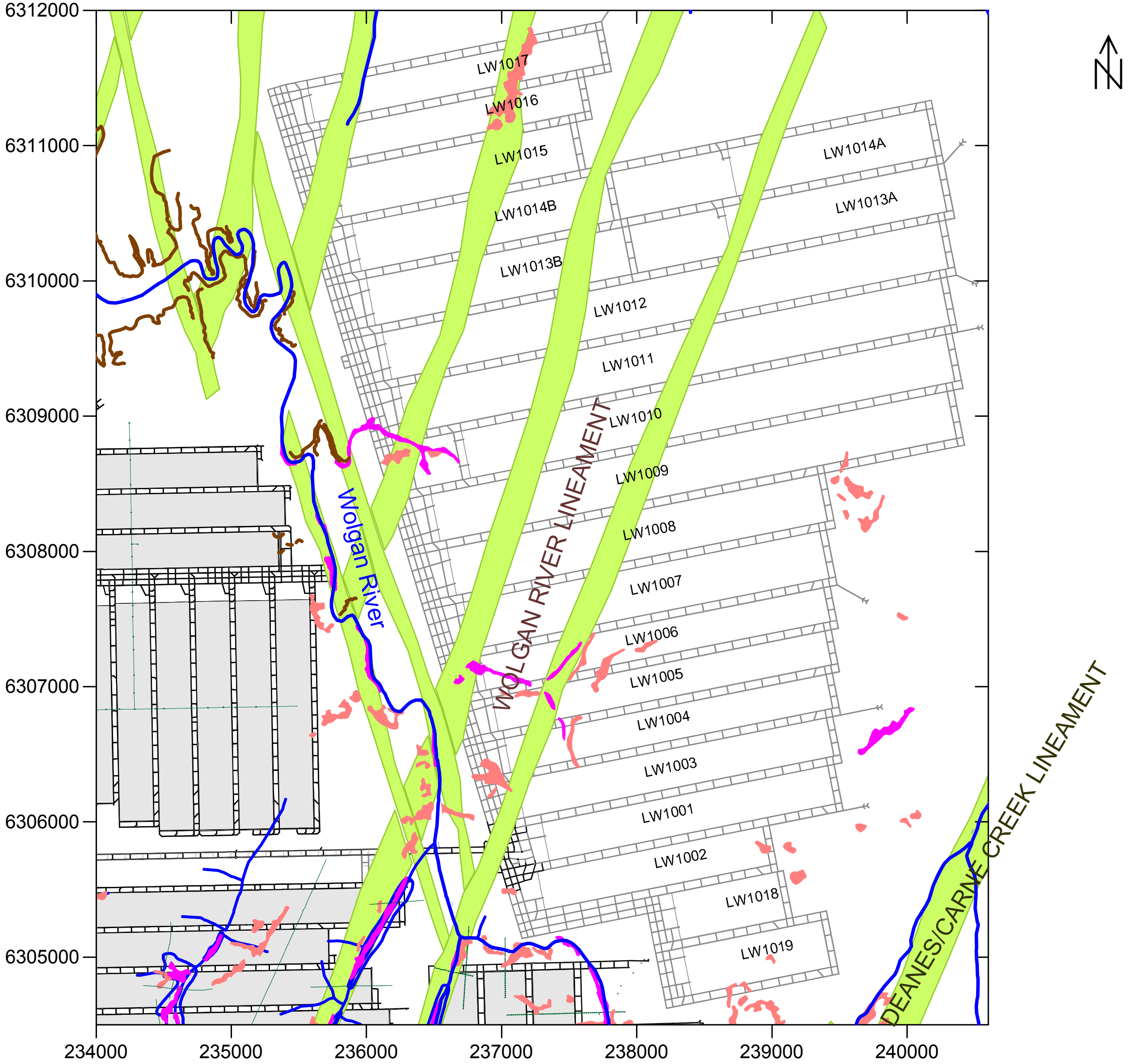
| | | | |
|---|---|---|---|
| Engineer: | S.Ditton | Client: | Centennial Springvale Coal<br>SPV-003/7b |
| Drawn: | S.Ditton | Title: | Interpreted/Mapped Geological Structure above the Springvale and Angus Place Mines |
| Date: | 09.04.13 | Scale: | 1:30,000 |
| | | Figure No: | 3b |



Key:

- 🟩 Type 1 Structure Zone (see Palaris, 2013)
- ― Watercourses
- ▰ Shrub Swamps (MU50 - DECC)
- ▼ Hanging Swamps (MU51 - DECC)
- ― Cliff lines (>20 m high)
- ― Rock Formations (5 - 20 m)
- ▭ Extracted Longwall Blocks
- ☐ Proposed Longwalls
- ― Installed Subsidence Lines

| | | | |
|---|---|---|---|
| DgS | Engineer: S.Ditton | Client: | Centennial Springvale Coal<br>SPV-003/7b |
| | Drawn: S.Ditton | | |
| | Date: 22.08.14 | Title: | Interpreted/Mapped Geological Structure above the Proposed Springvale Mine Extension Project Area LWs 424 to 432 & 501 to 503 |
| | Ditton Geotechnical Services Pty Ltd | Scale: | 1:40,000 |
| | | Figure No: | 3c |



Key:

| | |
|---|---|
| 🟩 | Type 1 Structure Zone<br>(see Palaris, 2013) |
| — | Watercourses |
| ⬟ | Shrub Swamps<br>(MU50 - DECC) |
| ▼ | Hanging Swamps<br>(MU51 - DECC) |
| — | Cliff lines (>20 m high) |
| — | Rock Formations (5 - 20 m) |
| ▨ | Extracted Longwall Blocks |
| ☐ | Proposed Longwalls |
| — | Installed Subsidence Lines |

DgS

Engineer: S.Ditton
Drawn: S.Ditton
Date: 22.08.14

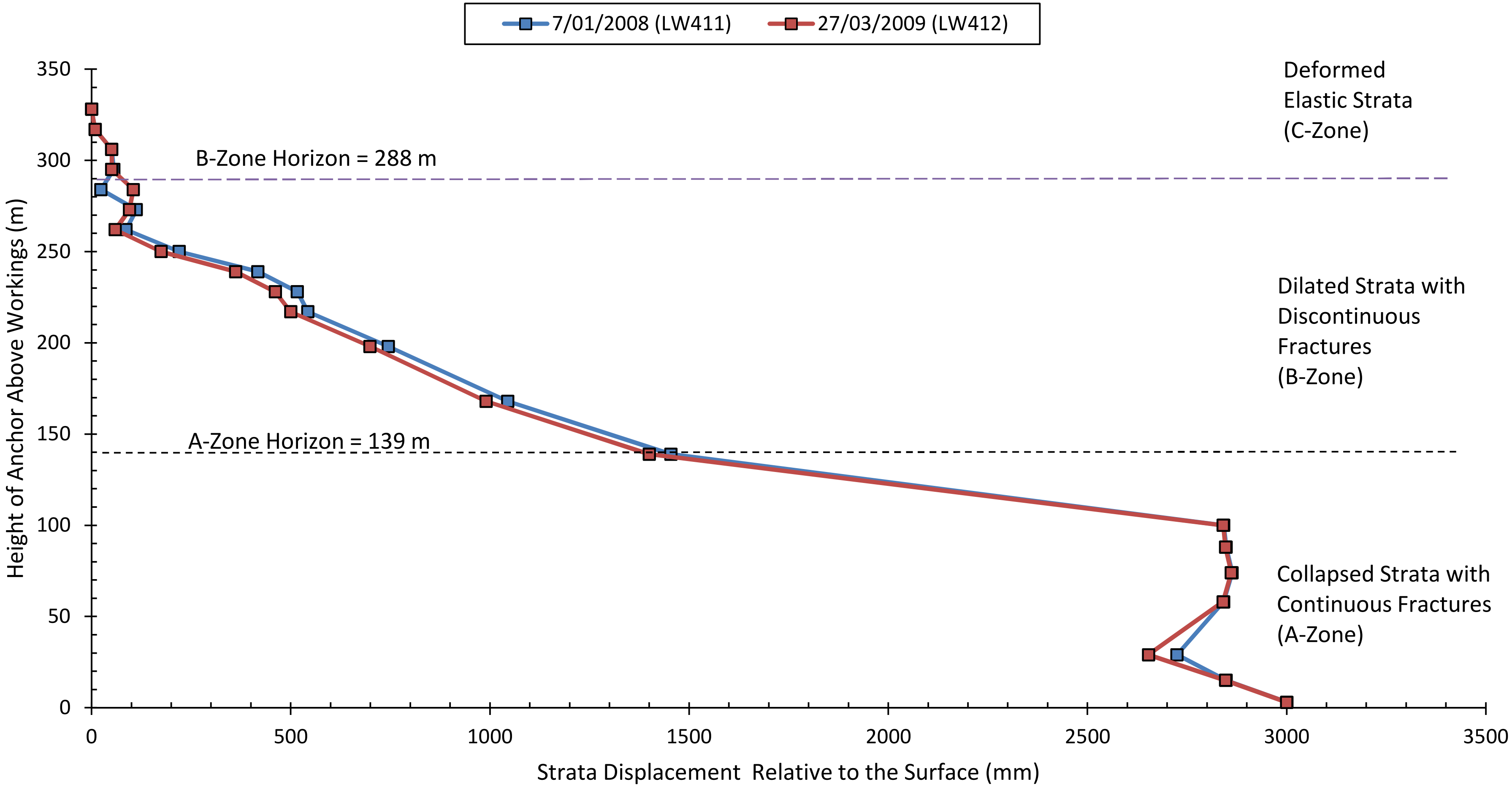
Ditton Geotechnical
Services Pty Ltd

Client: Centennial Springvale Coal
SPV-003/7b

Title: Interpreted/Mapped Geological Structure above the Proposed
Angus Place Mine Extension Project Area LWs 1001 to 1019

Scale: 1:50,000

Figure No: 3d



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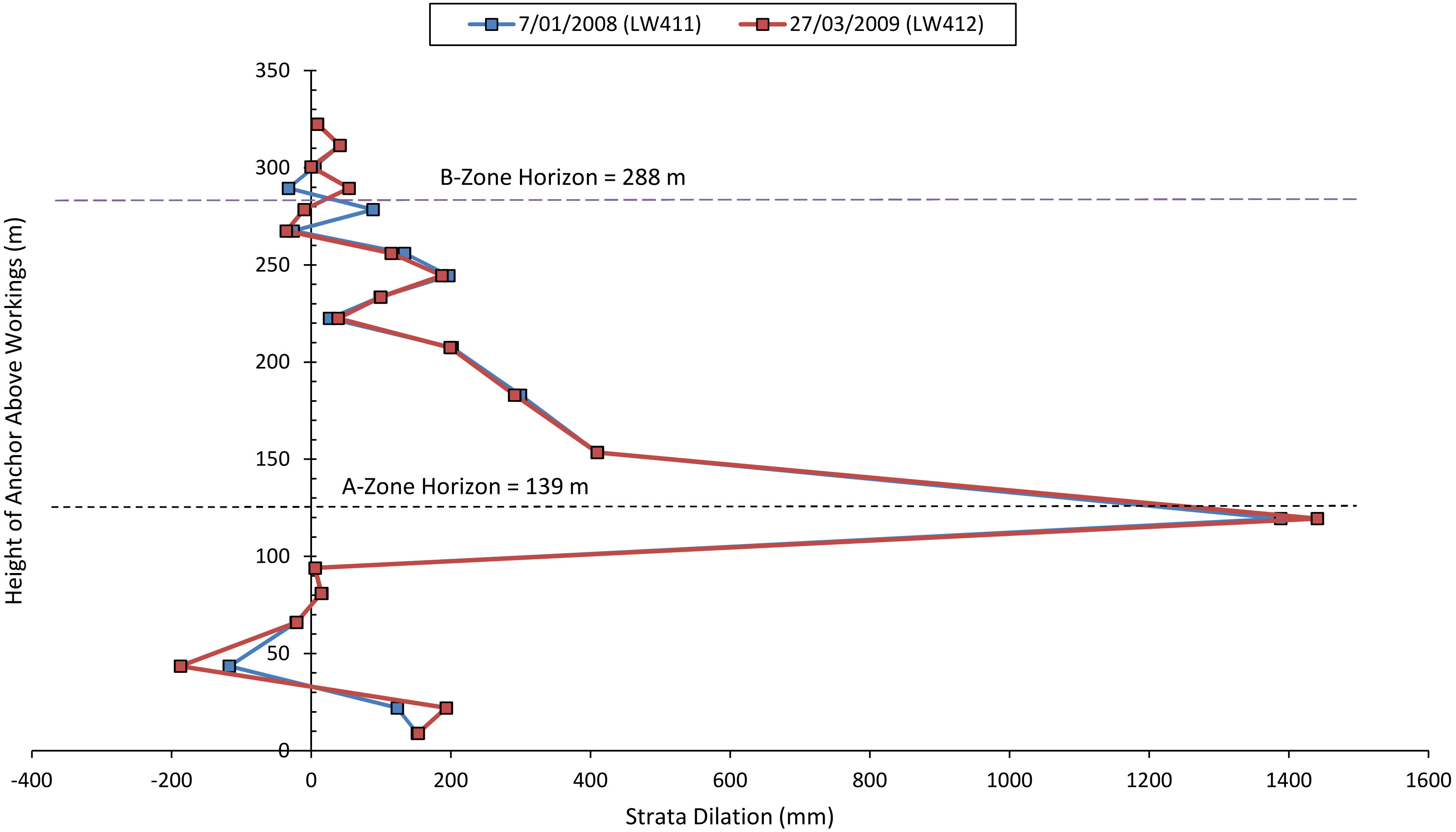
| | Drawn: | S.Ditton | | | |
| | Date: | 26.08.14 | Title: | Measured Strata Displacement Relative to Surface in SPR40 (LW411) | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: 4a |



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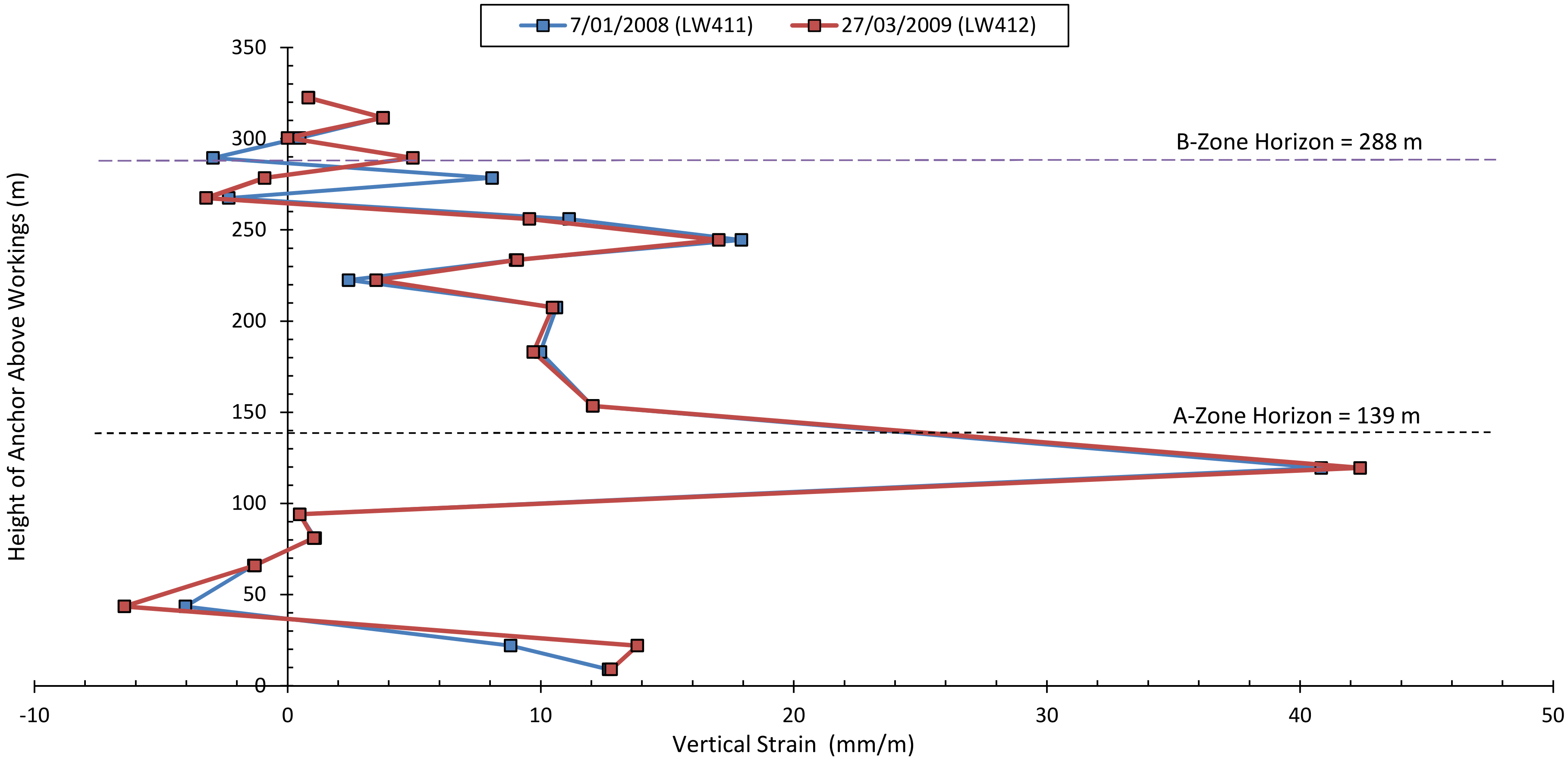
| | Drawn: | S.Ditton | | | |
| | Date: | 26.08.14 | Title: | Measured Strata Displacement Relative to Surface in SPR40 (LW411) | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: 4b |



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|---|---|---|---|---|---|
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| | Drawn: | S.Ditton | | | |
| | Date: | 26.08.14 | Title: | Measured Strata Displacement Relative to Surface in SPR40 (LW411) | |
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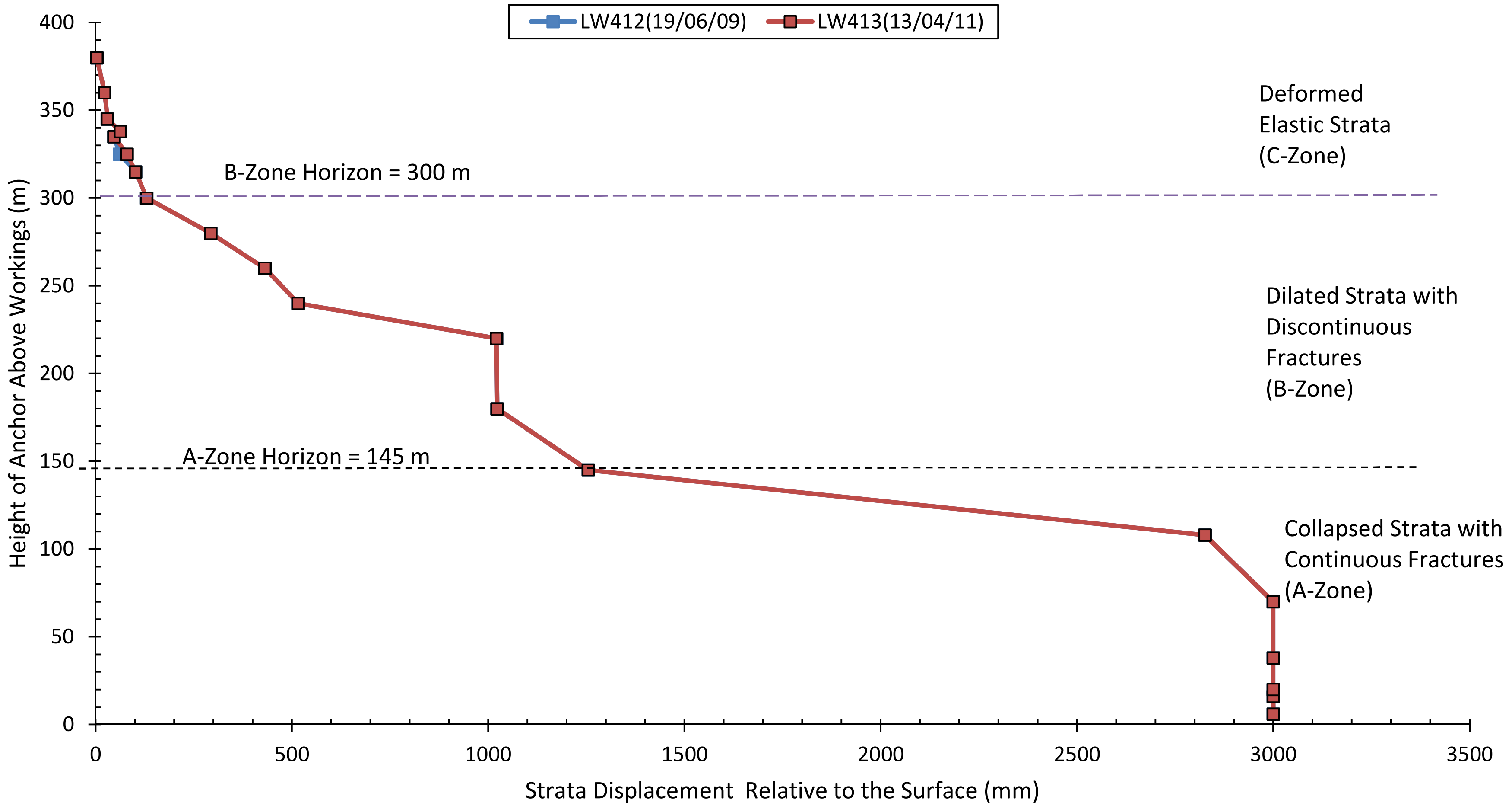

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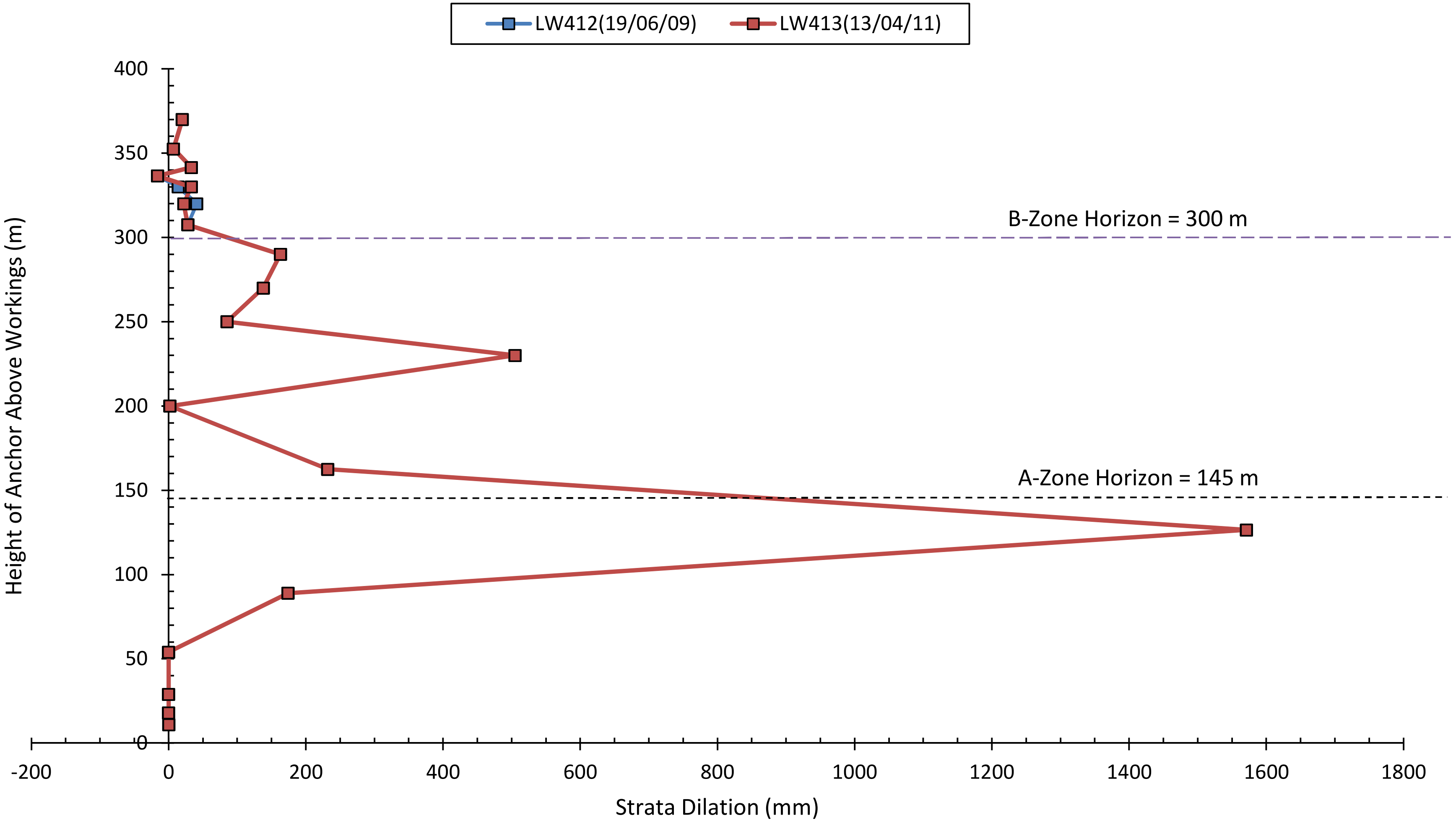
|---|---|---|---|---|---|
| Engineer: | S.Ditton | Client: | Centennial Springvale Coal Pty Ltd<br>SPV-003/7b | | |
| Drawn: | S.Ditton | | | | |
| Date: | 26.08.14 | Title: | Measured Strata Displacement Relative to Surface in SPR52 (LW412) | | |
| Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | 4d |



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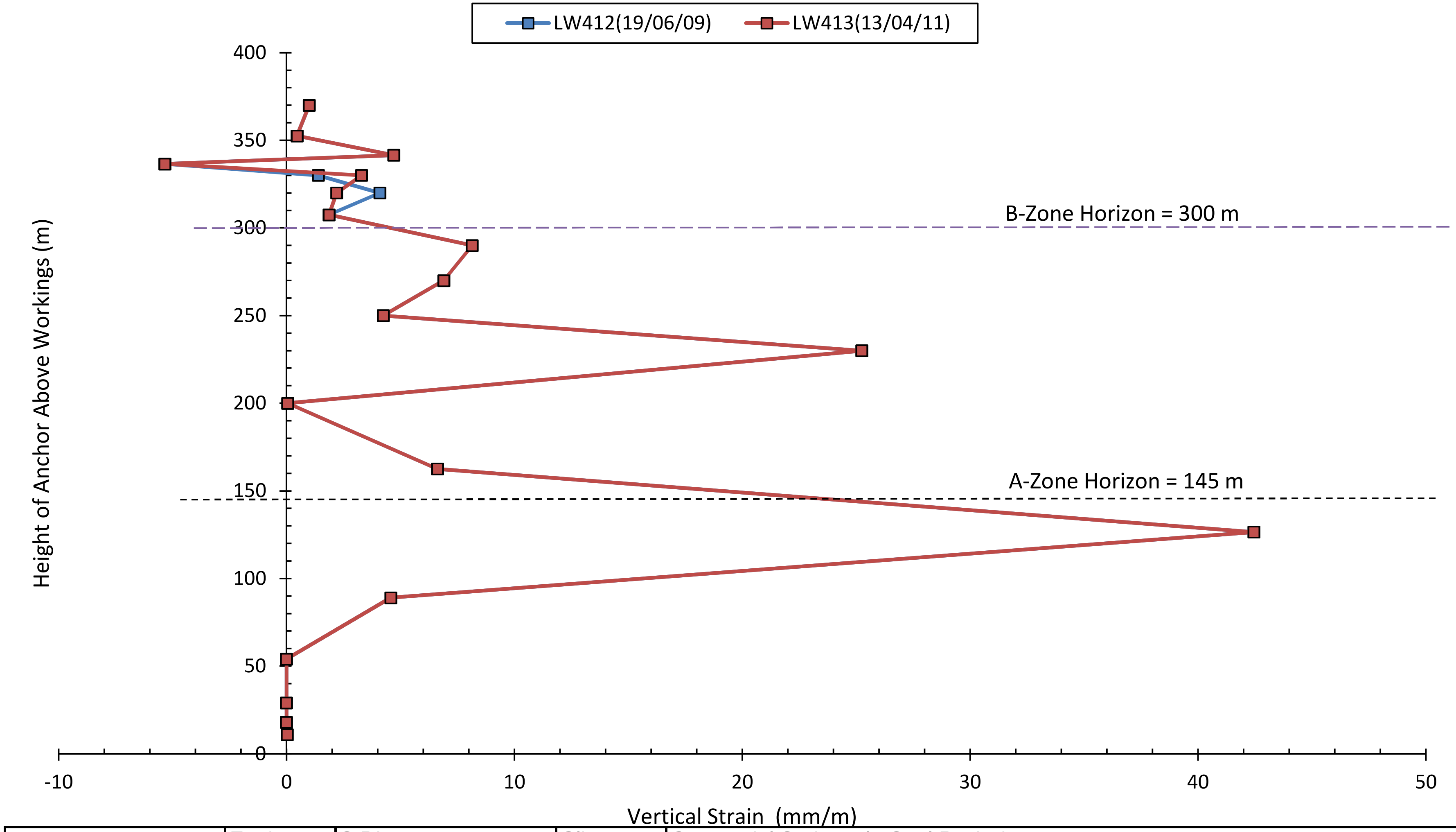
| DgS | Engineer: | S.Ditton | Client: | Centennial Springvale Coal Pty Ltd<br>SPV-003/7b |
| | Drawn: | S.Ditton | | |
| | Date: | 26.08.14 | Title: | Measured Strata Displacement Relative to Surface in SPR52 (LW412) |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS |
| | | | Figure No: | 4e |



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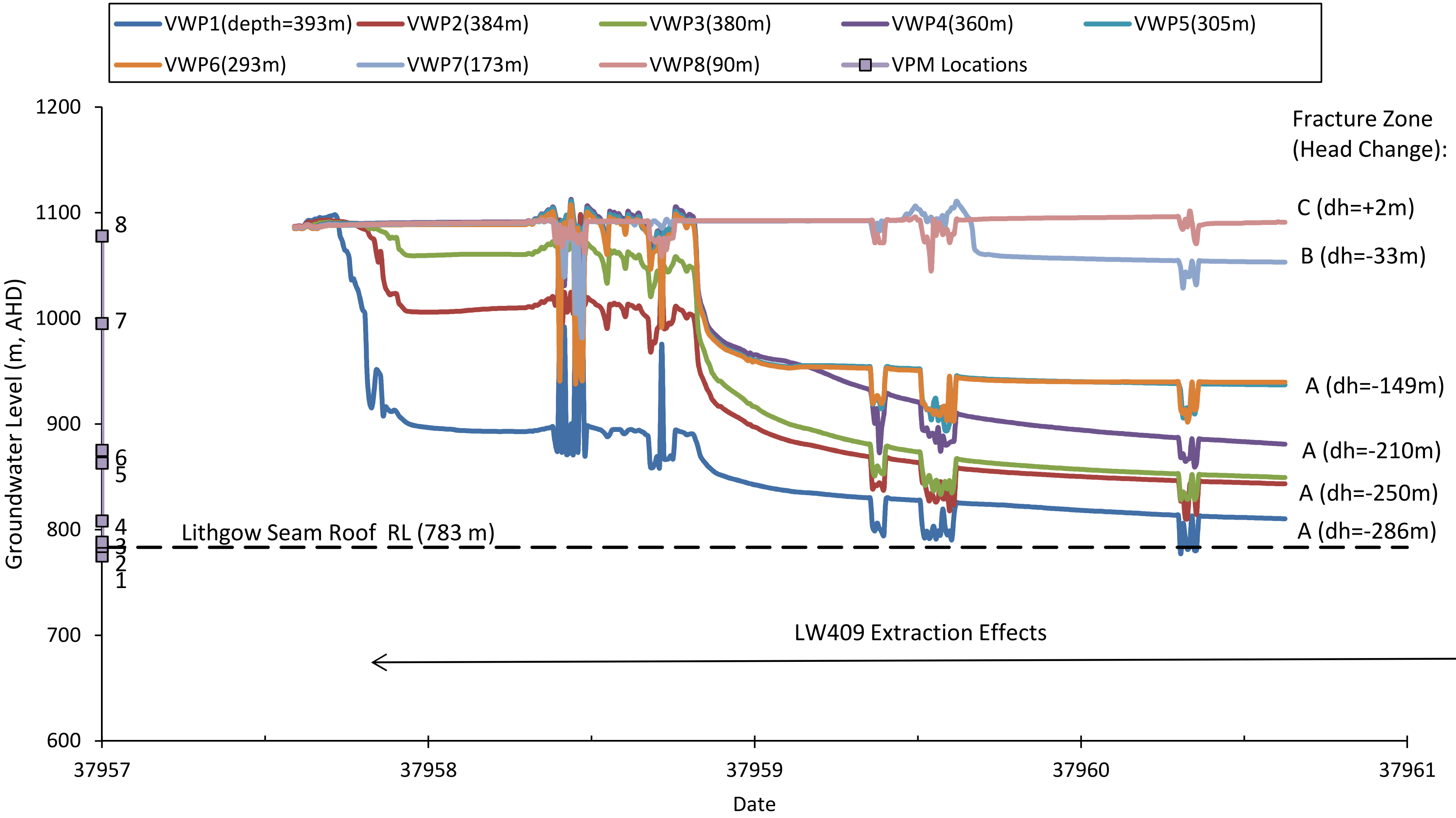
| | Drawn: | S.Ditton | | | |
| | Date: | 26.08.14 | Title: | Measured Strata Displacement Relative to Surface in SPR52 (LW412) | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: 4f |



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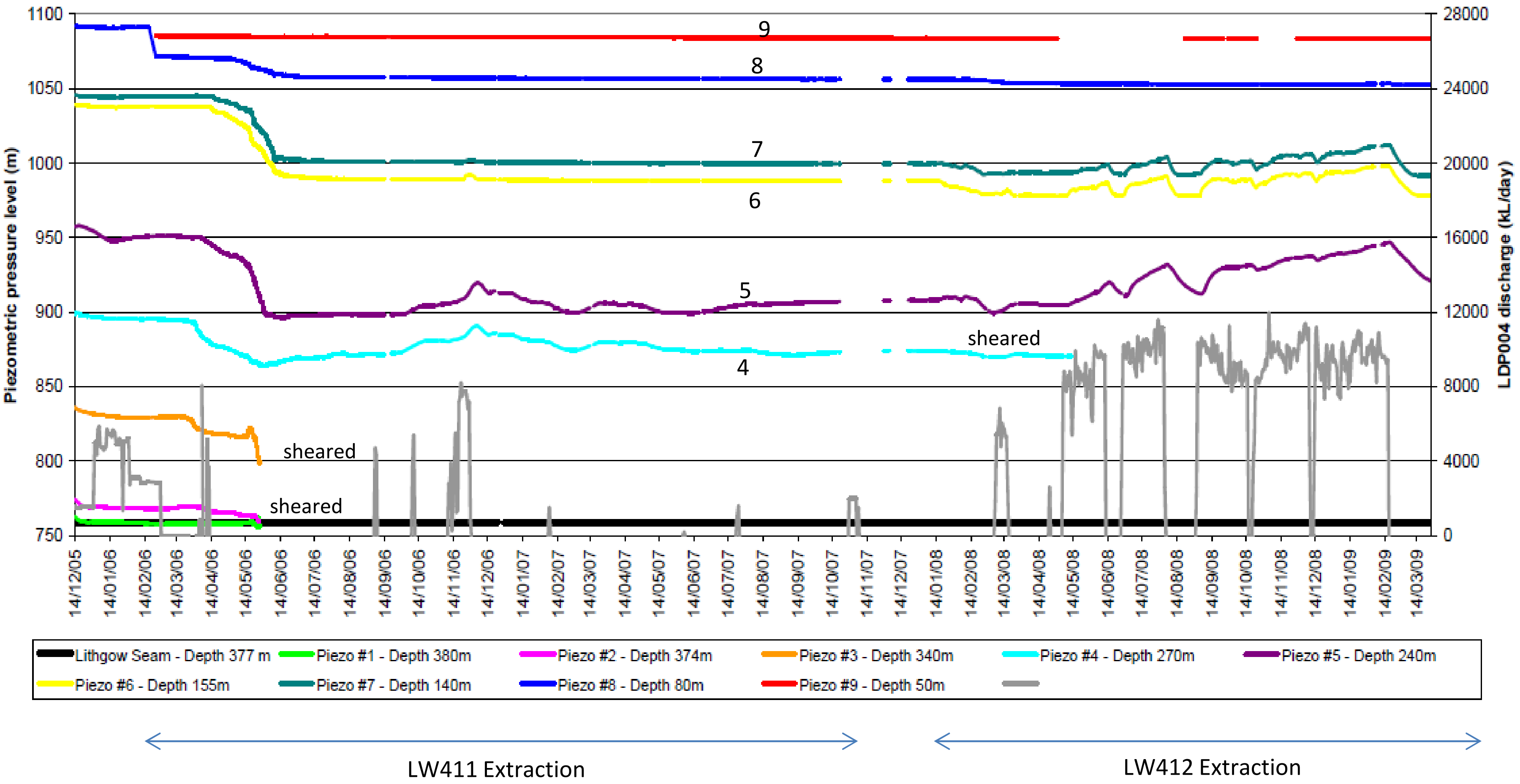
|---|---|---|---|
| Engineer: | S.Ditton | Client: | Centennial Springvale Coal Pty Ltd<br>SPV-003/7b |
| Drawn: | S.Ditton | | |
| Date: | 26.08.14 | Title: | Measured Piezometric Response to LW409 (SPR 31) |
| Ditton Geotechnical Services Pty Ltd | | Scale: | NTS |
| | | Figure No: | 5a |

ref: Aurecon, 2009

Figure 24 - SPR 39 Elevation Head of Piezometers



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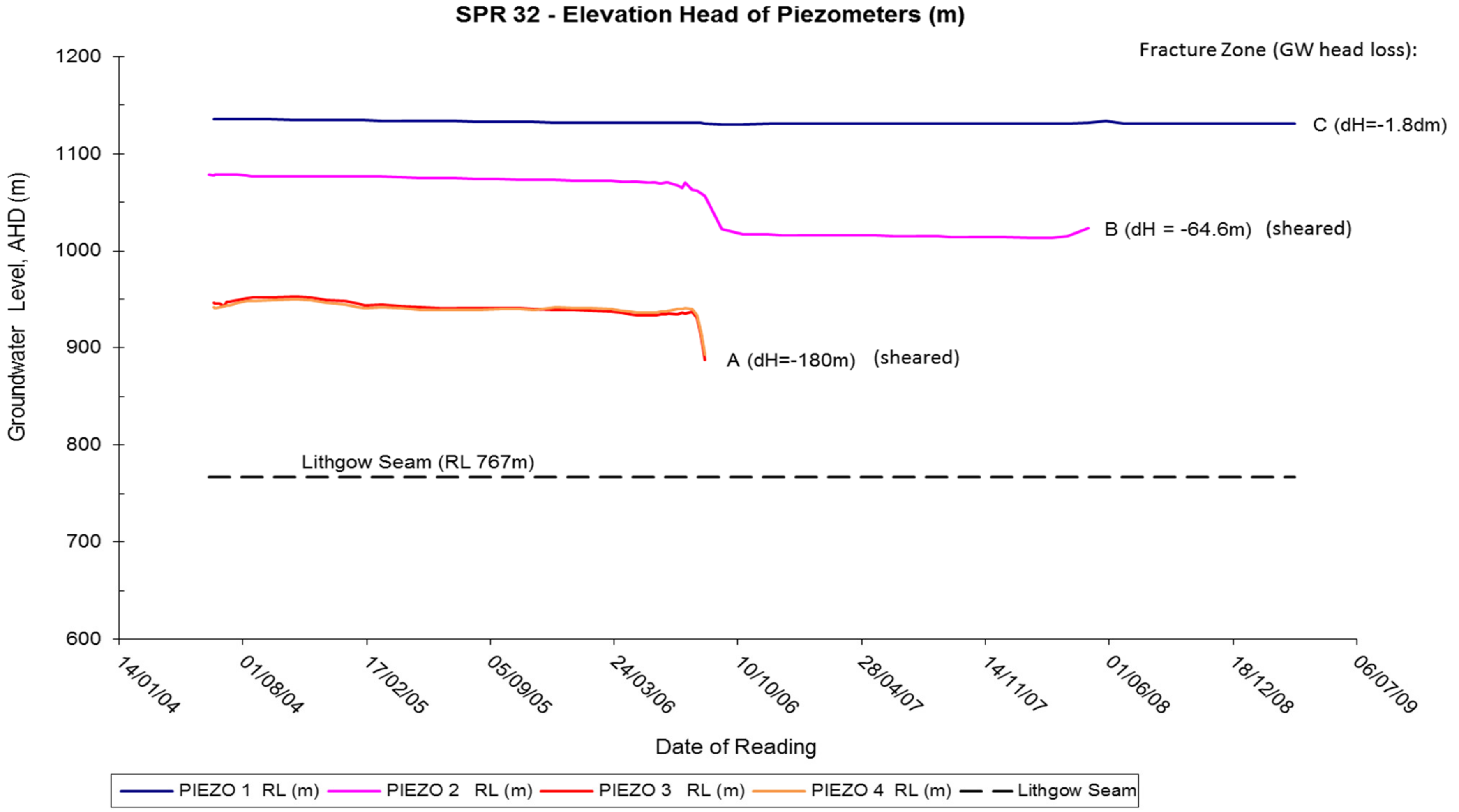
|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Centennial Springvale Coal Pty Ltd<br>SPV-003/7b | |
| | Drawn: | S.Ditton | | | |
| | Date: | 26.08.14 | Title: | Measured Piezometric Response to LW411 (SPR 39) | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: 5b |



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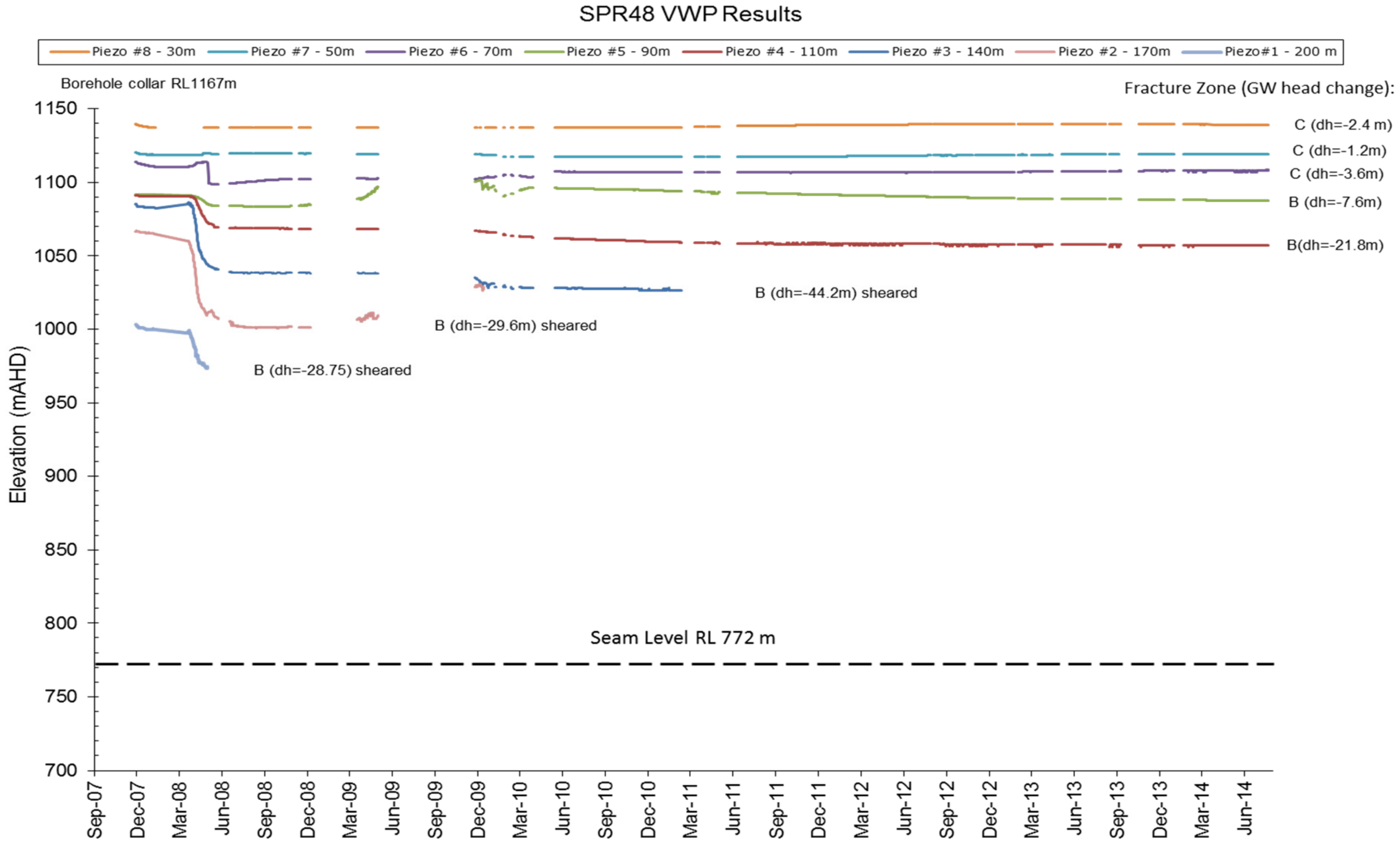
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Centennial Springvale Coal Pty Ltd<br>SPV-003/7b | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 26.08.14 | Title: | Measured Piezometric Response to LW411 (SPR 32) | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | 5c |



DgS

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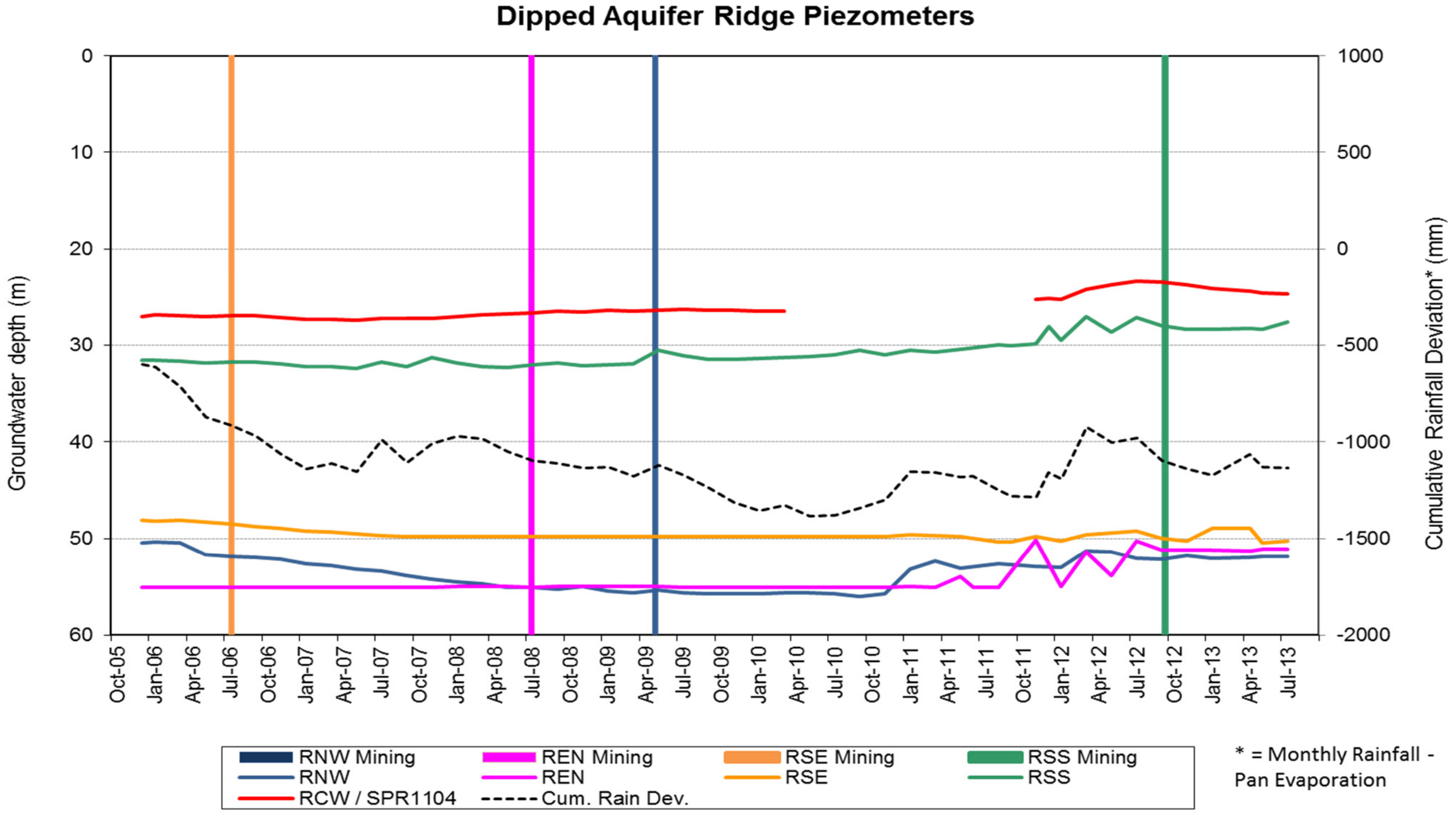
|---|---|---|---|
| Engineer: | S.Ditton | Client: | Centennial Springvale Coal Pty Ltd<br>SPV-003/7b |
| Drawn: | S.Ditton | | |
| Date: | 26.08.14 | Title: | Measured Piezometric Response to LW412 (SPR 48) |
| Ditton Geotechnical Services Pty Ltd | | Scale: | NTS |

Figure No: 5d



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|---|---|---|---|---|---|---|
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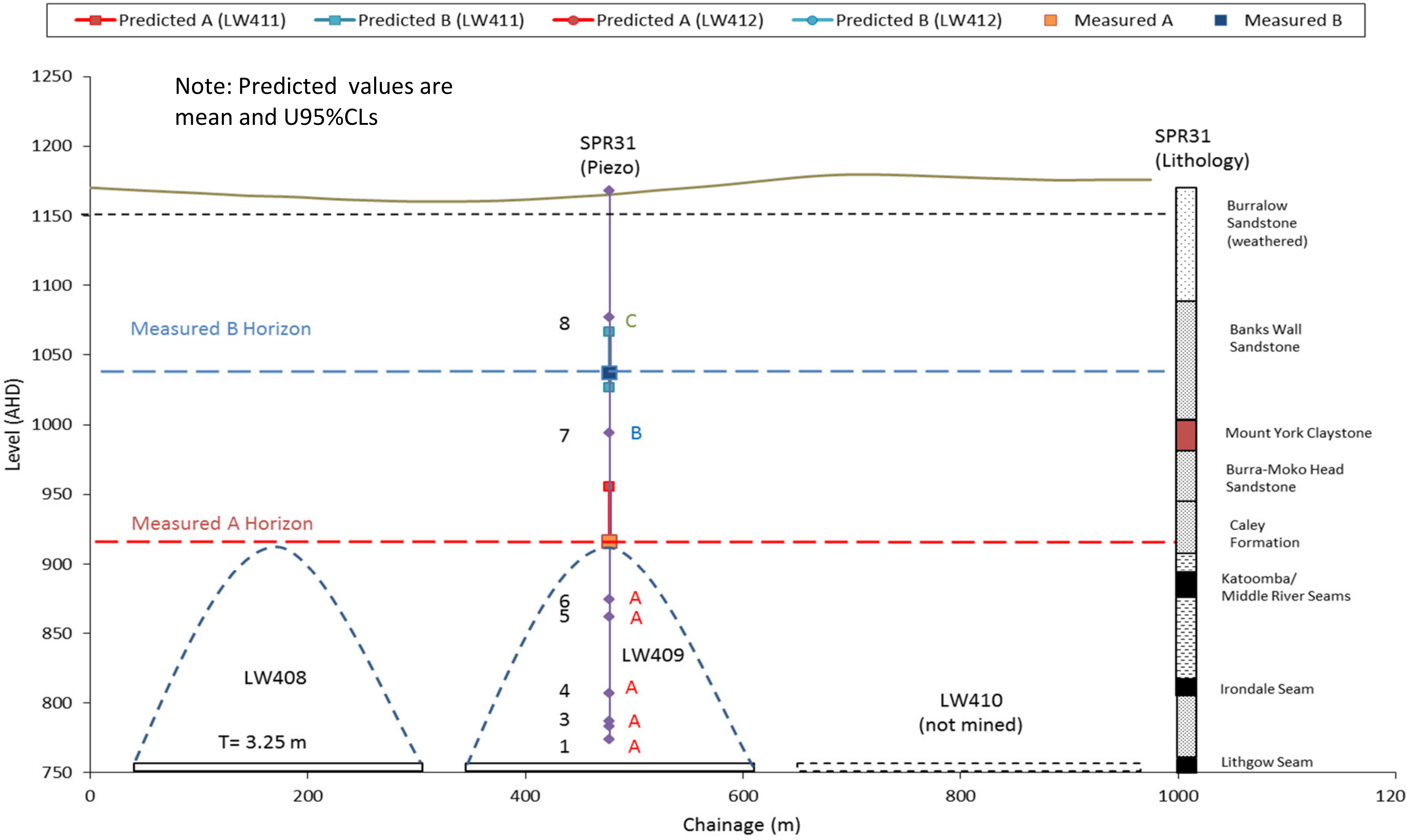
| | Drawn: | S.Ditton | | | | |
| | Date: | 26.08.14 | Title: | Measured Groundwater Depths in Ridge Piezometers between Jan 2006 and August 2013 | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | 5e |



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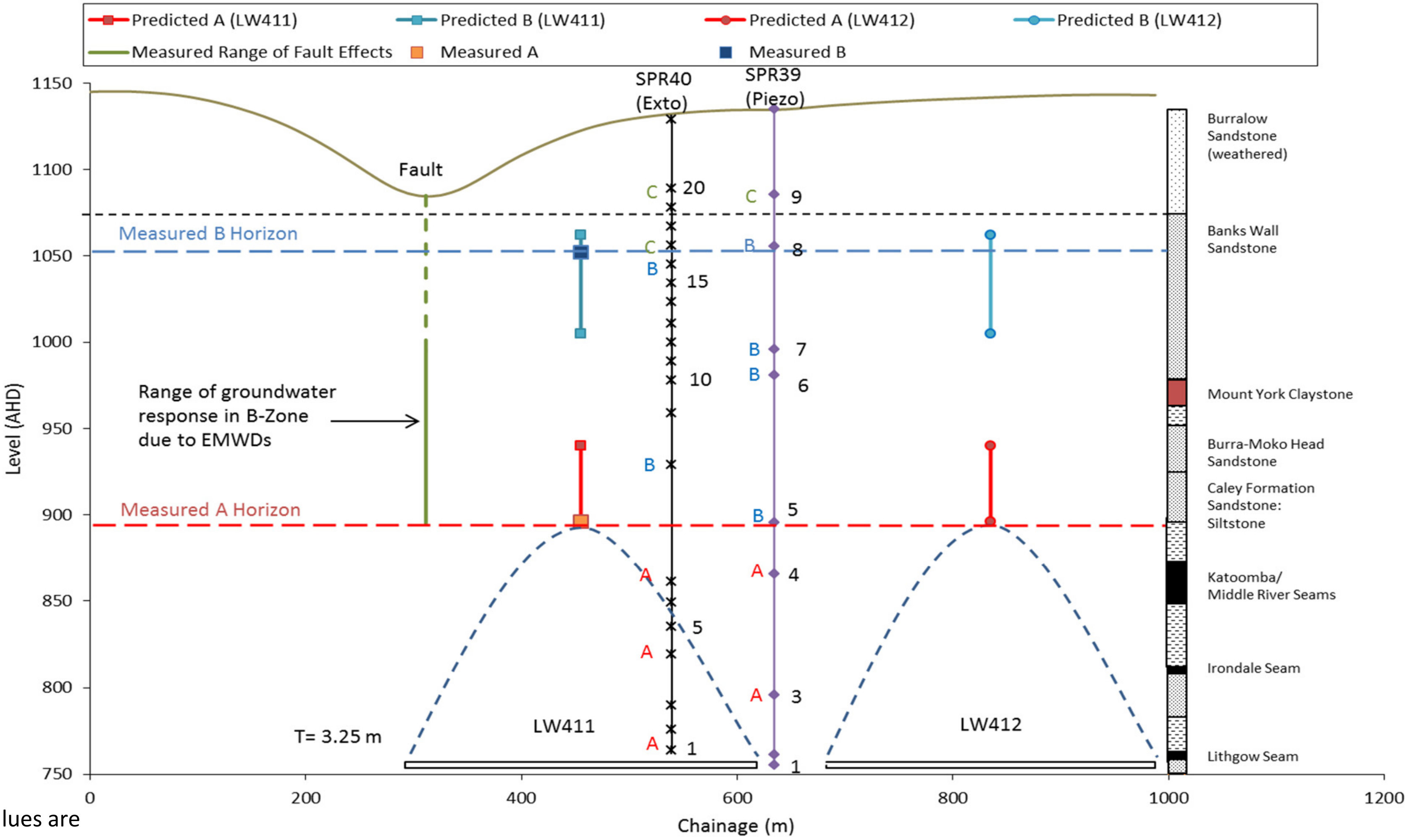
| DgS | Engineer: | S.Ditton | Client: | Centennial Springvale Coal Pty Ltd<br>SPV-003/7 |
| | Drawn: | S.Ditton | | |
| | Date: | 20.09.13 | Title: | Predicted v. Measured Sub-surface Fracture Zone Assessment Results Summary for LW409 |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS |
| | | | Figure No: | 6a |



Note: Predicted values are mean and U95%CLs

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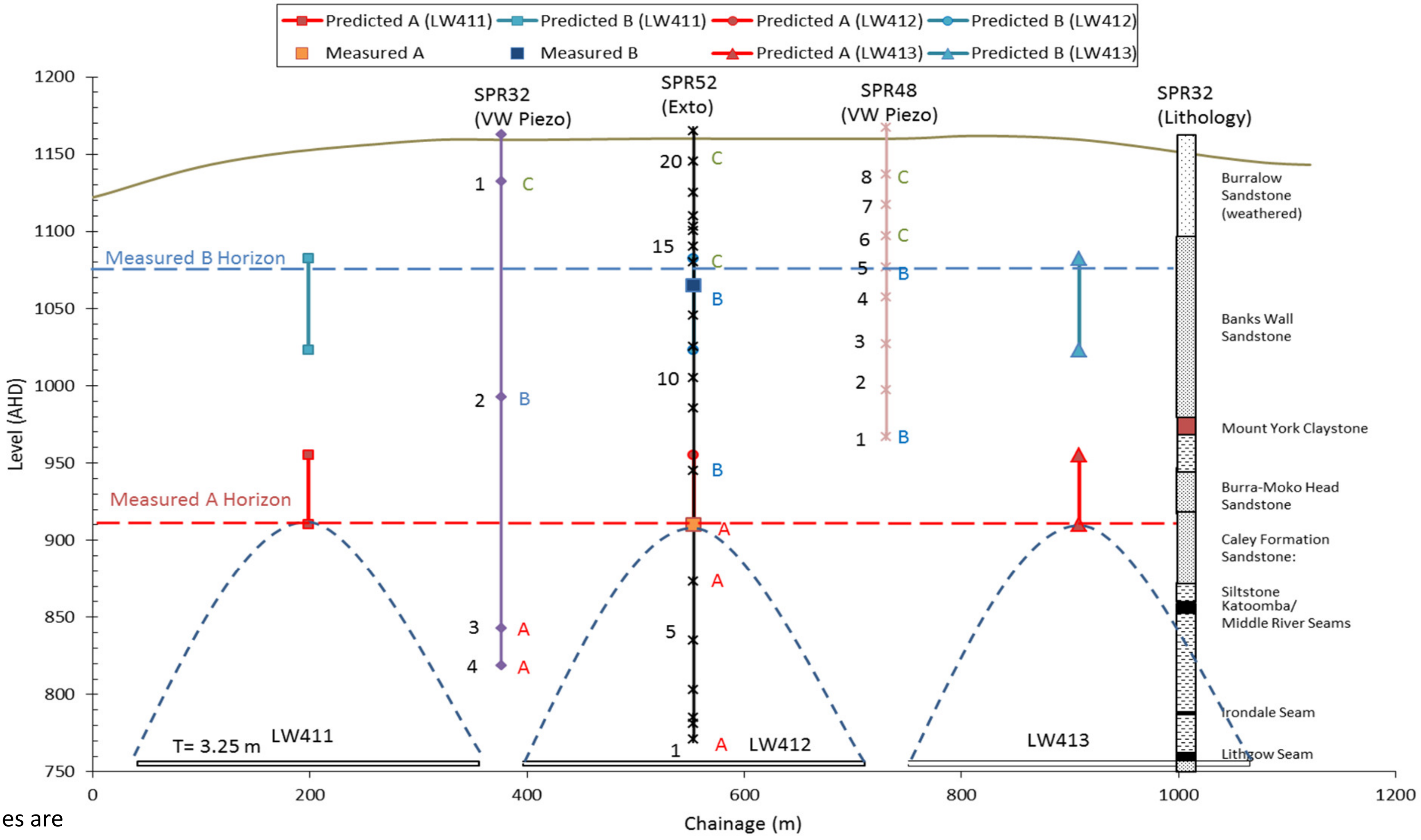
|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Centennial Springvale Coal Pty Ltd<br>SPV-003/7 | |
| | Drawn: | S.Ditton | | | |
| | Date: | 20.09.13 | Title: | Predicted v. Measured Sub-surface Fracture Zone Assessment Results Summary for LWs 411 and 412 | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: 6b |



Note: Predicted values are mean and U95%CLs

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|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Centennial Springvale Coal Pty Ltd<br>SPV-003/7 | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 20.09.13 | Title: | Predicted v. Measured Sub-surface Fracture Zone Assessment Results Summary<br>for LWs 412 and 413 | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | 6c |

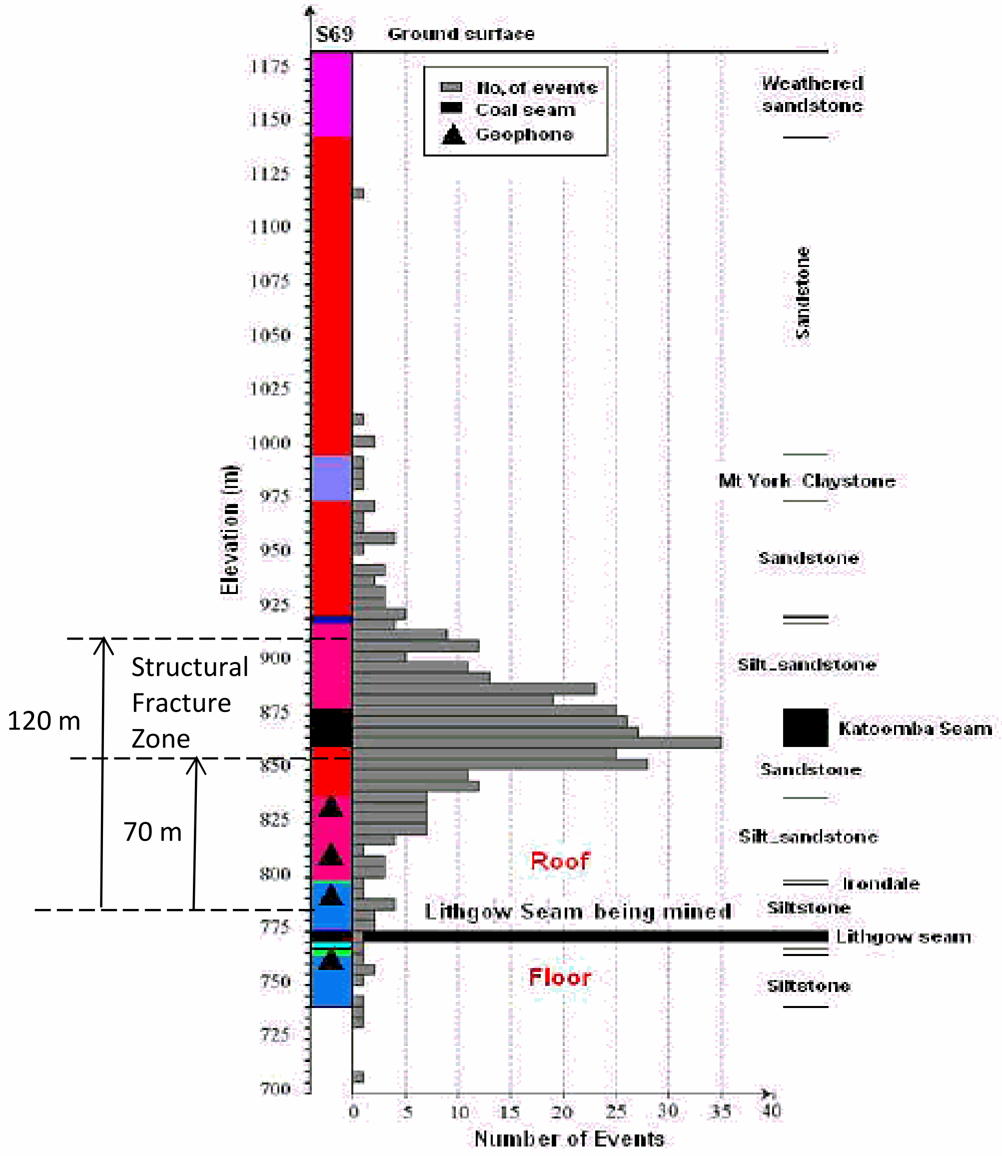

Figure 20 Depth distribution of the located events and simplified geology of borehole S69.

**Ref: CSIRO, 2011**

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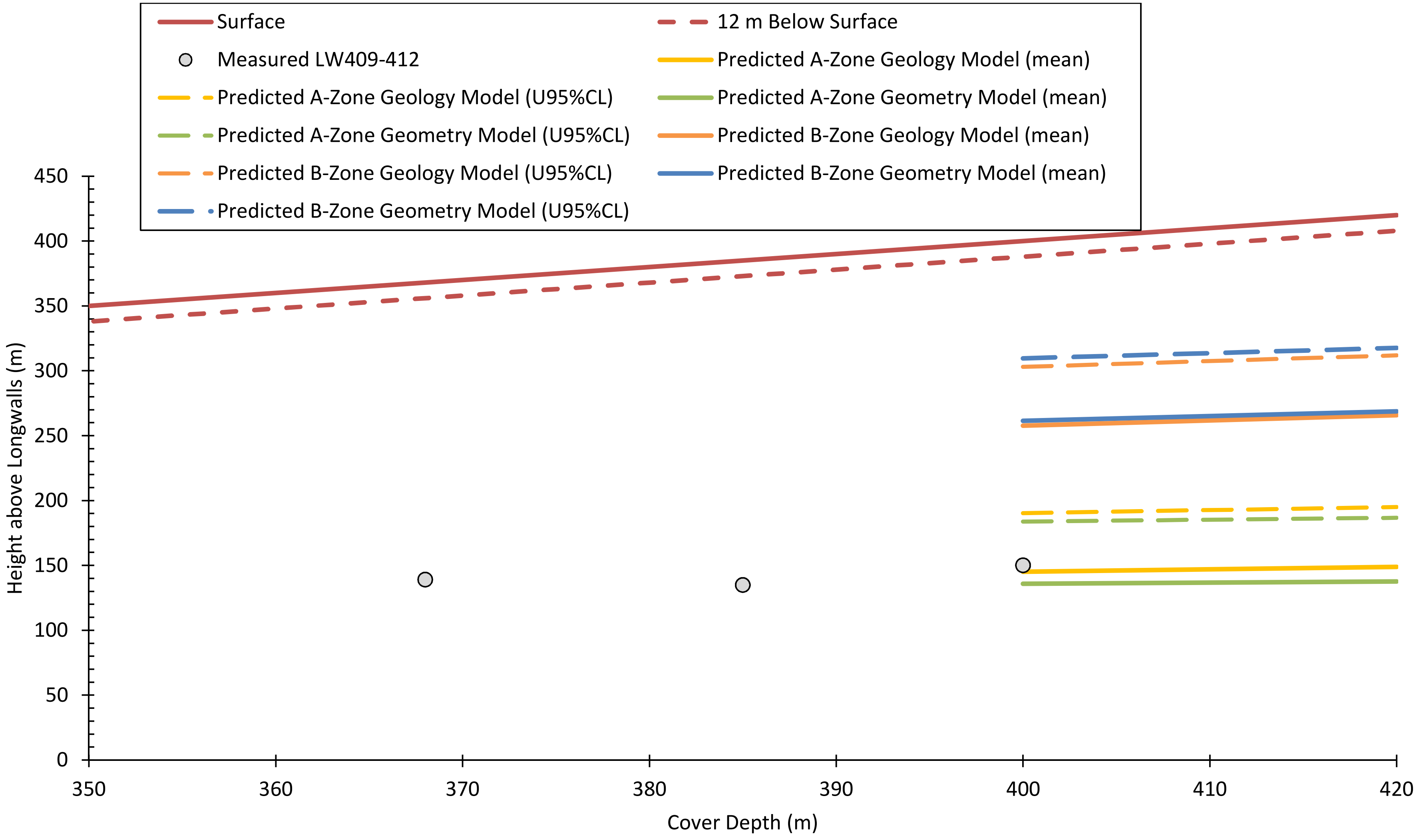
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Centennial Springvale Coal Pty Ltd | | |
| | Drawn: | S.Ditton | | SPV-003/7b | | |
| | Date: | 28.08.14 | Title: | Microseismic Event locations in Overburden above LW413 in Borehole S69 | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | 7 |



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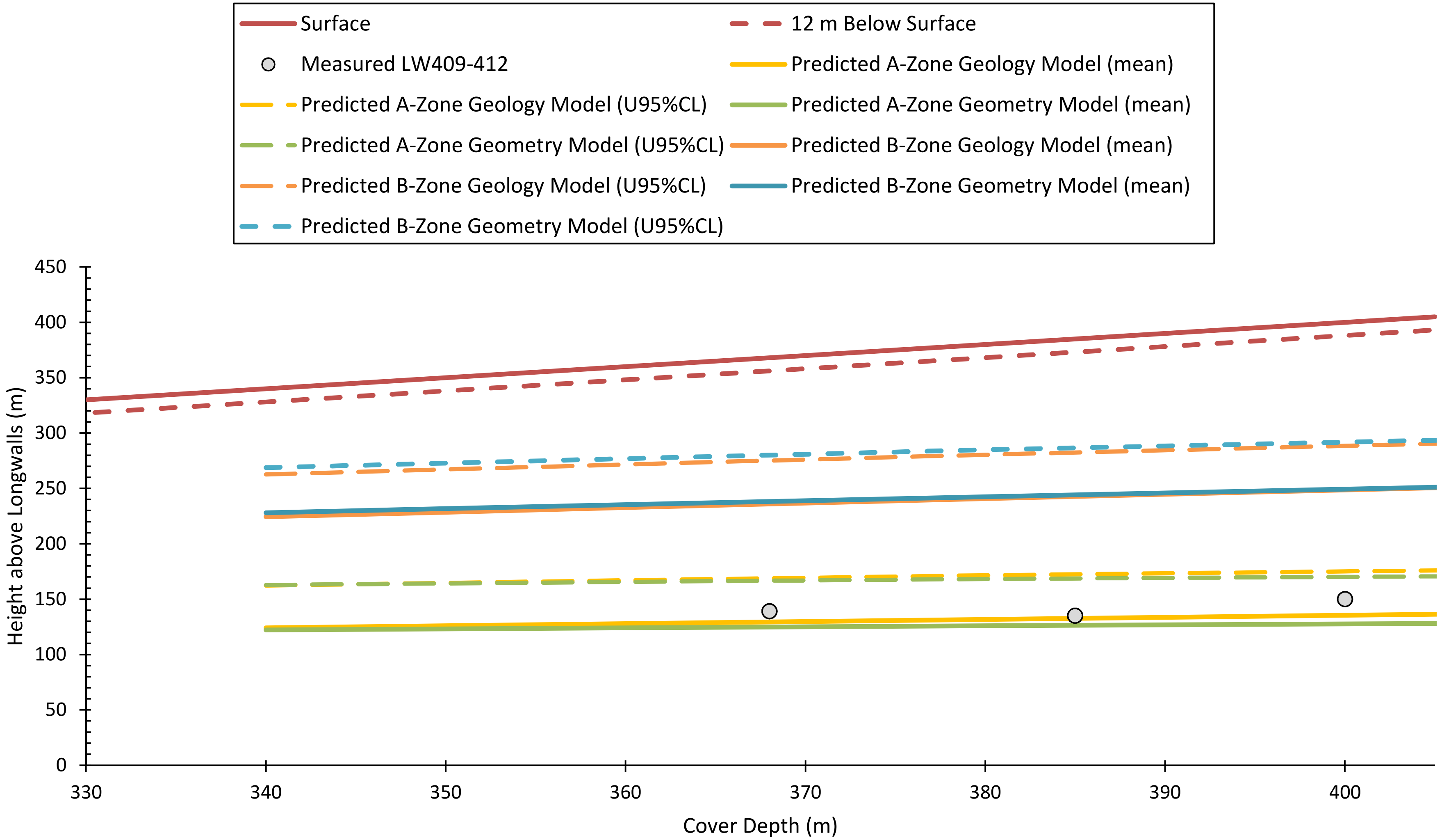
| DgS | Engineer: | S.Ditton | Client: | Springvale Pty Ltd<br>SPV-003/7b | |
| | Drawn: | S.Ditton | | | |
| | Date: | 11.08.14 | Title: | Predicted Continuous and Discontinuous Sub-Surface Fracture Heights<br>(A and B-Zones) for Springvale Mine's LW 415 | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: 8a |



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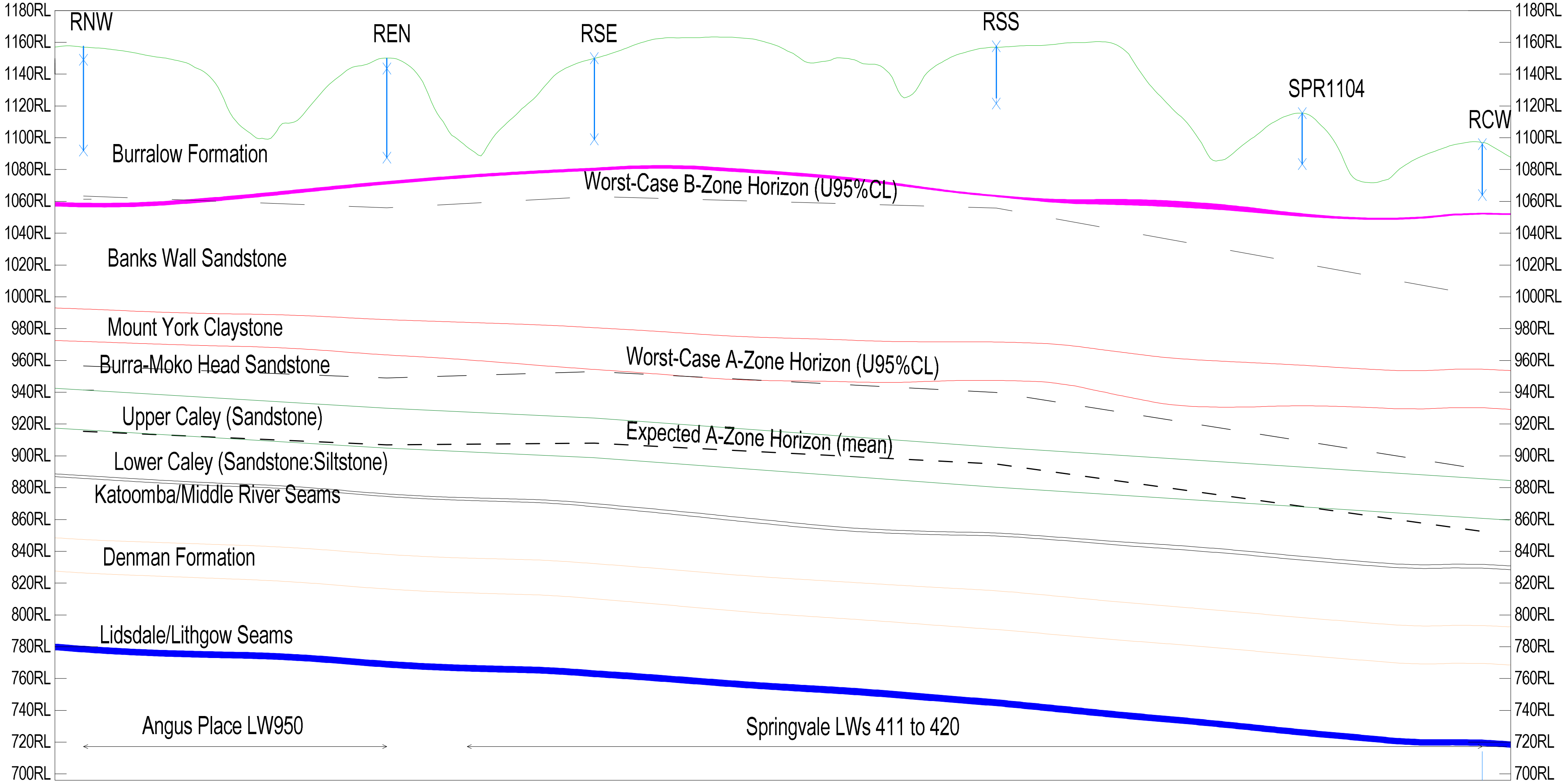
| DgS | Engineer: | S.Ditton | Client: | Springvale Pty Ltd<br>SPV-003/7b | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 11.08.14 | Title: | Predicted Continuous and Discontinuous Sub-Surface Fracture Heights (A and B-Zones) for Proposed Springvale Mine LWs 416 to 423 | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | 8b |



Key:

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| Seam YS6 | 🟪 |
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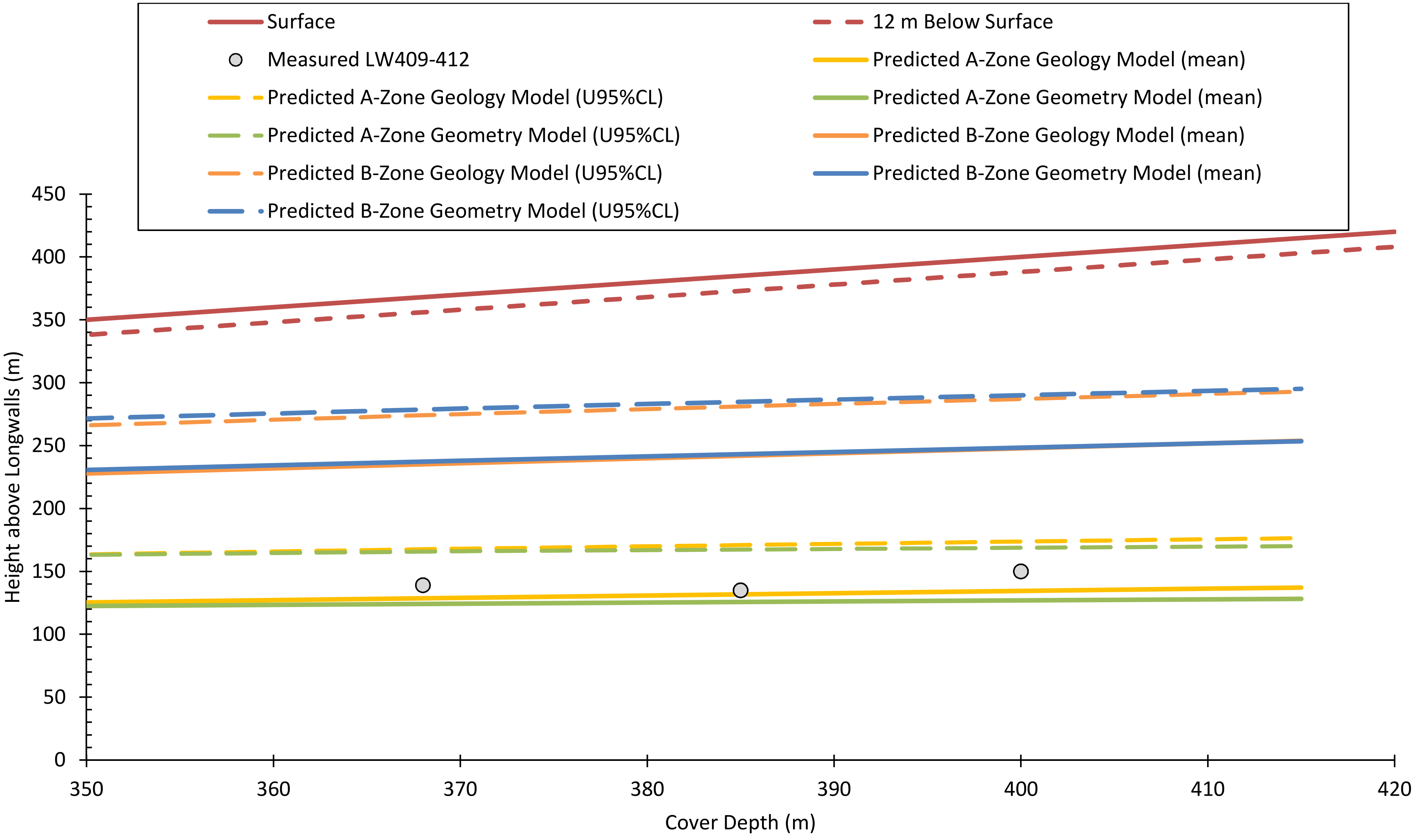
| Seam MDRU | ⬜ |
| Seam DEN | 🟧 |
| Seam LTH | 🟦 |

| DgS | | | | |
|---|---|---|---|---|
| Engineer: | S.Ditton | Client: | Centennial Springvale<br>SPV-003/7b | |
| Drawn: | S.Ditton | | | |
| Date: | 17.08.14 | Title: | Stratigraphy Section and Predicted Sub-Surface Fracture Zone Horizons for the Ridge Piezometers | |
| Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: 8c |



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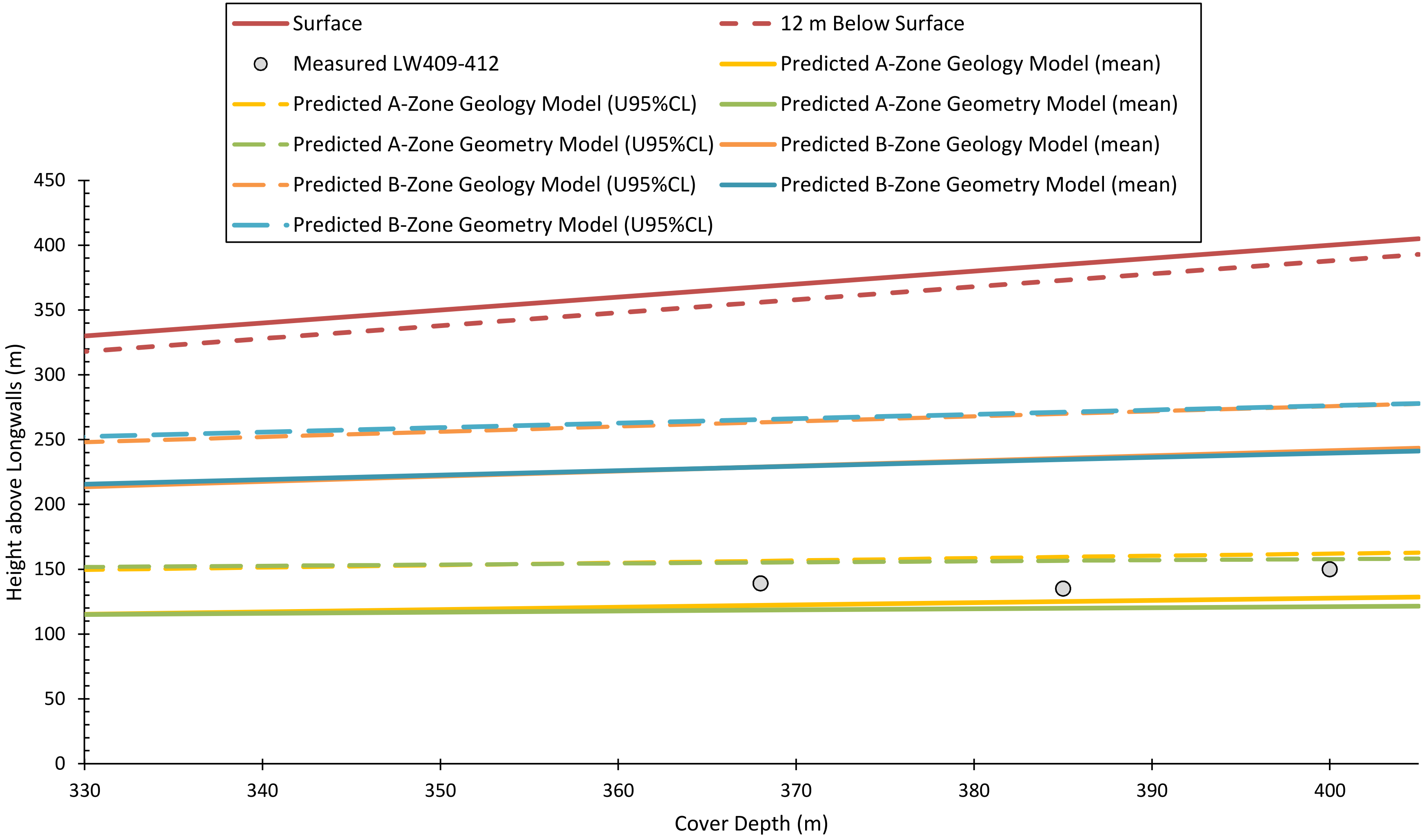
| DgS | Engineer: | S.Ditton | Client: | Springvale Pty Ltd<br>SPV-003/7b | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 11.08.14 | Title: | Predicted Continuous and Discontinuous Sub-Surface Fracture Heights (A and B-Zones) for the Proposed Springvale Mine Extension Area LWs 424 to 431 | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | 9a |



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|---|---|---|---|---|---|---|
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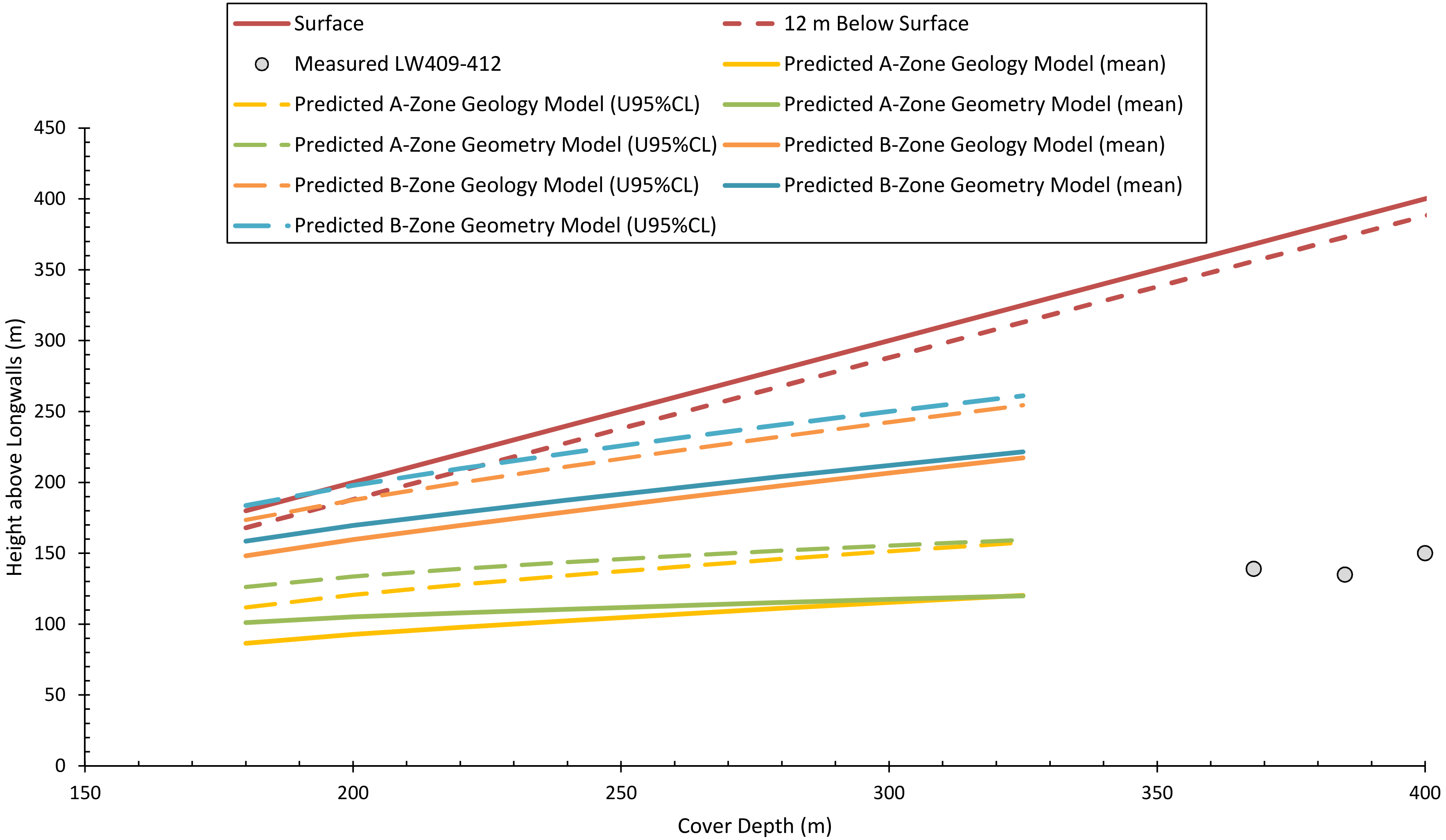
| | Drawn: | S.Ditton | | | | |
| | Date: | 11.08.14 | Title: | Predicted Continuous and Discontinuous Sub-Surface Fracture Heights<br>(A and B-Zones) for the Proposed Springvale Mine extension Area LW 432 | | |
| | Ditton Geotechnical<br>Services Pty Ltd | | Scale: | NTS | Figure No: | 9b |



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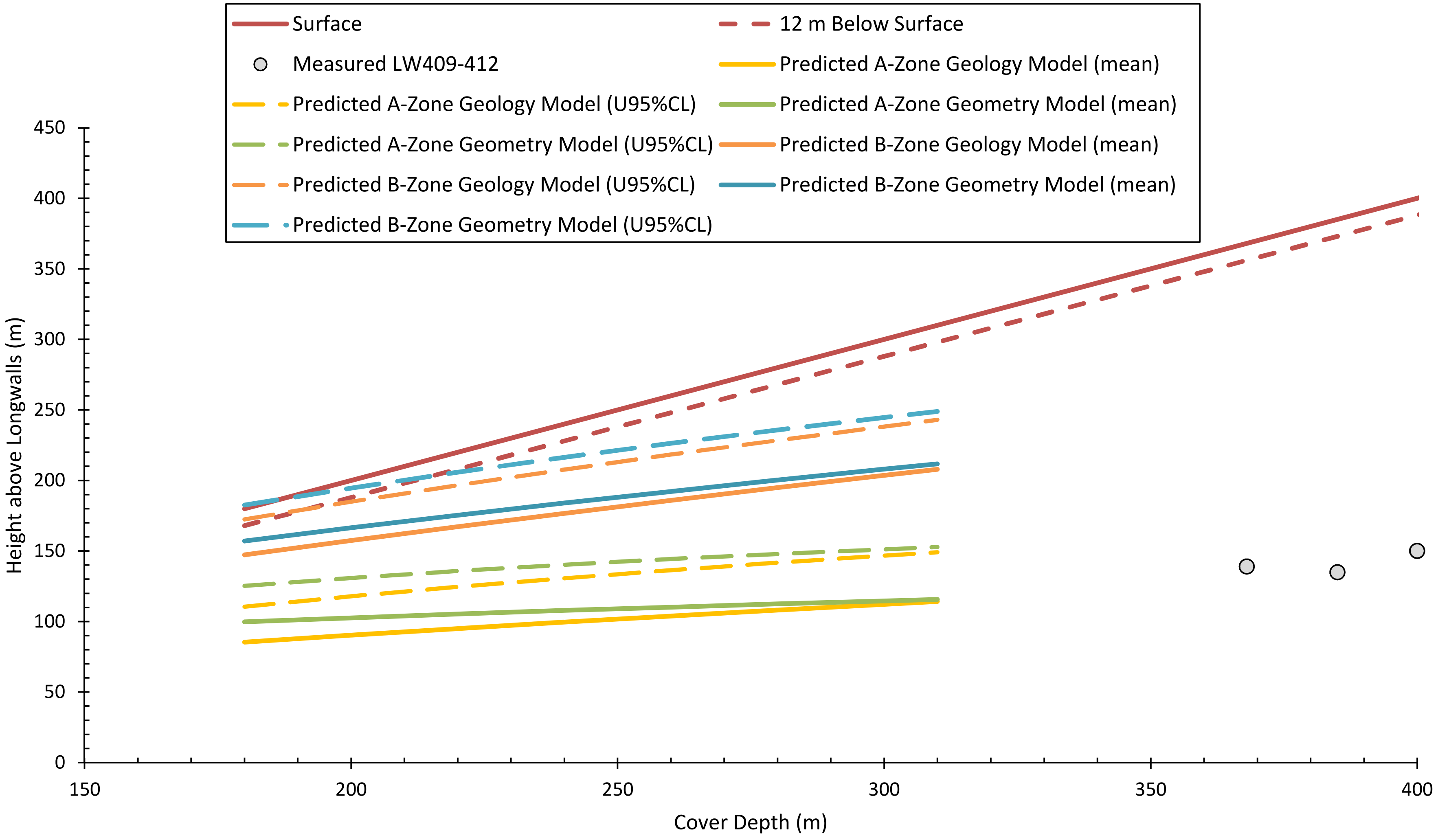
| | Drawn: | S.Ditton | | |
| | Date: | 11.08.14 | Title: | Predicted Continuous and Discontinuous Sub-Surface Fracture Heights (A and B-Zones) for the Proposed Springvale Mine Extension Area LW 501 |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS |
| | | | Figure No: | 9c |



DgS

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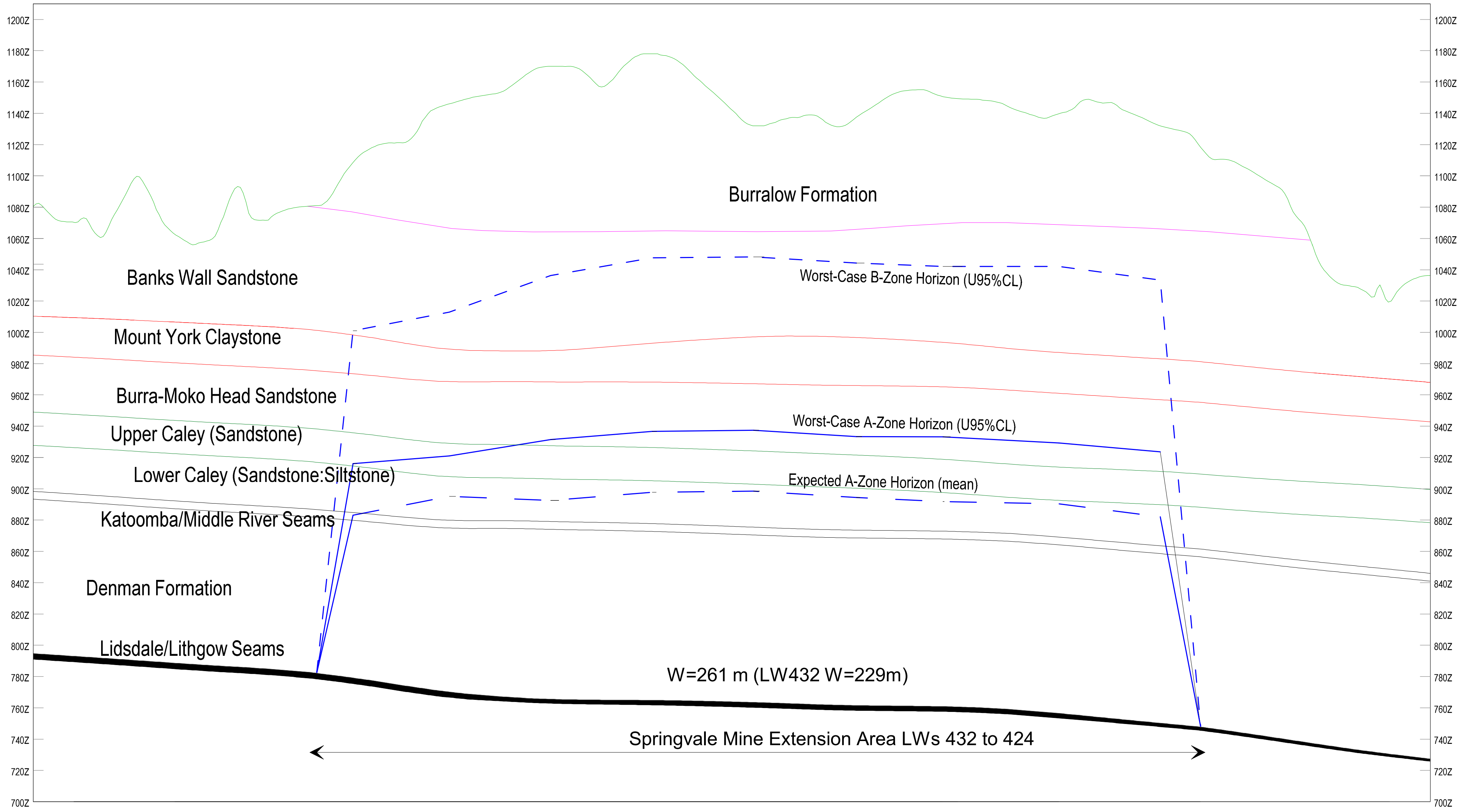
|---|---|---|---|
| Engineer: | S.Ditton | Client: | Springvale Pty Ltd<br>SPV-003/7b |
| Drawn: | S.Ditton | | |
| Date: | 11.08.14 | Title: | Predicted Continuous and Discontinuous Sub-Surface Fracture Heights (A and B-Zones) for the Proposed Springvale Mine Extension Area LW 502 |
| Ditton Geotechnical Services Pty Ltd | | Scale: | NTS |
| | | Figure No: | 9d |



DgS

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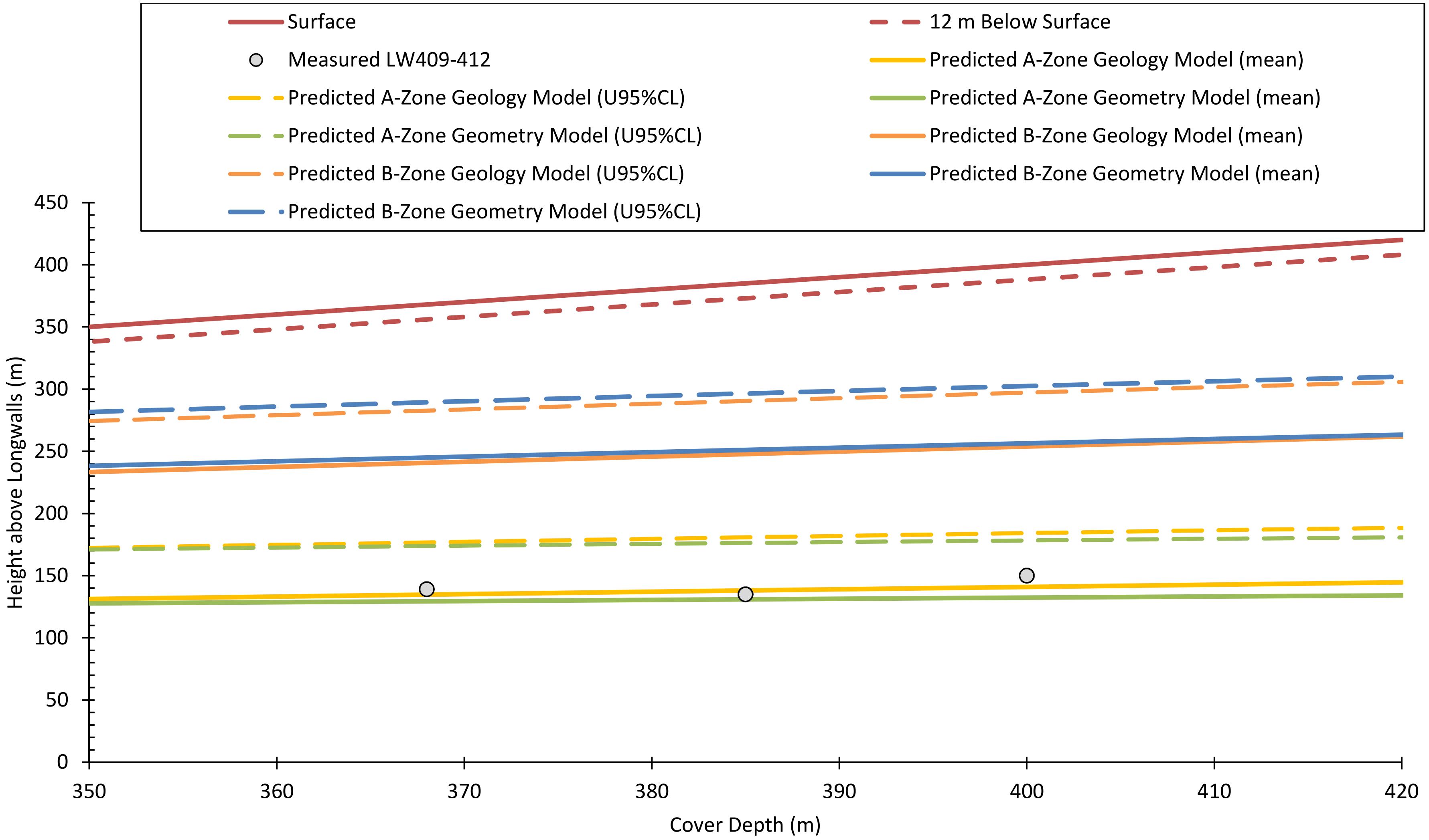
|---|---|
| Engineer: | S.Ditton |
| Drawn: | S.Ditton |
| Date: | 17.08.14 |

Ditton Geotechnical
Services Pty Ltd

| | |
|---|---|
| Client: | Centennial Springvale<br>SPV-003/7b |
| Title: | Stratigraphy Section and Predicted Sub-Surface Fracture Zone Horizons for the Proposed Springvale Mine Extension Project Area LWs 432 to 424 |
| Scale: | NTS |
| Figure No: | 9e |



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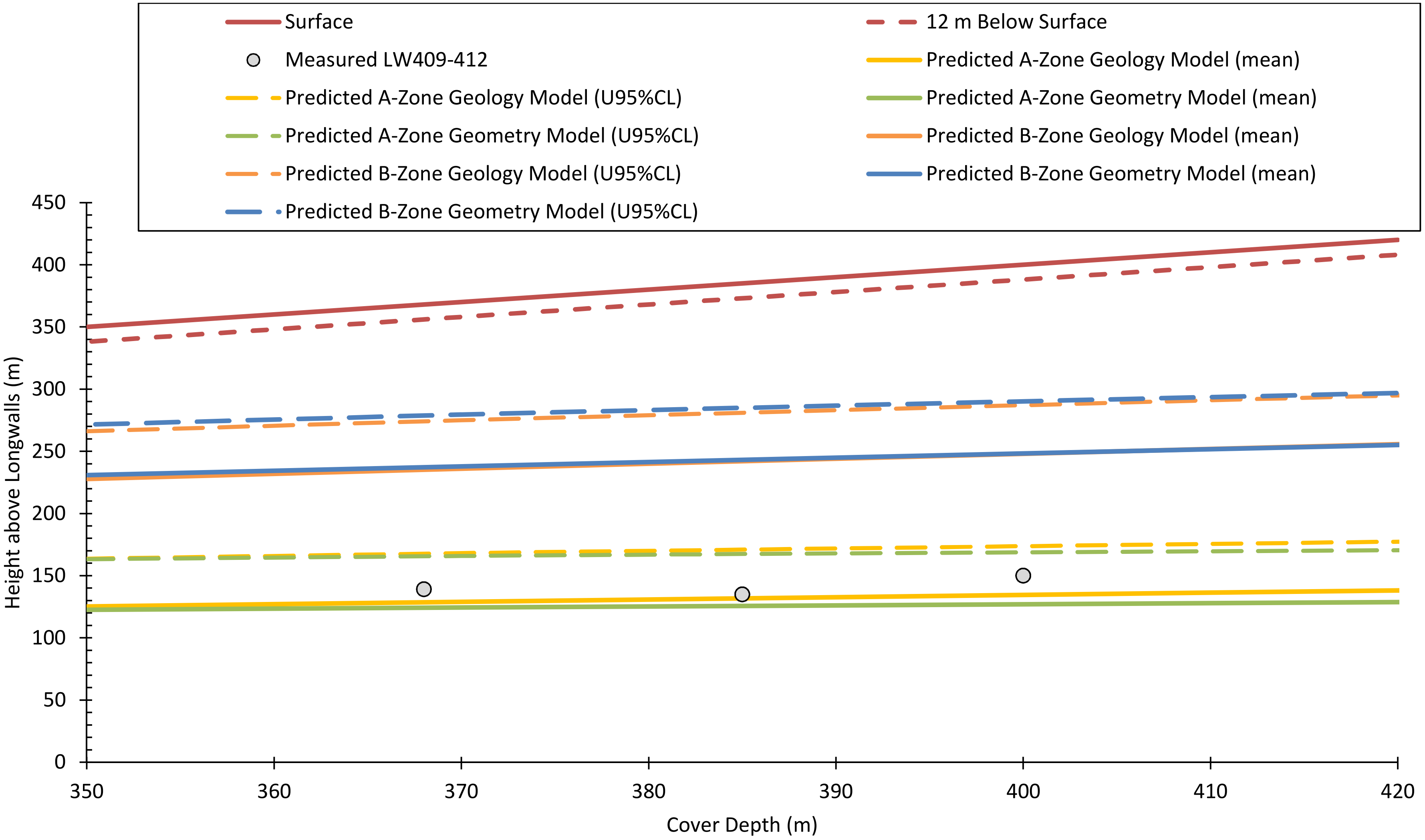
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Springvale Pty Ltd | | |
| | Drawn: | S.Ditton | | SPV-003/7b | | |
| | Date: | 11.08.14 | Title: | Predicted Continuous and Discontinuous Sub-Surface Fracture Heights<br>(A and B-Zones) for Proposed Angus Place Mine Extension Area LWs 1001 to 1003 | | |
| | Ditton Geotechnical<br>Services Pty Ltd | | | | | |
| | | | Scale: | NTS | Figure No: | 10a |



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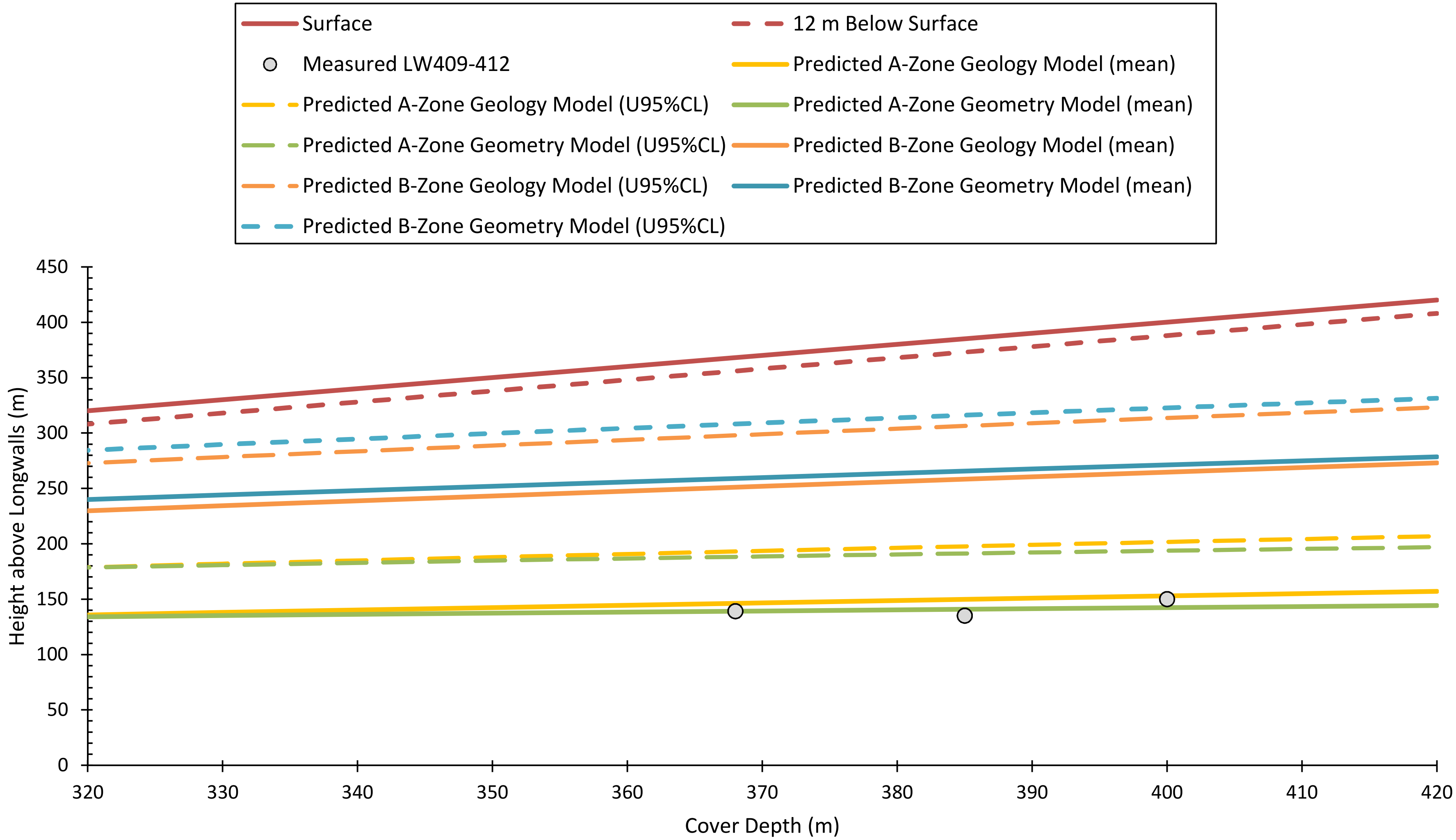
| | Drawn: | S.Ditton | | | | |
| | Date: | 11.08.14 | Title: | Predicted Continuous and Discontinuous Sub-Surface Fracture Heights (A & B Zones) for Proposed Angus Place Mine Extension Area LWs 1004-1006 & 1016-1017 | | |
| | Ditton Geotechnical Services Pty Ltd | | | | | |
| | | | Scale: | NTS | Figure No: | 10b |



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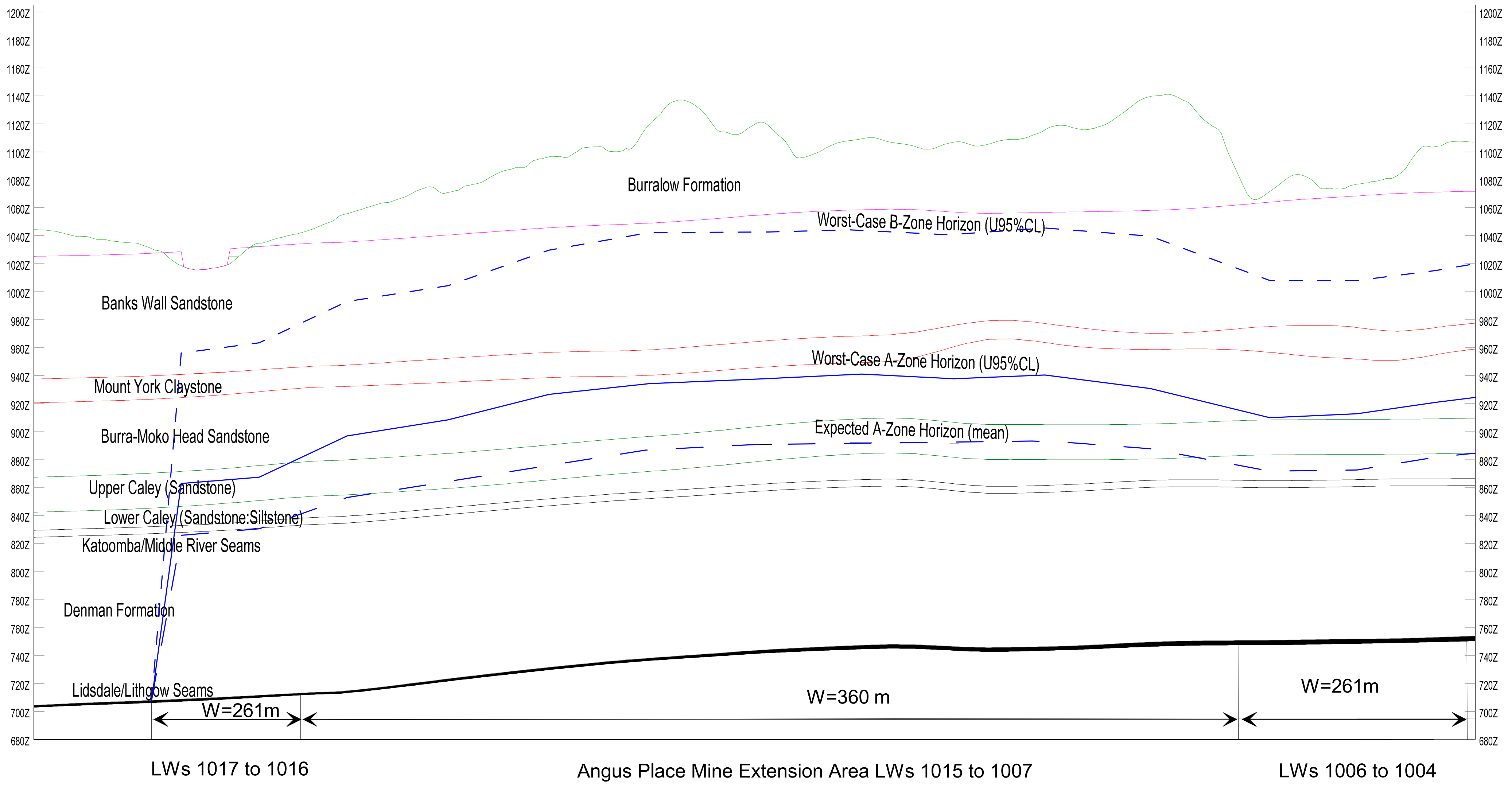
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Springvale Pty Ltd<br>SPV-003/7b | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 11.08.14 | Title: | Predicted Continuous and Discontinuous Sub-Surface Fracture Heights (A & B Zones) for Proposed Angus Place Mine Extension Area LWs 1007-1015 & 1018-19 | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | 10c |



| | | | |
|---|---|---|---|
| DgS | Engineer: S.Ditton | Client: | Centennial Springvale<br>SPV-003/7b |
| | Drawn: S.Ditton | Title: | Stratigraphy Section and Predicted Sub-Surface Fracture Zone Horizons for the Proposed Angus Place Mine Extension Area LWs 1004 to 1017 |
| | Date: 17.08.14 | | |
| Ditton Geotechnical Services Pty Ltd | | Scale: | NTS — Figure No: 10d |

# Attachment A - Height of Subsurface Fracturing Review and Pi-Term Model Development Details

## A11 Sub-Surface Fracturing Model

### A11.1 Sub-Surface Fracturing Zones

The caving and subsidence development processes above a longwall panel usually result in sub-surface fracturing and shearing of sedimentary strata in the overburden, according to **Peng and Chiang, 1984** (see **Figure A40a**) and **Whittaker and Reddish, 1989** (see **Figure A40b**). The height of fracturing (HoF) is dependent on mining geometry and overburden geology.

International and Australian research on longwall mining interaction with groundwater systems indicates that the overburden may be divided into essentially four or five zones of surface and subsurface fracturing. The zones are defined in **Table A4** (in descending order):

**Table A4 - Sub-Surface Fracture Zone Summary**

| Zone Type | Zone | Fracture and Groundwater Response Description | Typical Vertical Strain (mm/m) |
|---|---|---|---|
| **Surface Cracking Zone** (un-constrained) | D | Vertical cracking due to horizontal strains extending to maximum depths of 10 - 15 m. Surface waters may be diverted below affected area and resurface downstream where interaction with B & C Zones occur. | <3 |
| **Elastic Deformation Zone** (dilated bedding & constrained) | C | Generally unaffected by strains with some bedding parting dilation. Horizontal strains constrained by overlying/underlying strata.<br>Groundwater levels may be lowered temporarily due to new storage volume in voids between beds, but likely to recover at a rate dependant on climate.<br>Elastic Zone may not be present if B or A Zones extend up to Surface Zone. | <3 |
| **Discontinuous Fracture Zone** (dilated bedding & constrained) | B | Minor vertical cracking due to bending that do not extend through strata units. Increased bedding parting dilation and similar groundwater response to Zone C. Some groundwater leakage may occur to B Zone, however, losses likely to be recharged by surface hydro-geological system. | <8 |
| **Continuous Fracture Zone** (unconstrained) | A | Major vertical cracking due to bending that pass through strata units and allow a direct hydraulic connection to workings below. Full depressurisation of groundwater occurs in the Zone that may recover in the long term once mining is completed. | >8 |
| **Caved** (included in the A-Zone) | A | Caved strata up to 3 to 5 x Mining Height above the workings. Collapsed roof bulks in volume to provide some support to overlying strata. | >80 |

The characteristics of each HoF zone are further described below:

Starting from the seam level, the **Caved Zone** (included in the **A-Zone**) refers to the immediate mine workings roof above the extracted panel, which has collapsed into the void left after the coal seam has been extracted. The Caved Zone usually extends for 3 to 5 times the mining height, T, above the roof of the mine workings due to bulking factors of 1.3 to 1.5, and sometimes from 10 to 15T if the strata have low bulking properties (e.g. bulking factors of 1.10 to 1.15). Thinly bedded and laminated strata are likely to have lower bulking factors than thickly bedded or massive units within the Caved Zone.

The **Continuous Fracture Zone (A-Zone)** has been affected by a high degree of bending deformation, resulting in significant fracturing and bedding parting separation and shearing of the rock mass. Vertical tensile strains range from -10 to 140 mm/m with strata dilation in excess of 1 m. Compressive strains tend to develop at horizontal bedding separations after initial fracturing and overlying strata deflections occur resulting in re-compaction of the goaf and disturbed strata.

Continuous sub-surface fracturing refers to the zone of cracking above a longwall panel that is likely to result in a direct flow-path or hydraulic connection to the workings. All groundwater (or surface waters) within this Zone would be expected to drain vertically into the mine workings goaf.

The **Strata Dilation Zone (B-Zone)** refers to the section of overburden immediately above the A-Zone that has also been deformed by bending action, but to a lesser degree than the A-Zone. The B-Zone will have bedding parting separations and discontinuous fractures through bending strata units due to vertical strains ranging from -2 to 8 mm/m and strata dilation from 30 mm to 400 mm, depending on the panel width. An increase to horizontal rock mass permeability (hydraulic conductivity) is expected in the B-Zone with groundwater flowing horizontally into dilated strata.

Only minor vertical permeability increases are expected in the B-Zone due to alternating horizontal tensile and compression zones associated with Voussoir Beam action above the A-Zone. It is noted in **Whittaker and Reddish, 1989**, that some groundwater leakage from the B-Zone to the A-Zone is possible due to limited crack or joint interaction between the zones.

Overall, the majority of the B-Zone is considered to be a ‘constrained’ and ‘dilated’ zone with low connectivity potential to the mine workings. The B-Zone therefore represents a sub-surface fracturing zone that causes temporary groundwater system disturbance.

The **Elastic Deformation Zone (C-Zone)** is located above the B Zone and is the zone where the strata may have suffered minor bending and disturbance. Impacts include horizontal shearing and minor bed separations or dilation of up to 30 mm due to vertical tensile strains between 1 and 2 mm/m. The bedding separations may result in minor increases to horizontal hydraulic conductivity and negligible changes to vertical hydraulic conductivity. Groundwater system disturbance is expected to be negligible in this zone.

The development of the Elastic Deformation Zone (C-Zone) will depend on the mining geometry and the presence of spanning strata. The C-Zone is probably only likely to develop above critical to sub-critical mining geometries (i.e. W/H < 1.4) but may also be present above super-critical panels also if favourable geological conditions exist.

The strata in the B and C-Zones are also likely to be in compression due to natural arch formation (above sub-critical and critical panels). The arch will also act as barrier to vertical drainage of groundwater despite the presence of naturally occurring vertical joints in the rock mass. Low permeability strata such as claystone, tuff and mudstone will also limit rock mass ‘gaps’ and further retard vertical flow rates through these zones.

In the absence of significant geological structure (i.e. faults and dykes), the overall effect on the surface groundwater system due to leakage through the B and C-Zones will be minimal, with re-charging of groundwater losses likely to occur from the surface hydrological system. The presence of significant geological structure may increase the drainage rates through these strata zones however. Monitoring of mine groundwater makes v. rainfall - runoff data will determine the rate of leakage that is occurring through these zones.

The **Surface Cracking Zone (D-Zone)** includes the vertical cracking due to horizontal tensile and compressive strains caused by mine subsidence deformation. The D-Zone may extend to depths ranging from 5 m to 20 m (typically < 15 m) in the Newcastle Coalfield, and is dependent on near-surface geology and surface topography.

For mine design purposes, typical D-Zone depths in relatively flat terrain may be assumed to range from 10 m to 12 m (i.e. < 15m). *Note: **Forster and Enever, 1992** adopted a D-Zone thickness of <15 m based on data from Wyee and Cooranbong Collieries, and included it in the minimum cover depth formula of 45T+10 m for designing supercritical panels below tidal waters of Lake Macquarie in the Newcastle Coalfields.*

### A11.2 Impact on Rock Mass Permeability

In regards to changes to rock mass permeability, **Forster, 1995** indicates that horizontal permeabilities in the fractured zones above longwall mines could increase by 2 to 4 orders of magnitude (e.g. pre-mining $k_h = 10^{-9}$ to $10^{-10}$ m/s; post-mining $k_h = 10^{-7}$ to $10^{-6}$ m/s).

Vertical permeability’s could not be measured directly from the boreholes but could be inferred by assuming complete pressure loss in the ‘A Zone’, where direct hydraulic connection to the workings occurs. Only a slight increase in the ‘B zone’ or indirect / discontinuous fracturing develops (mainly due to increase in storage capacity) from bedding parting separation. It is possible that minor vertical flows will occur from B zone into A zone (and workings) as well.

Discontinuous fracturing would be expected to increase rock mass storage capacity and horizontal permeability without direct hydraulic connection to the workings. Rock mass permeability is unlikely to increase significantly outside the limits of extraction.

### A11.3 Mine Design Criteria for Sub-Surface Fracture Height Control

When designing mining layouts for sub-surface fracture control, the A-Zone is the most significant in regards to groundwater and surface water interaction as it represents the region of broken ground whereby a hydraulic connection to the mine workings will most certainly occur.

The B-Zone is probably just as important as it represents the transition zone between the continuously fractured ground and elastic deformation or surface zones. The B-Zone also includes strata which are confined and where bedding parting separations (i.e. dilations) occur in the sagging rock mass above the caved and broken strata units in the A-Zone.

The C-Zone has been deformed as well, but not to the same extent as the B-Zone.

*Note: It is difficult to define the boundary between the B and C-Zones without vertical strain measurements from extensometers. Both zones are considered to be ‘constrained’ and ‘dilated’ and will act as an effective barrier between the A-Zone and near surface groundwater and surface watercourses.*

The formation and thickness of the HoF Zones will firstly be dependent on the ‘criticality’ of the proposed longwall panel. The same terms used for subsidence prediction are also referred to below and are based on the ratio between panel width (W) and the cover depth (H) at Springvale Colliery:

- Subcritical refers to panels with W/H < 0.9;
- Critical refers to panels with W/H > 0.9 and < 1.4; and
- Supercritical refers to panels with W/H > 1.4.

Several case studies have been referred to below which consider super-critical and sub-critical panel geometries separately due to their fundamental differences in spanning behaviour.

Conceptual models of the A and B-Zones above supercritical panels are presented in **Whittaker & Reddish, 1998** and are based on physical modelling results. **Forster and Enever, 1992** indicated similar strata zoning from field monitoring (**Figure A40c**) above supercritical, total pillar extraction panels in the Lake Macquarie Area of the Newcastle Coalfield.

A conceptual model that includes the B and C-Zones was presented in **ACARP, 2007** (**Figure A40d**) for sub-critical mining geometries in the Western Coalfield. A similar sub-surface fracture zoning is also suggested by **Mark, 2007** (**Figure A40e**) for the US Coalfields and **Kendorski, 1993** for the UK Coalfields (**Figure A40f**).

From the above conceptual height of fracturing models, several simple empirical models have been developed over the years to estimate the thicknesses of the A, B and C-Zones for the purpose of avoiding groundwater and surface water connectivity with underground mines.

The suite of HoF prediction models that probably represent the state-of-the-art are summarised in the following sections.

### A11.3.1 Wardell, 1975, Reynolds, 1977 and Singh and Kendorski, 1981

**Wardell, 1975** recommended a minimum rock cover depth of 50T - Surface Zone thickness above total extraction or longwall panels when mining under tidal waters in the Newcastle Coalfield. The minimum cover depth (H) was based on a maximum horizontal tensile strain limit of 7.5 mm/m and the Newcastle Holla curves. It is noted that a maximum horizontal tensile strain of 10 mm/m has been specified in the UK when mining below permanent waters.

Wardell has also recommended a minimum cover depth of 60T (which included a Surface Zone thickness ranging from 12 m to 15 m) for mining below stored waters with longwalls in the Southern Coalfield.

The Wardell Guidelines recommended that panel widths should be limited to <0.4H to maximize the thickness of the Constrained Zone (i.e. B and C-Zones) beneath tidal waters. **Reynolds, 1977** recommended 0.33H for maximum panel widths at depths more than 120 m below the reservoirs in the Southern Coalfield.

The height of continuous fracturing was not estimated in the Wardell Guidelines, but probably assumed to be significantly lower than 50T - the 15 m thick surface cracking zone. **Holla, 1991** noted that the 60T value is dependent on the $S_{max}$ and K ratio (and hence W/H ratio) and should not be applied blindly to all mining geometries.

**Singh and Kendorski, 1981** adopted a general height of A-Zone Fracturing of $56T^{0.5}$ based on a review of international case studies with a minimum Constrained plus Surface Zone thickness of 45 m for mudstone and 57 m for sandstone strata conditions when mining below tidal waters. The model recognizes that fracturing may extend further through massive strata than thinly bedded units due to their propensity to carry greater load.

### A11.3.2 Whittaker and Reddish Physical Model, 1989

It is considered that the published physical modeling work in **Whittaker and Reddish, 1989** provides valuable insight into the mechanics of sub-surface fracturing over longwall panels. The outcomes included specific guidelines (over and above such work as the Wardell, 1975 Guidelines) for the prevention of inundation of mine workings beneath surface and sub-surface water bodies.

The **Whittaker and Reddish, 1989** height of fracturing model was developed in response to the water ingress problems associated with early longwall extraction at the Wistow Mine in Selby, UK. The longwall panel was located at 350 m depth and experienced groundwater inflows of 121 to 136 litres/sec when sub-surface fracturing intersected a limestone aquifer 77 m above the seam.

The physical model is a scaled down version of the real-world, and therefore requires compatible material strength properties (i.e. plaster) to generate fracturing from the laboratory-sized void widths and mining heights being simulated. The pattern of cracking and heights of fracturing observed should therefore not be dismissed because of the materials used to create the model.

The Whittaker and Reddish model identifies two distinct zones of fracturing above super-critical width extractions (continuous A-Zone and discontinuous B-Zone fracturing) and indicates the height of each is a function of maximum tensile strain at the surface. As such, its use is also based upon being able to make credible subsidence and strain predictions. The mechanical concepts of the model are shown in **Figure A40b**.

The definition of the ‘continuous’ height of fracturing refers to the height in which a zone of direct hydraulic connection for groundwater inflows to the mine workings develops (i.e. the A-Zone).

The definition of the extent of ‘discontinuous’ height of fracturing refers to the height at which the horizontal permeability increases as a result of strata de-lamination and incomplete fracturing through the strata beds (i.e. the B-Zone). Minor occurrences of direct connection of fractures to the workings is considered possible, but will depend on the geology (e.g. the presence of persistent vertical structure such as faults and dykes).
The outcomes of the modeling work resulted in two logarithmic type curves that relate the surface horizontal strain to the measured A and B fracture heights normalized to the cover depth (see **Figure A40b**).

The physical modeling work that was completed to derive the prediction curves is summarised below:

- The physical model was constructed from multiple 1.25 cm thick layers of coloured sand and plaster with sawdust bond breakers placed between each successive layer. Based on a real world/model ratio of 92, the model layers represented 1.15 m thick layers in the real world. The model was initially devoid of vertical joints or cracks.

- The scale and mechanical properties of the model satisfied dimensional analysis and similitude laws. *Note: This aspect of mechanical models is very important, as overburden strength properties will not fracture if they are too high for the model’s mining geometry.*

- The plaster layers for the model were equivalent to a rock mass with a density of 2.35 t/m$^3$, a UCS of 10.94 MPa and Youngs Modulus, E, of 984 MPa.

- The model was used to simulate the overburden behaviour of a panel with a W/H ratio of 1.31 and a progressively increasing working height range that commenced at 1.2 m and finished at 10.8 m. The advancing longwall face was simulated by removing timber blocks at the base of the model in 1.2 m to 2.0 m lift stages.

- The extent or heights of ‘continuous’ and ‘discontinuous’ fracturing above the longwall ‘face’ were measured and plotted with the associated peak tensile strain predictions at the surface. The subsidence and strains were measured from a grid and calculated using the method provided in the **UK Subsidence Engineers Handbook, 1975**.

- The fracturing path progressed up at an inward angle of approximately 18° to 19° from the solid rib and increased towards the centre of the panel higher up into the strata. Continuous fracturing occurred in the cantilever bending zone close to the rib-side only, as fracturing in the overburden above the middle portion of the panel tended to ‘close’ and did not appear to represent an area where groundwater inflows into the workings would eventuate.

- Surface cracks extended down from the surface for a depth up to 7.5 m.

- Other similar models were also prepared and used to demonstrate the “ability of strong overburden at the surface to cause bridging of the strata in this manner is dependent upon the strength and general competence of the rocks near to the surface, in addition to the width of the extracted region.”

- Any groundwater inflow conditions were therefore considered to be “mainly associated with the longwall rib-side fracture zone [or tensile strain zone]” above longwall panels.

The findings above are considered reasonable for super-critical longwall geometries where panel widths are greater than the critical width (i.e. 1.2 - 1.4H) and the height of fracturing is likely to be controlled primarily by the mining height and strata properties.

Using the analytical model equations derived in **Section A11.4.2**, the progression of the height of continuous fracturing was back analysed by DgS using the maximum compressive beam stress for spanning strata units under full loading conditions (Equation 1) and goaf supported strata units (Equation 2):

$$\sigma_c = 0.75\gamma(H - A)(W - 2A\tan\theta)^2/t_i^2 \qquad \text{(Lower Beam)} \qquad (1)$$

$$\sigma_c = 4\Delta E t_i/(W - 2A\tan\theta)^2 \qquad \text{(Upper Beams)} \qquad (2)$$

It was noted that the goaf did not ‘bulk’ in the model, resulting in no reduction in subsidence between the seam and surface (i.e. $S_{max} = T$) and measured surface strain/curvature ratio indicated $\Delta = 0.5T$ over the effective span, $W_i = W - 2y\tan\theta$ above the goaf.

The results of the model are summarized in **Table A5** below:

## Table A5 - Physical Model Results Summary for the Height of Continuous Fracturing Development above a Supercritical Longwall Panel

| Lift No | Mining Height T (m) | $S_{max}$ (m) | $E_{max}$ (mm/m) | A (m) | Effective Beam Span $W_i$ (m) | Measured Beam Curvature in Spanning Strata ($km^{-1}$) | Measured Effective Beam Thickness $t_i$ (m) | Stress in Lowest Beam after Lift & Prior to Collapse (MPa) | Stress in Spanning Unit above Goaf (MPa) | Predicted Minimum Beam Thickness Required to Span Goaf (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.2 | 1.2 | 7.6 | 23.96 | 137.55 | 0.51 | 105 (47.9) | 12.0 | 4.82 | **56.7** |
| 2 | 2.4 | 2.4 | 15.3 | 43.26 | 120.77 | 0.66 | 81 (38.6) | 12.5 | 7.81 | **43.6** |
| 3 | 4.2 | 4.2 | 26.8 | 67.38 | 107.25 | 1.46 | 62 (24.1) | 17.3 | 6.55 | *26.6* |
| 4 | 6.0 | 6.0 | 38.2 | 85.60 | 90.36 | 2.94 | 38 (18.2) (9.1) | 13.8 | 10.10 | *10.8* |
| 5 | 8.4 | 8.4 | 53.5 | 99.57 | 77.60 | 5.58 | 19.4 (14) (7) | 19.2 | 7.45 | *5.6* |
| 6 | 10.8 | 10.8 | 68.8 | 105.0 | 67.81 | 9.39 | 5.4 (2.7) | 12.5 | - | *3.0* |

Wi = Effective Span above mine workings at A-Zone Limit Horizon (W - 2Atanθ).
(9.1) - Bedding thickness halved as bedding sheared under load > it's shear strength during test.
**Bold** - stress limited to UCS based on full cover load (Equation 1).
*italics* - stress limited to UCS based on deflecting strata curvature (Equation 2).
UCS = 10.94 MPa; E = 984 MPa; $\theta=19.3^{o}$.

The measured strata unit thickness ($t_i$) required to span the goaf voids and limit the height of continuous fracturing (A) after each successive lift were back-analysed using the measured A-Zone heights and Equation (2); see **Figure A40g**. The minimum beam thickness required to span the goaf was also estimated based on the two analytical model Equations (1) and (2) and compared to the measured beam thickness at the A-Horizon in **Figure A40h**.

Several further salient points are apparent from the results as follows:

- After extraction of the panel, all of the spanning units deflected under gravity loading until the tensile, shear and compressive stresses in some of the rock mass bedding units were exceeded.

- It was apparent from the modelling data that the overburden above each mining stage resulted in the beam shearing into two or three separate beams, with the lower beam collapsing and the upper beam(s) left to span the void. It is noted that the maximum shear stress acting on the initial beam would have developed on the bedding surface near the middle of the beam section, so it would be expected to shear or slip there first.

- If the strata unit separated from the overlying rock mass, it either collapsed into the void below (if the stress exceeded the UCS of the beam) or it was thick enough to span under its own self weight. The sagging beam units were also supported by the underlying goaf to some degree.

- The rock mass units caved up into the overburden at an angle of break (θ) and effectively reduced the span of overlying units to $W_i = W-2y\tan(\theta)$.The potential load acting on the strata units also decreased linearly with the reduction in overlying cover.

- The height of continuous fracturing (i.e. the A-Zone) was defined as the point where the overlying strata were spanning the cracked and collapsed strata below it.

- The A-Zone height increased after the mining height T was increased, with no change to panel width or cover depth.

- The strata units continued to deflect after each incremental increase in mining height, with the lower units collapsing when the UCS of the beam was exceeded. In some of the lifts, it is apparent that the spanning strata units sheared into units that were approximately half the thickness of the original spanning beam. The beam stress was also subsequently decreased if shearing occurred. Estimates of shear stress at mid-beam thickness exceeded the shear strength of the strata unit (or bedding plane surface) in these instances, assuming a friction angle of $20^o$ along the bedding planes.

- The spanning strata lost stiffness when their thickness was decreased, resulting in further deflection (and stress acting in the beam).

- Collapsed strata units provided support to the sagging strata above and ultimately controlled the deflection of the overlying units.

- The A/T ratio ranged from 20 to 10 as the mining height increased from 1.2 m to 10.8 m. For real world mining heights of 2.4 m to 6 m, the A/T ranged from 18 to 14.

Further discussion on the analytical height of fracturing models for real world conditions is presented in **Section A11.4.2**.

### A11.3.3 Forster and Enever, 1992

A comprehensive monitoring program above two supercritical pillar extraction and one longwall panel in the Great Northern Seam was presented in **Forster and Enever, 1992**.

The outcomes of the work was to recommend a reduction in the minimum rock cover limit required to extract coal beneath Lake Macquarie to 45T + 10 m, and was based on borehole piezometric and rock mass permeability testing before and after total extraction mining. The 10 m was not added to account for the surface cracking zone, but to allow for localized depressions that could reduce the rock cover thickness to < 45T. The surface cracking zone of <15 m was therefore included in the 45T+10 m criterion.

The height of continuous fracture zone was assessed to have ranged between 21T and 33T above the mine workings. The thickness of the Constrained Zone was defined as being dependent on the cover depth, but should be > 12T + 10 m below tidal waters.

The thickness of the 'Constrained Zone' above the 'Fractured Zone' was also considered to have greater importance in regards to providing a groundwater drainage path barrier than the tensile strain limit of 7.5 mm/m set by **Wardell, 1975**. It was considered that the thickness of the Constrained Zone and the presence of low permeability lithologies, such as mudstone and claystone, were more likely to influence the performance of the strata barrier above the A-Zone than putting a limit on surface strain. The strain limit criterion has subsequently been left out of sub-aqueous mine design criteria in NSW Coalfields.

### A11.3.4 ACARP, 2006

This report reviews the impacts of shallow longwall mining on the groundwater systems based on fieldwork conducted in the Hunter Valley, NSW (Beltana Mine) and Bowen Basin, Queensland (Gregory Crinum Mine).

The **ACARP, 2006** report suggests that continuous cracking is likely to occur through the strata beams within the Fractured Zone defined by an "angle of break" of $12^o$ to the vertical and extending inwardly from the rib-sides. International research suggests a range between $10^o$ and $15^o$.

A complementary set of fractures would also be expected to develop further inside the panel on the undersides of the bending units where full subsidence develops in the strata. The angle to full subsidence ranges from $25^o$ to the vertical according to **ACARP, 2006** and from $32^o$ to $45^o$ in **Li and Cairns, 2000**.

Back analysis of the angles of break suggest that surface to seam cracking could theoretically reach the surface above panels that are wide enough to prevent the opposing cantilevering abutments to interact together and limit fracturing. For a panel width of 200 m, this would occur where cover depths are < 370 m to 470 m (due to angles of break of $12^o$ to $15^o$). It is also noted that the inferred height of fracturing is very sensitive to the assumed angle of break.

*Note: The panel geometry discussed is actually still in the sub-critical range (i.e. W/H < 0.7) and it is considered by DgS that theoretical fracturing to the surface can only occur in the critical to supercritical panel width range.*

**ACARP, 2006** also notes an absence of surface to seam fracturing connection or groundwater inflows in the literature, where sub-aqueous mining has occurred below a depth of cover of 120 m to 160 m (for assumed critical to super-critical panel widths). The reason for this phenomenon is considered to be related to the observation that cracked and rotated blocks may still interact and provide low permeability regions in the zones of compressive strain above and below tensile cracking in the deflected beams. It was assessed that the reduction in effective span due to the cantilever effect over the ribs and increase in support that develops to overlying strata units may also allow strata units as thin as 10 m or so span across the fractured zone.

The report concluded that the height of continuous fracturing is therefore likely to be controlled by either spanning strata units or units that are not spanning which are thick enough to stop fracturing occurring right through the unit.

In the case of the non-spanning strata mechanism, **ACARP, 2006** did not have the resources available to fully evaluate what the minimum strata thickness range is likely to be in order to limit the continuous fracturing height.

*Note: A similar conclusion was reached by DgS after a case by case review by DgS of supercritical longwall geometries in the NSW Coalfields in this study. It is also considered likely that this phenomenon would require the compressive stress in the deformed rock mass units to exceed their unconfined compressive strength for complete break-through to occur. However, it is also apparent that the presence of thin strata units that deform predominately in shear along slipping bedding partings, can also limit vertical cracking developing to the surface cracking zones.*

### A11.3.5 MSEC, 2011 and SCT, 2001

The MSEC and SCT models are based on several published case-studies for mining impacts in the NSW Coalfields and their own internal analytical and numerical modeling results. The ‘heights of fracturing’ are predicted based on longwall and total pillar extraction panel widths and indicate maximum values ranging from 1W to 1.5W (SCT) and 1.374 (W-30) (MSEC). The database of ‘observed heights of fracturing’ and the above panel width models are presented in **Figure A40i**.

Based on a review by DgS of the database from which the MSEC and SCT models are derived, and extensometer and vertical strain measurements at other mines, it is apparent that the models include cases of both A and B-Zone fracture heights (see **Figure A40j** and **Section 11.4** for further details). DgS concludes that the MSEC and SCT ‘height of fracturing’ models are probably conservative.

It is also apparent that there are three reported cases in the database which indicate ‘fracturing through to the surface’ has occurred (LW1 at Invincible, LW11 at Angus Place and LWE1 at South Bulga). A review of the extensometer data published by **Holla, 1991** for the Invincible case study, DgS concurs with the assessment that continuous fracturing has probably extended to the surface cracking zone (or to within 10 m below the surface). No data is available for the latter two cases, however, based on the above discussion, it is considered possible that surface to seam connectivity of the B-Zone (and not the A-Zone) occurred at these sites (further discussion on these sites are included in the following sections).

### A11.3.6 Bulli Seam PAC, 2010

The NSW Government Planning and Assessment Commission (PAC) for the Bulli Seam Project Application in 2010 identified several apparent deficiencies in the commonly used ‘height of sub-surface fracturing’ models as follows:

- It is apparent that the prediction models based on panel width only indicated significantly greater sub-surface fracture heights than the models based on mining height.

- The panel width only-based models did not distinguish between continuous and discontinuous fracture heights.

- The authors and reviewers of the prediction models all recognize the deficiencies in the height of fracturing models that are based solely on panel width or mining height. They also indicate that more thorough analysis is probably required to determine a 'more definitive' function that relates the height of connective cracking to the mining geometry.

Based on the PAC report and review of available published data the following comments are made by DgS:

- The data on which the Panel Width-Only models are based are likely to include both A and B type fracturing zones (hence the review of MSEC and SCT database presented in **Figures A40i** & **A40j**).

- The Panel Width only models appear to have been developed mainly from data obtained at deep, sub-critical mines of the Southern and Western Coalfields.

- The height of fracturing is considered unlikely to extend further up into the strata once the critical panel width is reached (for a given mining height) and no further deformation of the overburden can occur.

- The behaviour of the overburden is more likely to be influenced by panel width for sub-critical panels and mining height for supercritical panels.

### A11.3.7 State of the Art Summary and Gap Analysis for Alternative Models

In summary, the literature review outcomes indicate the following:

- The A-Zone is assessed to range from 21T to 33T above supercritical panels and up to 43T above critical and sub-critical panels. The B and C-Zone thicknesses will generally depend on the cover depth less the A-Zone Horizon estimate.

- The models that are based on the longwall panel widths only indicate maximum 'heights of fracturing' that range from 1.0W to 1.5W (SCT) and 1.374(W-30). These models however, probably include both A and B-Zone fracture heights in some instances and are therefore likely to be conservative.

- It is apparent that the published height of fracturing models based on mining height alone varies significantly for supercritical, critical and sub-critical mining geometries.

The A-Zone could (and does) extend higher up into the overburden above sub-critical panel geometries as the fracturing due to strata deformation is also influenced by the panel width.

- It is also reasonable to assume that the maximum height of the A-Zone will probably occur above the centre of a sub-critical longwall panel with a naturally spanning catenary arch.
- Surface drilling investigations above subsided longwall panels in NSW and QLD have found the maximum height of fracturing is in fact ‘dome-shaped’ and develops somewhere between the point of maximum tensile strain and the centre of the panels.
- In order to distinguish between A and B-Zones it is considered best-practice to install borehole extensometers and multiple-piezometers (deep and shallow) above longwall panels and measure the various fracture and dilated zones based on anchor displacements, vertical strain and the short to medium term impacts to established groundwater regimes.
- When longwall mining beneath lakes and sensitive groundwater aquifers, it is essential that the mining geometry be controlled to provide an effective B/C-Zone or Constrained Zone thickness to minimise the potential for connective cracking to develop up to the feature. The presence of geological structure should also be considered as it may act as a potential groundwater conduit between the A and B-Zones.
- Based on **Forster and Enever, 1992**, the minimum Constrained Zone (B/C Zone) thickness above the Fractured A-Zone should be >12T + 10 m and include the surface cracking zone thickness of <15 m beneath Lake Macquarie. The minimum B/C Zone thickness does not include weathered material and/or alluvial sediments.
- For cases where permanent water bodies do not exist, but surface to seam hydraulic connection is not desirable, it is recommended that the continuous height of fracturing zone should not encroach within the surface cracking zone (ie. A minimum of 10 m to 12 m below the surface should be assumed generally, but may need to be increased up to 20 m for steep topography affects).
- As mentioned earlier, the height of A-Zone fracturing is strongly dependant on the presence of the bridging capability of massive conglomerate or sandstone units above a given panel. Therefore, estimating the height of A and B-Zone fracturing also requires a review of the overburden lithology and the presence of geological structure.
- It is also apparent from a case by case review, that the height of fracturing may be controlled by strata that is not actually spanning, but may be thick enough or flexible enough to stop fracturing occurring right through the strata unit. For this scenario, it is considered the height of fracturing will be controlled by (i) the thickness and/or flexibility of the strata unit relative to the panel width and its location above the

workings, (ii) the thickness of compressible goaf material that will induce curvature in the overlying strata units as the goaf is compressed, and (iii) the presence of confined, semi-impermeable strata units such as mudstone and claystone in the B and C-Zones that will swell in the presence of groundwater and effectively seal off small width cracks.

- For the case of sub-critical panels, the maximum non-spanning strata height and load acting on the goaf may be limited by the 'natural' or catenary arch that can form across the mined void width. It is noted that the A-Zone has not intersected the surface above any of the 13 sub-critical longwall panels in the NSW Coalfields.

- For super-critical panels however, the height of fracturing could theoretically reach the surface and the maximum load acting on the goaf will probably equal the cover depth. It is noted that the A-Zone has not intersected the surface above critical and supercritical panels at 17 out of 20 longwalls (85%) in NSW and Queensland Coalfields.

- Near surface geology will affect the potential for surface cracking to intersect the sub-surface fractures above supercritical longwall panels. Based on physical modelling results and mine site case studies, thinner and weaker strata units may actually reduce the likelihood of cracking zone interconnection compared to thicker and stronger units.

- Subsidence effect data (i.e. Horizontal strain/curvature ratios or K Factors) also suggest that the near surface strata will behave like a beam with a thickness equal to twice this ratio or the observed cracking depths (i.e. the depth to the neutral axis of bending). For the Newcastle Coalfield, the effective beam thickness ranges from 10 m to 30 m (i.e. K Factors of 5 to 15). The Western and Southern Coalfields have effective beam thickness ranges from 30 m to 60 m (i.e. K Factors of 15 to 30).

Based on the HoF prediction model review, it was considered necessary in this study to:

(i) review and expand the database of continuous and discontinuous cracking to include a representative range of mining geometries on which to base the empirical models on;

(ii) update and re-evaluate the **ACARP, 2003** models;

(iii) attempt to develop further subsurface fracturing models that included the panel width, mining height, cover depth and lithology (effective strata unit thicknesses and their properties).

(iv) provide a clearer definition of the surface cracking depth (D-Zone).

## A11.4 Expansion of the Database and Review of Sub-Surface Fracturing Prediction Models Presented in ACARP, 2003

A recent review of the **ACARP, 2003** database and the inclusion of new HoF data has recently been undertaken by DgS in 2012 and 2013 for various projects in the Newcastle/Lake Macquarie and Hunter Valley Coalfields. The up-dated database is presented in **Table A6.1** and includes a greater number of cases where A and B-Zone fracture heights have been determined from borehole extensometer and piezometeric data collected over a reasonable period of time (i.e. > 12 months after mining impacts). Surface and groundwater interaction may also be established by other means in the absence of piezometers and extensometer results (e.g. mine water make increases several days or weeks (instead of months) after rainfall events, would indicate direct hydraulic connection to the surface).

The measured coalfield data base presented in **ACARP, 2003** was based mainly on a dataset of post-mining drilling data to estimate heights of fracturing for the A and B-Zones (except for the **Forster and Enever, 1992** data). The updated model database now includes further extensometer and/or piezometric data from the Southern, Western and Hunter Valley Coalfields in NSW, including Newcastle (West Wallsend, Mandalong, Wyee, Cooranbong, Teralba), Lower Hunter Valley (Abel, Austar, Ellalong); the Upper Hunter Valley (Homestead, Ashton, South Bulga), Southern Coalfield (Berrima, Metropolitan, Kemira, Belambi West, West Cliff, Tahmoor, Dendrobium, Appin) and the Western Coalfield (Springvale, Invincible). Two cases for Queensland (Oaky Creek and Crinum) were also included in the database.

Based on a review of published extensometer results presented in **Holla, 1991**, **Frith, 2006, MSEC, 2011** and **ACARP, 2007**, it is assessed that there are six cases in the database presented in **MSEC, 2011** that appear to include the A and B-Zones and four cases whereby the ‘height of fracturing’ are claimed to have reached the surface at distances above the workings of 21T (Homestead Mine, LWs 9/9A), 39T (Invincible Colliery, LW1), 57T (South Bulga, LWE1) and 106T (Angus Place, LW11).

In order to use the height of fracturing data presented in **MSEC, 2011** with the **ACARP, 2003** data, it was necessary to identify the likely A-Zone cases and B-Zone cases based on the following fracture zoning criteria:

(i) A-Zones are likely to have vertical strains > 20 mm/m and large strata dilations > 200 mm; and

(ii) B-Zones are likely to have vertical strains of < 8 mm/m and strata dilations < 200 mm, based on measured values for cases with piezometer-established B-Zone strains measured at other mines.

*Note: it does not necessarily follow that uniform vertical strains throughout the strata mean the height of continuous fracturing is likely to have reached the surface. The uniform strains may also be due to strata bedding dilations if strains are < 8 mm/m. Rock mechanics theory also indicates that a vertical tensile strain of 8 - 9 mm/m will induce a horizontal tensile strain of 2 - 3 mm/m in the rock mass due to*

> *Poisson's ratio effect. The theoretical strain to fracture a joint-free sample of rock is 0.3 to 0.6 mm/m. It has been observed in the field that existing joints and bedding in the rock mass allow it to 'absorb' higher levels of tensile strain before developing fresh cracks at around 2 - 3 mm/m. The use of the proposed vertical strain of 8 mm/m is therefore considered to be a reasonable indicator that fresh cracking is likely to occur in the rock mass.*

The following cases were changed from A to B-Zone fracturing horizons or reinterpreted by DgS based on the above criteria:

- Tahmoor LW3 (extensometer interpretation by **Holla & Buizen, 1991**)
- Westcliff / Endeavour Drift BH3 (post-mining bore interpretation by **MSEC, 2006**)
- Angus Place LW11 (fractures to surface interpreted by **Kay, 1990**)
- Springvale LW411 (extensometer & piezometer interpretation by **CSIRO, 2007**)
- Springvale LW409 (piezometer interpretation by **CSIRO, 2007**)
- Ellalong LW2 (extensometer interpretation by **Holla, 1986**)

The height of continuous fracturing for LWE1 at South Bulga (**SCT, 2000**) has been assumed to extend to within 10 m of the surface and into the surface cracking zone as the extensometer or piezometric data is not available to review at this stage.

The assessment in **Kay, 1990** that the height of fracturing above LW11 at Angus Place extended to the surface was well above previous ranges (106T) measured at the mine to-date. Further discussions by the mine with the author recently indicates that a 100 m high cliff face probably affected the overburdens spanning capability, resulting in a greater than normal level of subsidence and near surface cracking. Although the surface flows in the creeks may have been re-routed into near surface cracks at the time, it is not likely that a surface to seam connection occurred.

It has also been decided to remove two case study points (Central and Southern German Creek Mines) from the original **ACARP, 2003** data base as they appear to be much lower than other cases with similar geology and geometry and were based on drilling data only.

The results of the database review and re-assignment of A- to B-Zones are shown in **Figure A40j** with the reinterpreted values summarised in **Table 6.1.** A summary of several representative extensometer results that were used to review the published heights of fracturing data presented in **Table A6.1** are provided in **Table A6.2**.

The expanded database presented in **Table A6.1** has subsequently been used to (i) update the strain and curvature index-based models presented in **ACARP, 2003** and (ii) develop more technically concise models that allow variations in geology and geometry to be assessed in each coalfield. The results are presented in the following sections.

## Table A6.1 - Updated HoF Model Database for Australian Coalfields

| Site | Panels | Mine | Seam | W (m) | H (m) | W/H | T (m) | A (m) | B (m) | A/T | ACARP 2003 Model Predictions | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | t^ (m) | y^ (m) | Unit SRP* | U95% CL $S_{max}$ (m) | U95% CL $E_{max}$ (mm/m) |
| 1 | MW508 | Bellambi W. | Bulli | 110 | 421 | 0.26 | 2.50 | 92 | - | 37 | 100 | 90 | High | 0.30 | 2 |
| 2 | LW10 | Metropolitan | Bulli | 140 | 460 | 0.30 | 3.40 | 130 | - | 38 | 100 | 130 | High | 0.29 | 3 |
| 3 | LW1-4 | South Coast | Bulli | 110 | 325 | 0.34 | 2.50 | 85 | - | 34 | 100 | 85 | High | 0.24 | 3 |
| 4 | LW6 | Kemira | Wong. | 117 | 335 | 0.35 | 2.75 | 98 | - | 36 | 100 | 98 | High | 0.16 | 2 |
| 5 | LW20 | Metropolitan | Bulli | 163 | 450 | 0.36 | 3.40 | 100 | - | 29 | 100 | 100 | High | 0.34 | 2 |
| 6 | LWA1 | Austar | Greta | 159 | 417 | 0.38 | 6.00 | *87* | 277 | 15 | 100 | 80 | High | 0.56 | 4 |
| 7 | LW514 | Bellambi W. | Bulli | 150 | 400 | 0.38 | 2.70 | 90 | - | 33 | 100 | 90 | High | 0.29 | 2 |
| 8 | LW28 | Appin | Bulli | 200 | 500 | 0.40 | 2.30 | 90 | - | 39 | 120 | 90 | *High* | 0.27 | 1 |
| *9* | *LW2* | *Ellalong* | *Greta* | *150* | *368* | *0.41* | *3.50* | *113* | *210* | *32* | 100 | 113 | *High* | *0.40* | *3* |
| *10* | *LW3* | *Tahmoor* | *Bulli* | *180* | *424* | *0.42* | *2.18* | - | 204 | - | 100 | 100 | *High* | *0.29* | *2* |
| 11 | LW9 | Teralba | YW | 150 | 350 | 0.43 | 2.70 | *110* | 150 | 41 | 34 | 110 | High | 0.32 | 2 |
| *12* | *TE* | *West Cliff* | *Bulli* | *200* | *446* | *0.45* | *2.50* | *101* | *245* | 40 | 100 | 101 | *High* | *0.30* | *1* |
| 13 | TE | Berrima | Wong. | 120 | 176 | 0.68 | 2.3 | 76 | 112 | 33 | 100 | 76 | High | 0.50 | 3 |
| 14 | *LW409* | *Springvale* | *Lithgow* | *265* | *385* | *0.69* | *3.25* | *133* | *254* | 41 | 55 | 133 | High | *0.6* | *3* |
| 15 | LW9 | Mandalong | WW | 160 | 220 | 0.73 | 4.50 | - | - | - | 30 | 160 | High | 0.5 | 3 |
| 16 | ***LW11*** | ***Angus Place*** | ***Lithgow*** | ***211*** | ***263*** | ***0.80*** | ***2.47*** | **-** | ***253*** | **-** | 100 | ***253*** | High | ***0.5*** | ***3*** |
| 17 | *411* | *Springvale* | *Lithgow* | *315* | *368* | *0.86* | *3.25* | 139 | 288 | 43 | 55 | 139 | High | *0.68* | *5* |
| 18 | LW5 | Mandalong | WW | 160 | 179 | 0.89 | 3.70 | 118 | 154 | 32 | 25 | 83 | *Mod* | 1.38 | 3 |
| 19 | LW5 | Dendrobium | Wong. | 245 | 255 | 0.96 | 3.75 | 123 | - | 33 | 80 | 123 | High | 1.25 | 5 |
| 20 | LW1 | Wyee | Fassifern | 216 | 206 | 1.05 | 3.44 | 126 | - | 37 | 30 | 126 | High | 1.09 | 5 |
| **21** | **LW1** | **Invincible** | **Lithgow** | **145** | **116** | **1.25** | **2.70** | **106** | ***111*** | **39** | **15** | **106** | **Low** | **1.62** | **16** |
| 22 | TE1 | Abel | U. Don. | 120 | 95 | 1.26 | 2.55 | 45 | *75* | 20 | 15 | 41 | Low | 1.51 | 22 |
| 23 | LWs | Ashton | Pikes Gully | 216 | 154 | 1.40 | 2.55 | 82 | *130* | 32 | 30 | 82 | Low | 1.5 | 15 |
| 24 | LW40 | WWC | WBH | 179 | 113 | 1.58 | 3.80 | 80 | *108* | 21 | 20 | 80 | Low | 2.28 | 21 |
| **25** | **LWE1** | **Sth Bulga** | **Whybrow** | **259** | **155** | **1.67** | **2.55** | **145** | **150** | **57** | **20** | **145** | **Low** | **1.53** | **8** |
| 26 | LW41 | WWC | WBH | 179 | 105 | 1.70 | 3.80 | 72 | 100 | 19 | 20 | 72 | Low | 2.28 | 24 |
| 27 | LW9 | Crinum | Lillyvale | 280 | 155 | 1.81 | 3.50 | 85 | *150* | 24 | 35 | 105 | High | 1.82 | 8 |
| 28 | LW39 | WWC | WBH | 179 | 97 | 1.84 | 3.90 | 68 | 92 | 17 | 20 | 68 | Low | 2.18 | 25 |
| 29 | TE-3D | Wyee North | GN | 355 | 185 | 1.92 | 1.90 | 63 | *143* | 33 | 50 | 63 | High | 1.14 | 4 |
| 30 | TE-355 | Wyee North | GN | 355 | 180 | 1.97 | 1.90 | 40 | - | 21 | 50 | 40 | High | 1.14 | 4 |
| 31 | Panel2 | Abel | U. Don | 150 | 76 | 1.97 | 1.88 | 45 | 71 | 24 | 15 | 33 | Low | 1.13 | 23 |
| 32 | TE-Nth B | Cooranbong | G.N | 150 | 75 | 2.00 | 2.80 | 58 | *70* | 21 | 20 | 58 | Low | 1.68 | 33 |
| 33 | LW1 | Oaky Ck | German Ck. | 205 | 95 | 2.16 | 3.20 | 55 | *90* | 17 | 30 | 55 | Low | 1.92 | 25 |
| **34** | **LW9/9a** | **Homestead** | **Whybrow** | **200** | **80** | **2.50** | **3.40** | **75** | **75** | **23** | **15** | **65** | **Low** | **1.98** | **29** |

- = not available; **bold** - surface to seam fracturing assessed by others; *italics* - Continuous Fracture Zone heights (A-Zone) was originally reported by others and included the Discontinuous Fracture and Dilated Zone (B-Zone). A and B- Zone height of the B-Zone heights were re-assessed by DgS based on a review of available measured vertical strains and piezometric data (see **Figure A40i and A40j**); No shade - Sub-critical panels (W/H<0.7); Light grey shade - Critical panels (0.7<W/H<1.4); Grey shade - Supercritical panels (W/H>1.4).
* - SRP = Subsidence Reduction Potential for strata unit with thickness t and distance y above the workings. The SRP may be due to spanning or bulking behavior over the range of W/H and is also considered to be an indicator of whether a strata unit will limit the height of continuous fracturing; ^ - likely values assessed from borehole and subsidence data; Wong. = Wongawilli; YW= Young Wallsend; WW = West Wallarah; U. Don = Upper Donaldson; WBH = West Borehole; GN - Great Northern.

## Table A6.2 - Summary of Measured A, B, C & D Zone Strains in Extensometers*

| **Parameter** | **Underground Coal Mines** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Angus Place$^\$$** | | **West Wallsend** | | | | **Abel^** | | | |
| Panel No. | LW11 | | LW39 | | LW40 | | Panel 1 | | Panel 2 | |
| Cover Depth H (m) | 211 | | 97 | | 113 | | 95 | | 76 | |
| Panel Width W (m) | 263 | | 179 | | 179 | | 120 | | 150 | |
| W/H | 0.8 | | 1.84 | | 1.58 | | 1.26 | | 2.0 | |
| Mining Height, T | 2.5 | | 3.8 | | 3.9 | | 2.1 | | 2.1 | |
| **Fracture Zone** | Dilation (mm) | **Strains$^\#$ (mm/m)** | Dilation (mm) | **Strains$^\#$ (mm/m)** | Dilation (mm) | **Strains$^\#$ (mm/m)** | Dilation (mm) | **Strains$^\#$ (mm/m)** | Dilation (mm) | **Strains$^\#$ (mm/m)** |
| *D-Zone* | - | ***3 - 5*** | - | ***25*** | - | ***24*** | - | ***24*** | - | ***23*** |
| C-Zone | - | **-** | - | **-** | - | **-** | - | **-** | - | **-** |
| B-Zone | ~60 - 120 | **5 - 6** | 8 - 17 | **1 - 2** | 25 - 50 | **5 - 8** | 14 - 19 | **1 - 2** | <20 | **-1 - 0** |
| A-Zone | ~1000 | **100** | 234 - 957 | **115 - 139** | 390 - 769 | **39 - 77** | 279 - 1289 | **28 - 129** | 158 - 185 | **16 - 19** |

| **Parameter** | **Mandalong** | | **Austar** | | **Ellalong** | **Invincible** | **Tahmoor** |
|---|---|---|---|---|---|---|---|
| Panel No. | LW5 | | LWA1 | | LW2 | LW1 | LW3 |
| Cover Depth H (m) | 179 | | 453 | | 368 | 116 | 424 |
| Panel Width W (m) | 160 | | 159 | | 150 | 145 | 180 |
| W/H | 0.89 | | 0.35 | | 0.41 | 1.25 | 0.42 |
| Mining Height, T | 3.7 | | 6.0 | | 3.5 | 1.26 | 2.2 |
| **Fracture Zone** | Dilation (mm) | **Strains$^\#$ (mm/m)** | Dilation (mm) | **Strains$^\#$ (mm/m)** | **Strains$^\#$ (mm/m)** | **Strains$^\#$ (mm/m)** | **Strains$^\#$ (mm/m)** |
| *D-Zone* | - | ***5*** | - | ***3*** | ***3*** | ***10*** | ***1*** |
| C-Zone | <20 | **<1** | <10 | **<1** | **<1** | **-** | **<1** |
| B-Zone | 19 - 29 | **2 - 5** | 24 - 133 | **1 - 7** | **1 - 5** | **<5** | **1 - 4** |
| A-Zone | 73 - 672 | **80** | 222 - 1177 | **11 - 59** | **>10** | **10 - 75** | **N/A** |

* - A, B & C-Zone strains are vertical and approximately 3 to 4 times the horizontal strain due to Poisson's ratio effect; *italics* - D-Zone strains are horizontal.

# - tensile strains are positive. Negative strains or compression develops after full subsidence occurs and goaf compresses under load from sagging overburden strata; ^ - Effective mining height for total pillar extraction (Te = 0.85T); $ - Strain data not available and quoted from published literature.

## Table A6.2 (Cont…) - Summary of Measured A, B, C & D Zone Strains in Extensometers*

| Parameter | Underground Coal Mine | | | |
|---|---|---|---|---|
| | Springvale | | | |
| Panel No. | LW411 | | LW412 | |
| Cover Depth H (m) | 368 | | 400 | |
| Panel Width W (m) | 315 | | 315 | |
| W/H | 0.90 | | 0.79 | |
| Mining Height, T | 3.25 | | 3.25 | |
| **Fracture Zone** | **Dilation (mm)** | **Strains$^{\#}$ (mm/m)** | **Dilation (mm)** | **Strains$^{\#}$ (mm/m)** |
| *D-Zone* | - | *3* | - | *3* |
| C-Zone | <42 | <5 | <33 | <5 |
| B-Zone | 39 - 410 | 4 - 10 (**17**) | 2 - 505 | 4 - 8 (**25**) |
| A-Zone | 194 - 1441 | 14 - 42 | 174 - 1571 | 5 - 42 |

* - A, B & C-Zone strains are vertical and approximately 3 to 4 times the horizontal strain due to Poisson's ratio effect; *italics* - D-Zone strains are horizontal.
# - tensile strains are positive. Negative strains or compression develops after full subsidence occurs.
^ - Effective mining height for total pillar extraction (Te = 0.85T).
**bold** - measure strain near the top of the B-Zone where a bedding separation occurred. Piezometer data indicates the height of continuous fracturing is further below this point.

### A11.4.1 Updated Tensile Strain Model

The physical model presented in **Whittaker and Reddish, 1989** related the ratio of the height of continuous and discontinuous fracturing (A and B) above longwall panels over cover depth (H) with the maximum tensile strain ($E_{max}$) at the surface due to mine subsidence. Actual drilling data over extracted longwall panel goaf was subsequently used to define a real-world relationship between these variables at several Australian Coalfield mines in **ACARP, 2003**.

The additional data presented in **Table A6.1** has been added to the original database and the regression equations have been revised below:

{A-Line} Mean A/H $= 0.180 \, \mathrm{Ln}(E_{max}) + 0.1405, \quad R^2 = 0.70$

U95%CL A/H* $= 0.180 \, \mathrm{Ln}(E_{max}) + 0.3742.$

{B-Line} Mean B/H $= 0.146 \, \mathrm{Ln}(E_{max}) + 0.5315, \quad R^2 = 0.47$

U95%CL B/H* $= 0.146 \, \mathrm{Ln}(E_{max}) + 0.8426.$

* - Maximum A/H and B/H = 1.

where

A, B = height above workings to A and B-Zone horizons,
H = cover depth,

$E_{max}$ = the maximum predicted tensile strain for a 'smooth' subsidence profile.

The new tensile strain model is presented in **Figure A41a** and has a much stronger fit to the new database for the A-Zone than the **ACARP, 2003** model, with only a slight improvement for the B-Zone horizon. The $R^2$ value for the logarithmic regression curve fitted to the revised A-Zone data was previously 0.44 and is now 0.70. The $R^2$ value for the B-Zone was previously 0.46 and is now 0.47.

The measured database model still appears to indicate a similar height of fracturing trend to the **Whittaker and Reddish, 1989** physical model. However, as was concluded in **ACARP, 2003**, the predicted heights of 'continuous' and 'discontinuous' fracturing in the real world were again higher for a given tensile strain at the surface, and probably due to the influence of jointing in the rock mass (compared to none in the physical model).

The real world database indicates that the tensile strain probably needs to be >32 mm/m for surface to seam connection to occur, and is approximately 50% of the physical model value of 60 mm/m. It should also be noted that if connective cracking is likely to extend into the Surface Cracking Zone (a depth of 10~15 m below the surface), then the maximum tensile strain for surface to seam connection reduces to 25 mm/m. It is assessed however, that the predicted strains are also dependent on surface crack width development and should therefore not be used to assess surface to seam connectivity directly without considering the near surface B and C-Zone lithologies.

Considering the potential difficulties with predicting strains after the onset of cracking, it is still assessed that it is unlikely that the tensile strain-based model will be reliable. **ACARP, 2003** attempted to modify the strain-based model to a curvature-based approach. The resulting regression equations however, did not improve the correlation between the adopted variables (i.e. both methods had $R^2$ values of 0.44). The curvature-based model of height of sub-surface fracture prediction was subsequently revised with the expanded model database in **Section A11.4.2** to see if the regression equations could be improved upon.

### A11.4.2 Updated Overburden Curvature Index Model

The Overburden Curvature Index or $S_{max}/W'^2$ term was introduced in **ACARP, 2003** in an attempt to provide a readily measurable field parameter that would not be compromised as much by surface strain concentration effects (i.e. cracking). The logarithmic regression lines were re-derived using the expanded database to give new predictions of the mean and U95%CL values for both A and B-Zones as follows:

{A-Line} Mean A/H $= 0.198 \ln(S_{max}/W'^2) + 1.1518$, $R^2 = 0.66$

U95%CL A/H* $= 0.198 \ln(S_{max}/W'^2) + 1.3915$.

{B-Line} Mean B/H $= 0.152 \ln(S_{max}/W'^2) + 1.3265$, $R^2 = 0.52$;

U95%CL B/H* $= 0.152 \ln(S_{max}/W'^2) + 1.5928$.

* - Maximum A/H and B/H = 1.

where

A, B = height above workings to A and B Horizons,

H = cover depth (m).

$S_{max}/W'^2$ = Overburden Curvature Index,

W' = lesser of W and 1.4H

*Note: It is reasonable to assume the effective mining width (W') and height of fracturing (A/B) will be limited beyond the point where the maximum subsidence or strata deformation has been reached above supercritical mining geometries (i.e. W/H > 1.4).*

The revised regression results are shown in **Figure A41b**.

Despite the apparent improvement in the regression equations, the same apparent differences still remain between the Australian height of fracturing database and the UK physical modelling results. One obvious difference is that the UK physical model represents a supercritical case study where the panel width and cover depth was constant (i.e. W/H = 1.34). The Australian database however, has a significant range of sub-critical, critical and super-critical panel geometries and further investigation of this difference is therefore required (see **Section A11.4.4**).

### A11.4.3 Influence of Lithology on Sub-Surface Fracture Heights

An assessment was made in **ACARP, 2003** on whether massive lithology had the potential to control or limit the height of fracturing above a longwall panel. The expanded model database presented in **Table A6.1** still indicates that it does, with the A-Horizon likely to have coincided with the base of the massive strata units in 17 out of 21 cases with 'Moderate' to 'High' SRP strata units.

The potential for massive strata units to mitigate the height of continuous fracturing above the workings should therefore not be ignored where subsidence magnitudes and HoF are clearly being controlled by spanning strata.

Overall, the HoF results suggest that the presence of massive sandstone or conglomerate lithology can control the height of hydraulic fracturing due to their spanning capability or thickness generally. However, as has been observed at Mandalong and Springvale Mines, the presence of geological structure (faults, dykes, seam rolls and shear zone or joint swarms) has resulted in a weakening of the overburden by the tectonic activity and there has been increased subsidence due to the breakdown of massive sandstone / conglomerate into several thinner units and (ii) increased shearing and tensile stress acting on the discontinuities has resulted in groundwater conduits developing deeper into the overburden.

It is therefore usually recommended that a mine undertake a sub-surface fracture-monitoring program which includes a combination of borehole extensometer and piezometer measurements during extraction in non-sensitive areas of the mining lease. Mitigation strategies for longwall mining are generally limited to (i) reducing the extraction height, (ii) decreasing the panel width and (iii) panel location adjustment. On-going monitoring of surface alluvium and near surface rock mass aquifers is also undertaken with standpipe piezometers to check the post-mining integrity of ground water dependent ecosystems (GDE) and surface water systems generally.

### A11.4.4 Height of Fracturing Angle Model, DgS 2012

Due to the currently held belief in the Australian mining industry that the sub-surface fracture heights are strongly influenced by panel width and mining height, an alternative model was developed by DgS in 2012 using a different approach to analysing the UK model data presented in **ACARP, 2003**.

Predictions of the heights of continuous and discontinuous fracturing (the A and B-Zone horizons) were re-analysed using the panel width, the mining height and a simple parabolic profile formula to estimate A and B-Zone fracture heights from a calibrated abutment angle at seam level ($\theta_A$ and $\theta_B$) as follows:

- Continuous Fracture Zone Height, $A = W'/(4\tan(\theta_A))$
- Discontinuous Fracture Zone Height, $B = W'/(4\tan(\theta_B))$

where,

W' = Effective Panel width or minimum of W and 1.4H.

$\theta_A$ = abutment angle to estimate height of A-Zone

$\theta_B$ = abutment angle to estimate height of B-Zone

When the UK model's fracture height data is plotted as a height of fracturing angle (estimated from an assumed parabolic fracturing profile between rib abutments), a strong correlation is apparent between the mining height for a given panel width and cover depth (W/H = 1.34); see **Figures A41c** and **A41d** for A and B-Zone Horizons respectively.

The regression analysis indicates the following fracture height angles (in degrees) apply for estimating A and B-Zone fracture heights in the real world:

$\theta_A = 41.617T^{-0.467}$ (mean) and $25.083T^{-0.401}$ (lower 95%CL)

$\theta_B = 21.806T^{-0.233}$ (mean) and $17.295T^{-0.238}$ (lower 95%CL)

Real world fracture height data measured with piezometers and borehole extensometers indicates a similar trend as the physical model results, although there is more scatter in the data that is probably due to both mining geometry (W/H) and geological variability.

The UK physical model assessed mining heights of 1.2 m to 10.8 m, and generated fracture height angles at the abutments ranging from $55^o$ to $18^o$ for the A-Zone and from $37^o$ to $18^o$ for the B-Zone horizon. The fracture height angle tends to follow a decaying power law as the mining height increases.

For real-world mining heights of 1.9 m to 6.0 m (median of 3.0 m), the calibrated fracture height angles range from $34^o$ to $18^o$ for the A-Zone, and from $22^o$ to $13^o$ for the B-Zone. One A-Zone case had a fracture height angle of $58^o$ due to the apparent 'truncating' effect of a 40 m thick conglomerate strata unit 40 m to 60 m above a supercritical panel in the Great Northern Seam (Wyee Colliery's North-3D Panel).

As was found in the strain and curvature-based model's, the presence of pre-existing jointing in the rock mass is likely to have contributed to greater fracture heights determined from the field data compared to the laboratory model.

The effect of massive strata units is apparent in the database (see **Figure A41c**) and further measurements are necessary to develop a more discerning prediction model that allows 'Low' and 'High' SRP strata to be assessed separately using this model. The height of fracturing model proposed at the time was considered likely to be conservative for greenfields sites if based on the lower bound fracture height angles and to give upper bound fracture height predictions.

Further review of sub-critical, critical and supercritical panel case studies in 2013 has found that the A and B-Zone fracture height angle model could also be further divided into sub-critical, critical and supercritical panel geometries (see **Figure A41e** and **A41f**) as follows:

$\theta_A = 32.448T^{-0.241}$ for the mean fracture height angle.

*Upper 95%Confidence limits for the A-Zone were estimated by reducing the mean angle by $5^o$, $7^o$ and $10^o$ for supercritical, critical and sub-critical longwalls respectively.*

$\theta_B = 31.5T^{-0.373}$ for the mean fracture height angle for supercritical panels
$= 25.4T^{-0.373}$ for the mean fracture height angle for critical/sub-critical panels

*Upper 95%Confidence limits for the B-Zone were estimated by reducing the mean angle by $3.5^o$, $7^o$ and $7^o$ for supercritical, critical and sub-critical longwalls respectively.*

The review outcomes suggest that heights of subsurface fracturing appear to increase above sub-critical panels for a given mining height, but are also likely to be due to the panel width and changes in macro-scale structural behaviour of the overburden as well.

Whilst the trend from sub-critical to supercritical panel geometries appears reasonably consistent across the abutment angle model database (with a few cases where thick strata has clearly limited the fracture heights) it is noted that the predicted heights of fracturing are highly sensitive to the selected value of theta. It was therefore considered that a new modelling approach based on Dimensional Analysis and Buckingham's Pi-Theorem would be needed to reasonably establish definitive relationships between the key variables over a broader range of mining geometries and geological conditions.

## A11.5 Alternative Sub-surface Fracture Model Development

Starting with the influence of mining height (T) on the height of A-Zone fracturing, if we firstly consider a supercritical panel of a given width (W) and cover depth (H), **Whittaker and Reddish, 1989** and **Singh & Kendorski, 1991** each demonstrated that the height of continuous fracturing (A) will increase with the square root of the mining height, $T^{\sim 0.5}$, or a power rule of the form $A = aT^b$, as shown in **Figure A41g**. It is apparent that the database of real-world fracture heights with W/H range from 0.3 to 2.22 has greater scatter than the UK model curve for supercritical panel geometry, and therefore indicates that other factors such as the panel width and geology should probably be considered. The apparent under prediction of A-Zone fracture heights by the **Forster and Enever, 1992** model, also supports this view.

If the fracture heights are plotted against panel width (W) only, a similar ‘scattered’ outcome results as shown in **Figure A41h**. The conservative nature of the height of fracturing models presented by SCT and MSEC is also demonstrated in the figure and suggests that both A and B-Zones are included in their models.

A slightly improved regression analysis results if A is plotted against W/H in **Figure A41i** or when normalized to the panel width (A/W) and is plotted against T in **Figure A41j** for sub-critical, critical and super-critical panel geometries.

Based on these plots, it is clear that consideration needs to be given to the structural behavior of the overburden across the full range of mining geometries, its constituent strata units (or ‘beams’) and the influence of mining height, T on the development of fracture heights above longwall panels.

### A11.5.1 Strata Behaviour Mechanisms that Influence Fracture Heights above Longwalls

Based on structural analysis theories, a conceptual model of the macro-scale and micro-scale mechanisms of sub-surface fracture height development are described below and shown graphically in **Figure A42a**:

Macro-Scale Mechanisms:

- For sub-critical panels, a natural catenary will probably form and transfer the weight of the top half to 2/3 of the overburden to the abutments. The strata below the arch will be subject to sagging or bending forces caused by the void formation. Depending on the span and thickness of individual strata units, the strata in the immediate roof will bend, separate, crack and ultimately cave into the extracted coal void (see *Micro-scale Mechanisms* below).

- Natural catenary arching action infers that the spanning overburden can remain entirely in compression and there is an absence of tensile and shear or ‘bending’ stresses. Subsidence data indicates that catenary arching stops occurring once W/H exceeds 0.7.

- Once W/H exceeds 0.7, the overburden will still attempt to span, however, the geometry of the arch will be too shallow for a catenary arch to develop, resulting in bending and cracking of the rock mass.

- The load will still be able to be carried over the void by the overburden, provided the rock mass has adequate strength and stiffness to resist the applied bending moments and shear and tensile stresses (along with increased compressive stresses from inward strata block rotation). This type of behaviour is known as Voussoir or 'cracked beam' behaviour, and is basically a flatter, but a less stiff version of a catenary arch.

- Shallow arching or Voussoir beam action will continue across the panel until it can no longer support the span or weight of the shallow arch. This is usually assumed to have occurred once W/H reaches 1.2 to 1.4H. The weight of the overburden will then be fully supported by the goaf beyond this point and subsidence will be a function of the mining height and cover depth or goaf load.

- The above macro-mechanisms will influence the behavior of the overburden strata units and subsequent development of the sub-surface fracture heights as follows:

Micro-scale Mechanisms:

- Soon after the coal seam is extracted from beneath the overburden, its constituent 'beams' in the immediate roof will generally deflect and behave elastically until the tensile and shear stresses within the rock mass units exceed the material and/or bedding parting strength of the units.

- The strata units will subsequently crack at the abutments and mid-span and the confinement will be partially lost. The cracked beam segments will then rotate inwardly and create a shallow compression arch within the beams (Voussoir action) that may or may not support the load.

- The cracks in the beams at this stage are likely to be discontinuous, with the beam continuing to behave pseudo-elastically with zones of compressive stress above and below the tensile cracks.

- The beam will continue to span and deflect under the applied loading until the compressive strength of the beam is reached, where the beam will then either collapse into the available void, or yield and load the previously failed strata units and goaf below it.

- Based on the physical model results presented in **Whittaker and Reddish, 1989**, the beams may also shear into two or three thinner units before the lower units ultimately crush if their UCSs are exceeded. Bending beam theory indicates that the maximum shear stress will occur at mid-beam thickness. The beams are therefore likely to break down into half their thickness units each time shearing occurs along bedding partings.

- The goaf will compress and cause further overlying strata units to deflect, shear and crack. The goaf load will continue to increase as cracking continues up into the strata.
- The curvature induced in the beams will probably not cause complete fracture to develop through the beam until the compressive strength of the beam materials is reached. The induced curvature will therefore be a function of the stiffness of the goaf, the stiffness (and thickness) of the deflecting beam and the load acting on it.
- The goaf stiffness will initially be a function of the mining height and the bulking properties of the collapsed roof materials. The goaf stiffness will also increase as the load acting upon it increases (i.e. strain hardening behavior).
- The goaf load will be a function of the rock mass density and effective height of rock above it. The effective goaf load height is likely to be somewhere between the height to the underside of the spanning arch (above sub-critical and critical panels) and the full cover depth. Full load spanning of strata units above supercritical panel geometries are unlikely to occur and full cover depth load may be assumed to act upon the goaf.

### A11.5.2 Analytical Height of Fracturing Model

An analytical model of how sub-surface fracturing develops in the overburden is described below in an attempt to define the likely relationships between the mining geometry and overburden as described in the previous section.

Initial Conditions - Elastic Beam Response to Longwall Mining

The maximum horizontal tensile stress before fracturing ($\sigma_t$) in a beam of thickness (t) with an effective span of $W_i$ at a distance (y) above the workings will be:

$$\sigma_t = 6M/t^2 = 3\gamma(H-y)W_i^2/4t^2$$

where

$M$ = surcharge load x span$^2$ /12 = $\gamma D W_i^2/12 = \gamma(H-y)\, W_i^2/12$

$\gamma$ = unit weight of the rock mass

D = the depth to the base of the spanning beam (or H-y)

The equation shows that the tensile stress in a stack of beams will be greatest near the roof of the mine workings and then decrease linearly towards the surface. The effective span $W_i$ of the beam will decrease as a function of the angle of break of the collapsing strata in the

Caving Zone. The angles of break ($\theta$) are likely to range between $12^o$ and $19^o$ according to the literature and underground observations.

Elastic beam Cracking and Voussoir Beam Development

The fracturing will continue to progress higher up into the strata until a beam of a certain critical thickness is reached that can either span the distance between the naturally occurring abutments or is thick enough not to fracture right through the beam after it has failed. It is also important to note that the angle of break is not the same as the height of fracturing angles ($\theta_A$ and $\theta_B$) discussed in **Section A11.3.4**, as the latter angles were back-calculated from measured heights of continuous fracturing and assumed parabolic fracture limit profiles.

As discussed earlier, the cracking of the strata will lead to the development of Voussoir arching or 'cracked beam' behaviour. The stability of the Voussoir beam will depend upon the compressive stress ($\sigma_c$) developed in the beam of thickness (t) that is located a distance, y, above the workings with an effective span ($W_i$) as follows:

$$\sigma_c = \gamma(H'-y)W_i^2/(4nt^2(1-0.667n))$$

where

n = the proportion of the beam t in compression and may be determined iteratively by minimizing $\sigma_c$ as the arch shortens under load and develops a new equilibrium (and provided the stress remains in the elastic region or is less than the UCS). Voussoir analysis results based on the method presented in **Diedrichs and Kaiser, 1999**, indicate that 'n' can range from 0.5 and 0.75 in spanning beams, and will be closer to 0.5 when beam crush conditions are reached.

$W_i$ = W - 2ytan$\theta$ = effective span of the bending beam at distance, y above the mine workings.

H' = Effective Goaf Load Height, H' or Cover Depth, H.

Voussoir Beam Crushing and Height of Continuous Fracturing

It follows then, that the height of continuous fracturing, A, is likely to develop up to the point where the beam crushes or $\sigma_c$ = UCS and infers the following relationship exists at the point where the beam starts to yield or crush:

$$UCS = \gamma(H'- A)(W-2A\tan\theta)^2/(4nt^2(1-0.667n))$$

$$= 0.75\gamma(H'- A)(W-2A\tan\theta)^2/t^2 \qquad (1)$$

where

$\theta$ = the angle of break that subtended to vertical from the rib side and ranges from $12^o$ - $19^o$ based on subsidence data and underground observations.

H'- A = thickness of rock supported by the beam and may decrease to t (the beam thickness) if the strata beds shear and dilate during subsidence development.

n = 0.5 (conservative).

Equation (1) indicates that the height of A-Zone fracturing is likely to be a cubic function that is dependent on the following variables:

- Panel width, W
- Effective Goaf Load Height, H' or Cover Depth, H.
- Thickness, location and strength and stiffness of the strata units within the overburden (t, y, UCS, E)
- Angle of break, $\tan\theta$

Stresses in Overlying Beams Supported by Collapsed/Fractured Beams

It is noted that Equation (1) ignores the presence of collapsed and fractured material within the A-Zone itself. The formation of the goaf will provide support to overlying fractured units, but also influence the magnitude of curvature and bending stress in the overlying beams as the goaf is compacted and the beams deflect. The curvature of the overlying 'beams' ($p_i$) may be estimated as follows:

$$p_i = 8\Delta/(y+W_i)^2 = 8(S_{max})/(y+W_i)^2 = 8(\varepsilon_g 4T)/(y+W_i)^2 = 32(\sigma_g/E_g)T/(y+Wi)2$$
$$= 32(\gamma H'/E_g)T/(y+W_i)^2$$

where

$\Delta$ = mid-span deflection of beam with an effective span, $W_i = W - 2y\tan\theta$.
$\varepsilon_g$ = vertical strain of goaf with thickness of 4T (T+3T) and a bulking factor of 1.3.
$\sigma_g$ = maximum vertical stress acting on the goaf = $\gamma H'$.
H' = effective goaf load height = minimum of H and W'/(4tanθ)).
$E_g$ = stiffness of the goaf, which is likely to be a function of H, W, T and t.

From the estimated curvature of the strata units above the compacting goaf, the bending stress in the beam may be estimated as follows:

$$\sigma_c = 2M/(Znt) = 2p_i E't^3/[12(nt^2(1-0.667n))] = 16(\gamma H)T\,t\,E'/(E_g(A+W_i^2)) \qquad (2)$$

where

E' = rock mass Young's Modulus = 100 - 300UCS (depending on rock mass Geological Strength Index (**Hoek & Diderichs, 2006**));

n = 0.5 for beam at the yield point (i.e. $\sigma_c$ = UCS)

As before, if $\sigma_c$ exceeds the UCS, the cracking may extend right through the beam and the height of fracturing, A, may then continue to develop up to the next strata unit. The following relationship will therefore exist at the A horizon:

$$\sigma_c = UCS = 16(\gamma H')T\ t\ E' / E_g\,(W+A(1-2\tan\theta))^2$$

Overall, the equations represent the physical relationships for either spanning strata (Equation (1)) or non-spanning strata (Equation (2) that are of sufficient thickness to limit fracture continuation through it for a given UCS and mining geometry. As discussed in the following sections, the goaf modulus is likely to be dependent on the mining geometry (W, T and H').

The above equation indicates a complex system with a significant number of independent variables that will influence the height of fracturing outcomes.

Considering the complexity of the above equation and uncertainty in regards to assigning the rock mass and goaf properties, the physical relationship between the variables may also be assessed practically with Dimensional Analysis, a commonly used tool by hydraulics engineers (see **Section A11.5.3**).

### A11.5.3 Dimensional Analysis and Buckingham's Pi Theory

According to **Vennard and Street, 1982**, Dimensional Analysis is "the mathematics of dimensions of quantities" built on Fourier's 1882 "principle of dimensional homogeneity". The underlying principle states that "an equation expressing a physical relationship between quantities must be dimensionally homogeneous" i.e. the dimensions of each side of the equation must be the same. It is a valuable means of determining physical relationships between variables in complex systems that defy analytical solution and must be solved by empirical means (i.e. observation, intuition or experiment).

Buckingham's Pi-theory accomplishes this by the formation of dimensionless groups of independent variables that are measureable in the field. For the theory to work, the Pi-terms together must represent all of the three fundamental or primary dimensions of Mass (M), Distance (L) and Time (T), be independent of each other, and not break down into further dimensionless groups.

Buckingham's Pi theory states that in order to determine the physical relationship between a set of 'n' independent parameters in a complex system, it follows that n-3 dimensionless parameters (known as Pi-terms) will be required to reasonably define the dependent variable.

The final equations obtained are in the form of:

$$\pi_1 = f\,(\pi_2, \pi_3 \ldots \pi_{n-3}) \text{ or } f'(\pi_1, \pi_2 \ldots \pi_{n-3}) = 0$$

From the previous analytical equations derived in **Section A11.5.2**, it is assessed that up to 10 variables may influence the height of Continuous Fracturing (A) and Discontinuous Fracturing (B) as follows:

$$A, B = f(W, H, T, t, \rho, UCS, E, E_{g,} \tan\theta)$$

The above variables may then be expressed as a combination of products and powers:

$$A, B = aW^{b} H^{c} T^{d} t^{e} UCS^{f}, \rho^{g} E^{h} E_{g}^{i} \tan\theta^{j}$$

Seven dimensionless Pi-terms will therefore be necessary to describe the relationships between ten variables identified in a system driven by horizontal and vertical stress, panel width, cover depth, mining height, rock mass density, rock mass strength and stiffness, goaf stiffness, caving angle or angle of break and the location of competent or relatively thick strata units in the overburden.

*Notes:*
*1. The y term may be ignored as it corresponds with the dependent variable (A or B).*
*2. The goaf modulus ($E_g$) and caving angle ($\theta$) are considered to be dependent on the mining geometry and may therefore be precluded from the regression analysis.*
*3. The beam thickness, t refers to the thickness likely to exist just above the fracture height location (t is the most difficult of the parameters to assess, as the strata units may 'break down' into thinner units during subsidence development. The assignment of the appropriate t value therefore requires engineering judgment and analysis that includes a review of borehole logs and rock mass properties with extensometer and piezometer data (if available).*

The first step in the analysis is to select a suitable set of recurring variables that cannot themselves be formed into a dimensionless group and can be used to represent one or more of the fundamental dimensions. The recurring variable set selected included the panel width, W, rock mass strength, UCS, and density, ρ, and were used to express the fundamental variables as follows:

Length, L: W;  Mass, M: $\rho W^3$;  Time, T: $\rho^{0.5} W / UCS^{0.5}$

The dimensionless π terms for the remaining independent variables were then assessed using the recurring variable set as follows:

$\pi_1$: $A \cdot L^{-1} = A/W$ (Height of Fracturing Term)

$\pi_2$: $H \cdot L^{-1} = H/W$ (Goaf Load Index Term)

$\pi_3$: $T \cdot L^{-1} = T/W$ (Strata Curvature Index Term)

$\pi_4$: $t \cdot L^{-1} = t/W$ (Strata Unit Thickness Term)

$\pi_5$: $E \cdot M^{-1} L^{1} T^{2} = E/UCS$ (Strata Unit Stiffness Term)

which gives:

$$A/W = a\,(H'/W)^{b}(T/W)^{c}\,(t/W)^{d}\,(E/UCS)^{e}$$

The constants and powers for each Pi-term can now be determined using measured values in the field and non-linear regression techniques.

If we assume for the moment that the last $\pi$ term representing the ratio of rock mass stiffness over strength for all cases in the database will be constant (E is typically 250 to 300 times the UCS), then the full equation of dimensionless $\pi$ terms may be simplified as follows:

$$A/W = a\,(H/W)^b\,(T/W)^c\,(t/W)^d \text{ and } B/W = e\,(H'/W)^f\,(T/W)^g\,(t/W)^h$$

The form of the dimensionless $\pi$ term equations will be explained in the following sections.

*Note: Some of the published literature recommends that the super-critical panel width W' = 1.4H should be used instead of the Panel Width, W, for estimating the height of fracturing above super-critical panels. This is because it was argued that the height of fracturing would probably not continue to develop higher into the strata once the overburden had reached the critical width and had already completely failed. The author agrees with this view and considers the height of continuous fracturing beyond this point would then be controlled by the mining height, cover depth (or goaf load) and geological conditions only.*

### A11.5.4 Pi-Term Model for Predicting Height of Continuous Fracturing (A) above Longwalls based Mining Geometry Only (i.e. Geometry Model)

For the purposes of demonstrating that height of fracturing prediction models need to consider the influence of geology, a regression analysis was completed without the strata unit thickness Pi-term (t'/W') included. Based on the empirical database presented in **Table A6.1**, the statistics software XLSTAT® was used to complete a multi-nonlinear regression analyses on the first three Pi-terms defined earlier as follows:

$$\underline{\text{Mean } A/W' = 2.215\,(H/W')^{0.271}(T/W')^{0.372}} \qquad R^2 = 0.61 \text{ \& r.m.s.e.} = 0.12W' \ (21\%)$$

$$\underline{\text{U95\% } A/W' = \text{Mean } A/W' + a}$$

where a = 0.16 for subcritical panels; 0.16 - 0.085(W/H - 0.7) for critical panels; and 0.10 for supercritical panels.

W' = Effective Panel Width = minimum of W and 1.4H.

T = Mining Height.

Re-arranging the above equation in terms of A gives:

$$\underline{A = 2.215W'^{0.357}H^{0.271}\,T^{0.372} \qquad +/- \ aW'}$$

The regression results suggest that the height of continuous fracturing (A) will increase with effective panel width (W'), the cover depth or goaf load (H) and the mining height (T) all raised to powers ranging from 0.27 to 0.37.

The above equation(s) may be used to estimate A-Zone fracture heights in the absence of specific geological information (i.e. borehole data). The predicted v. measured outcomes using the "geometry" Pi-terms only model are presented in **Figures A42b** to **A42d**.

The plots indicate that the 'geometry only' Pi-term model is likely to provide reasonably conservative predictions, provided that the geology is not too dissimilar to the conditions that were present for the given mining geometry. For cases where the geology is significantly different above a proposed mining geometry, the above equation may underestimate or overestimate the fracture heights by a significant amount.

The development of a Pi-term model that considers the influence of overburden geology is subsequently addressed in **Section A11.5.5**.

### A11.5.5 Pi-Term Model for Predicting Height of Continuous Fracturing (A) above Longwalls with the Geology Pi-Term Included

The presence of massive strata units such as sandstone, conglomerate and igneous rock that may span the fractured strata in the A-Zone is likely to limit the potential range of continuous fracture height development above the mine workings. Based on the analytical models (Equations (1) and (2)), the minimum thickness required to span the A-Zone or limit its development will depend on a number of factors, including span, thickness and rock mass axial and diametric strength. The minimum strata unit thickness required to span the A-Zone may be estimated using empirical and analytical methods, and are described in **Sections A11.5.6** and **A11.5.7** respectively.

If no obvious strata unit thickness is present in the overburden, then it will be necessary to adopt an appropriate minimum value based on subsidence data and typical or atypical geological conditions. The minimum effective t' values are also defined in **Section A11.5.6**.

Based on the empirical database presented in **Table A6.1**, the statistics software XLSTAT® was used to complete a multi-nonlinear regression analyses on the first four Pi-terms defined earlier as follows:

$$\underline{\text{Mean } A/W' = 1.52\,(H/W')^{0.535}(T/W')^{0.464}(t'/W')^{-0.4}} \qquad R^2 = 0.81 \text{ \& rmse} = 0.09W'(15\%)$$

$$\underline{\text{U95\% } A/W' = \text{Mean } A/W' + a}$$

where a = 0.15 for subcritical panels; 0.15 - 0.0714(W/H - 0.7) for critical panels; and 0.10 for supercritical panels.
H = cover depth = the maximum potential goaf load height.
W' = effective panel width = minimum of W and 1.4H.
T = mining height.
t' = effective strata unit thickness; see **Sections A11.5.6**.

Re-arranging the above equation in terms of A, gives:

$$\underline{A = 1.52W'^{0.4}H^{0.535}T^{0.464}t'^{-0.4} \qquad +/- \; aW'}$$

The regression results indicate that the height of continuous fracturing (A) will increase with effective panel width (W'), the cover depth or goaf load (H) and mining height (T), all raised to powers ranging from to 0.4, 0.54 and 0.46 respectively and decrease with effective strata unit thickness (t') raised to the power of -0.4. The form of the power rule equation requires the powers to sum to unity to achieve dimensional consistency. The back-analysed powers are also similar in magnitude to the analytical models previously discussed.

### A11.5.6 Effective Strata Unit Thickness Estimates for the Geology Pi-Term Model using Empirical Modelling Techniques

In order to calibrate the geological Pi-term model, it was necessary to use back-analysis techniques to estimate the likely strata unit thicknesses that existed immediately above the measured heights of continuous fracturing for a given mining geometry.

One of the difficulties in estimating the effective strata thickness from borehole data is the uncertainty in regards to the response of the 'bedded' strata under bending forces and whether they will break down into thinner units.

For example, a 33 to 40 m thick unit of Munmorah Conglomerate existed 80 m above LW5 at the Mandalong Mine and extensometer data measured the beam shearing into 15 m and 20 m thick units, which reduced the effective thickness of the conglomerate beam by approximately 50% (i.e. 15 m to 20 m). The height of continuous fracturing was estimated to occur at 118 m or near the top of the conglomerate, based on piezometer data.

Other longwalls with similar geometry at Mandalong did not break down into thinner units (based on measured subsidence data). The presence of a seam roll and thrust fault to the near the panel was identified in the mine workings and indicates that the strata may have been significantly 'worked' and weakened by tectonic activity prior to mining. It is suggested that assessments in greenfields sites should consider the outcome of massive units shearing into two beams for worst-case geological condition scenarios.

Initial values of t' were therefore estimated from borehole log and extensometer data to derive the general form of the equation presented in **Section A11.5.5**. The resulting regression equation indicated the strata unit thickness should be raised to a power of -0.4 to -0.5. A single iteration was then required to re-define the coefficients and remaining Pi-term powers. The results of the analysis are summarized in **Table A6.3a** and **Figure A42e**.

The results indicate that the back-analysed (or measured) t' values ranged between 18 m and 80 m (median of 46 m) for the *sub-critical* panels; from 8.5 m to 42 m (median of 25 m) for the *critical* panels and between 6 m and 34 m (median of 23 m) for the *supercritical* panel geometries. The measured t' values for the deeper panels appear to be generally thicker than the panels at lower depth of cover in areas with similar geological conditions (i.e. massive sandstones and conglomerate units capable of spanning the longwall voids were present in both cases). Further review of the geomechnical properties of the overburden is necessary to increase our understanding of this phenomenon.

## Table A6.3a - Effective Strata Unit Thicknesses (t') Back Analysed from HoF Model Database for Australian Coalfields

| Site | Panels | Mine | W (m) | H (m) | W/H | A (m) | Back Analysed t' (m) | Bore log $t_{log}$ (m) | $t_{max}$ 95% goaf span probability | Rock Mass Conditions (see TA6.3b) | $t_{min}$ from subsidence data (m) | Effective Strata unit thickness* t' (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MW508 | Bellambi W. | 110 | 421 | 0.26 | 92 | 36.5 | 100 | 49 | Normal | 30 | 49 |
| 2 | LW10 | Metropolitan | 140 | 460 | 0.30 | 130 | 31.5 | 100 | 49 | Normal | 30 | 49 |
| 3 | LW1-4 | South Coast | 110 | 325 | 0.34 | 85 | 31.5 | 100 | 41 | Normal | 20 | 41 |
| 4 | LW6 | Kemira | 117 | 335 | 0.35 | 98 | 27 | 100 | 40 | Normal | 20 | 40 |
| 5 | LW20 | Metropolitan | 163 | 450 | 0.36 | 100 | 68 | 100 | 70 | Normal | 30 | 70 |
| 6 | LWA1 | Austar | 159 | 417 | 0.38 | *87* | 160 | 100 | 78 | Normal | 30 | 78 |
| 7 | LW514 | Bellambi W. | 150 | 400 | 0.38 | 90 | 54 | 100 | 64 | Normal | 30 | 64 |
| 8 | LW28 | Appin | 200 | 500 | 0.40 | 90 | 80 | 120 | 103 | Normal | 40 | 103 |
| *9* | LW2 | Ellalong | 150 | 368 | 0.41 | 113 | 37 | 100 | 49 | Normal | 30 | 49 |
| *10* | LW3 | Tahmoor | 180 | 424 | 0.42 | - | 60 | 100 | 74 | Normal | 30 | 74 |
| 11 | LW9 | Teralba | 150 | 350 | 0.43 | *110* | 27 | 34 | 48 | Normal | 30 | 30 |
| *12* | TE | West Cliff | 200 | 446 | 0.45 | *101* | 57 | 100 | 85 | Normal | 30 | 85 |
| *13* | TE | Berima | 120 | 176 | 0.68 | *76* | 18 | 100 | 29 | Normal | 20 | 29 |
| *14* | LW409 | Springvale | 265 | 384 | 0.69 | *133* | 42 | 55 | 78 | Normal | 32 | 32 |
| 15 | LW9(11) | Mandalong | 160 | 220 | 0.73 | - | 30 | 30 | 25 | Normal | 20 | 25 |
| 16 | LW11 | Angus Place | 211 | 263 | 0.80 | - | 30 | 100 | 26 | Normal | 10 | 26 |
| *17* | 411 | Springvale | 315 | 368 | 0.86 | 139 | 42 | 55 | 86 | Normal | 32 | 32 |
| 18 | LW5 | Mandalong | 160 | 179 | 0.89 | 118 | 14.5 | 25 | 37 | Normal | 20 | 20 |
| 19 | LW5 | Dendrobium | 245 | 255 | 0.96 | 123 | 32 | 80 | 55 | Normal | 20 | 55 |
| 20 | LW1 | Wyee | 216 | 206 | 1.05 | 126 | 18.2 | 30 | 39 | Normal | 20 | 20 |
| **21** | **LW1** | **Invincible** | **145** | **116** | **1.25** | **96** | **8.5** | **15** | 19 | **Adverse** | **10** | **10** |
| 22 | TE 1 | Abel | 120 | 95 | 1.26 | 45 | 18 | 15 | 29 | Normal | 15 | 15 |
| 23 | LWs | Ashton | 216 | 154 | 1.40 | 82 | 25.5 | 30 | 44 | Normal | 15 | 15 |
| 24 | LW40 | WWD | 179 | 113 | 1.58 | 80 | 21 | 20 | 25 | Normal | 20 | 20 |
| **25** | **LWE1** | **Sth Bulga** | **259** | **155** | **1.67** | **145** | **6.2** | **15** | 28 | **Adverse** | **10** | **10** |
| 26 | LW41 | WWD | 179 | 105 | 1.70 | 72 | 23 | 20 | 24 | Normal | 20 | 20 |
| 27 | LW9 | Crinum | 280 | 155 | 1.81 | 85 | 34 | 35 | 36 | Normal | 20 | 20 |
| 28 | LW39 | WWD | 179 | 97 | 1.84 | 68 | 22.5 | 20 | 22 | Normal | 20 | 20 |
| 29 | TE (3D) | Wyee North | 355 | 185 | 1.92 | 63 | 54 | 50 | 78 | Normal | 20 | 20 |
| 30 | TE(LW4) | Wyee North | 355 | 180 | 1.97 | 40 | >54 | 50 | 109 | Normal | 20 | 20 |
| 31 | TE | Abel | 150 | 76 | 1.97 | 45 | 15.5 | 15 | 26 | Normal | 15 | 15 |
| 32 | TE(NthB) | Cooranbong | 150 | 75 | 2.00 | 58 | 12.5 | 20 | 16 | Normal | 20 | 16 |
| 33 | LW1 | Oaky ck | 205 | 95 | 2.16 | 55 | 29 | 30 | 25 | Normal | 15 | 25 |
| **34** | **LW9/9a** | **Homestead** | **200** | **80** | **2.50** | **70** | **11** | **15** | 16 | **Normal** | **15** | **15** |

W' = minimum (W, 1.4H); $t_{min}$ - minimum beam thickness values at A-Horizon based on subsidence and borehole extensometer data; t' = effective beam thickness above A-Zone derived from back analysis techniques; * - t' is selected by consideration of tlog, $t_{max}$ and $t_{min}$ (see text below).

**Bold** - surface to seam fracturing reported by others; *italics* - Continuous Fracture Zone heights (A-Zone) was originally reported and included the Discontinuous Fracture and Dilated Zone (B-Zone). The A and B- Zone heights were re-assessed by DgS based on a review of available measured vertical strains and piezometric data (see **Figure A40i and A40j**).

In order to be able to make credible height of continuous fracturing predictions at a 'green fields' site based on borehole data alone, it was necessary to identify strata unit thicknesses that <u>did</u> and <u>did not</u> stop the height of fracturing.

To do this, the effective strata unit thicknesses from the database that appeared to have stopped the height of fracturing were normalized to the effective panel width (t'/W') and plotted against the unit's location factor (y/H); see **Figure A42f**. A similar exercise was completed for the strata units that did not stop the height of fracturing development, and are plotted on the above figure as well.

The two strata thickness categories were subsequently used in a logistic regression analysis to define the probabilistic power line equation below to indicate whether a strata unit is likely to span the goaf and limit the development of the height of fracturing at a given horizon above the workings:

$$P(i=1)=50\% \text{ for } t_{max} = W'[0.035(y/H)^{-1.3}]$$

where

i = 1 for a spanning unit, and

P(i=1)=50% for $t_{max}$ refers to a 50% probability that a beam of a given thickness will span the fractured zone at a given location in the overburden.

A similar exercise was completed in order to define for the 95% probability of spanning equation:

$$P(i=1)=95\% \text{ for } t_{max} = W'[0.12(y/H)^{-0.85}]$$

where

i = 1 for a spanning unit, and

P(i=1)=95% for $t_{max}$ refers to a 95% probability that a beam of a given thickness will span the fractured zone at a given location in the overburden.

The two above equations above are shown in **Figure A42f** with the database of 'goaf spanning' and 'non-goaf spanning' units.

For conservative or worst-case height of fracturing prediction, subsidence data was also reviewed to indicate the minimum effective beam thickness values ($t_{min}$) when massive strata units are not obviously present to span and limit the height of the A-Zone.

For this scenario, it is considered that $t_{min}$ is likely to equal twice the measured peak surface strain to curvature ratios or twice the depth of observed cracking (whichever is the greater). For the Newcastle and Hunter Coalfields, a $t_{min}$ range from 15 m to 20 m is indicated from subsidence monitoring data, with a t' range from 30 m to 40 m indicated for the Western and Southern Coalfields.

The $t_{min}$ values for the likely cover depths are provided in **Table A6.3b**.

### Table A6.3b - Minimum Effective Strata Thickness Based on Subsidence Data for Normal and Adverse Rock Mass Conditions in Australian Coalfields

| Cover Depth H (m) | Minimum Effective $t_{min}$ | | | | | |
|---|---|---|---|---|---|---|
| | Normal* | | | | | Adverse** |
| | Southern | Western | Newcastle/ Greta | Tomago/Hunter Valley/Narrabri | Bowen Basin | All Coalfields |
| >450 | 40 | - | - | 30 | 30 | 15 |
| 350 - 450 | 40 | 40 | 30 | 20 | 20 | 15 |
| 250 - 350 | 20 | 20 | 20 | 20 | 20 | 10 |
| 150 - 250 | 20 | 20 | 20 | 15 | 15 | 10 |
| <150 | 20 | 15 | 20 | 15 | 15 | 10 |

* - Normal conditions refer to rock mass behaviour that is unlikely to be adversely affected by geological structure or atypical rock mass conditions (e.g. deep weathering or a lack of low permeability units in the B-Zone).
** - Adverse are likely to be affected by geological structure or atypical rock mass conditions (see definition above).

Validation of the model involved the application of the following algorithm to check that the predicted beam thickness values (t') from the available borehole data ($t_{log}$) were consistent with the back-analysed results and the maximum ($t_{max}$) and minimum thicknesses ($t_{min}$) derived from borehole and subsidence data that is required to span the goaf:

- If $t_{log} > t_{max\ \text{(for 95\% spanning probability)}}$ then $t' = t_{max\ \text{(for 95\% spanning probability)}}$ (so as not to bias the database above the required t' to span the goaf at a given horizon);

- If $t_{log} < t_{max\ \text{for 95\% spanning probability}}$ then $t' = t_{min\ \text{based on subsidence data}}$ (see below).

A summary of the back analysis v. predicted effective strata unit thickness presented in **Table A6.3a** are compared graphically in **Figure A42g**. It is assessed that the proposed algorithm to estimate the likely strata unit thickness for the Pi-Term model is reasonable to give an $R^2$ value of 0.8 and root mean square area of 15%.

The predicted v. measured outcomes using the "Geology" Pi-term model are presented in **Figures A42h** to **A42j**. Further validation of the Geology Pi-term model outcomes are presented in **Sections A11.5.7** and **A11.5.8**.

### A11.5.7 Analytical Models of Goaf Spanning Strata Unit Thickness

The minimum thicknesses of the strata units required to limit the height of continuous fracturing have also been estimated analytically for the following scenarios:

(i) Strata units that can support the full overburden load.

(ii) Single goaf spanning units, which are single strata units that have sheared / dilated away from the overlying rock mass but are able to support their own weight and span any partial voids immediately below.

For Scenario (i) the minimum strata unit thickness to fully support the overburden above it was assessed using Voussoir Beam theory presented in **Diedrichs and Kaiser, 1999**. For a factor of safety against crushing of 2:

$$t_{min,\ full} = \sqrt{(1.5\gamma(H\text{-}y)(W\text{-}2y\tan\theta)^2/UCS)}$$

For Scenario (ii) the minimum strata unit thickness to support its self-weight only was also assessed using Voussoir Beam theory presented in **Diedrichs and Kaiser, 1999**. For a factor of safety against crushing of 2:

$$t_{min,\ single} = 1.5\gamma(W\text{-}2y\tan\theta)^2/UCS$$

*Note: The above equations were derived from Equation (1) and assume that the compression arch forms within 50% of the beam thickness (conservative).*

Back analysis of the database indicated the angle of break increases with W/H and ranges from $\theta = 12^o$ for sub-critical panels and $19.3^o$ for supercritical panels. The following equations give the best fit to the geology model presented in **Section A11.5**:

$\theta = 12^o$ or $W/H < 0.45$
$\theta = 9.63^o + 4.42(W/H) + 1.8(W/H)^2$ for $0.45 < W/H < 1.4$
$\theta = 19.3^o$ for $W/H > 1.4$

Published laboratory UCS testing data on sandstone / conglomerate / igneous core samples from each coalfield were adopted as shown in **Table A6.4**.

A summary of the analytical goaf spanning equation results and back analysed strata unit thicknesses and beam stresses are presented in **Table A6.4**. It is considered that the minimum beam stress will govern the loading/spanning scenario for a given mining geometry. The results again demonstrate the complexity of how the fracture zone heights develop and the difficulties involved with using analytical or numerical techniques v. empirical methods.

The analytical beam thicknesses estimated for the goaf spanning scenarios are also plotted in **Figure A42f**. It is apparent the minimum thicknesses determined for the full rock mass loading case scenario and single spanning unit scenario generally plot above and below the logistic regression line for a 50% Probability of Spanning respectively. This would suggest that the Scenario (i) model is more likely to reflect the loading behaviour of the rock mass compared to Scenario (ii) (assuming the rock mass properties adopted are reasonable).

The predicted v. observed A values for the proposed Geology Pi-term model are presented in **Figures A42f** and **Figure A42g** respectively. The residual errors reasonably follow a normal probability distribution about the regression curve according to Central Limit Theory in statistics (see **Figure A42h**).

## Table A6.4 - Minimum Strata Unit Thicknesses Required for Spanning the Goaf based on Analytical Models of the Overburden

| Site | Panels | Mine | W (m) | H (m) | $W_i$ | UCS (MPa) | t (m) | y (m) | y/H | Back analysed t' (m) | Full Load $t_{min}$ (m) | Single Beam $t_{min}$ (m) | Full Beam Load Stress (MPa) | Goaf Supported Beam Stress (MPa) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MW508 | Bellambi W. | 110 | 421 | 71 | 70 | 100 | 90 | 0.21 | 36.5 | 30 | 3 | 23 | 72 |
| 2 | LW10 | Metropolitan | 140 | 460 | 85 | 70 | 100 | 130 | 0.28 | 31.5 | 36 | 4 | 45 | 49 |
| 3 | LW1-4 | South Coast | 110 | 325 | 74 | 70 | 100 | 85 | 0.26 | 31.5 | 26 | 3 | 25 | 66 |
| 4 | LW6 | Kemira | 117 | 335 | 75 | 70 | 100 | 98 | 0.29 | 27 | 27 | 3 | 35 | 52 |
| 5 | LW20 | Metropolitan | 163 | 450 | 120 | 70 | 100 | 100 | 0.22 | 68 | 52 | 8 | 21 | 100 |
| 6 | LWA1 | Austar | 159 | 417 | 122 | 70 | 100 | 80 | 0.19 | 160 | 51 | 8 | 18 | 208 |
| 7 | LW514 | Bellambi W. | 150 | 400 | 112 | 70 | 100 | 90 | 0.23 | 54 | 46 | 7 | 25 | 75 |
| 8 | LW28 | Appin | 200 | 500 | 162 | 70 | 120 | 90 | 0.18 | 80 | 76 | 14 | 31 | 61 |
| *9* | LW2 | Ellalong | 150 | 368 | 102 | 70 | 100 | 113 | 0.31 | 37 | 38 | 6 | 36 | 59 |
| *10* | LW3 | Tahmoor | 180 | 424 | 180 | 70 | 100 | 100 | 0.24 | 60 | 75 | 17 | 72 | 85 |
| 11 | LW9 | Teralba | 150 | 350 | 103 | 70 | 34 | 110 | 0.31 | 27 | 37 | 6 | 66 | 34 |
| *12* | TE | West Cliff | 200 | 446 | 157 | 70 | 100 | 101 | 0.23 | 57 | 68 | 13 | 49 | 45 |
| *13* | TE | Berima | 120 | 176 | 84 | 70 | 100 | 76 | 0.43 | 18 | 19 | 4 | 40 | 34 |
| *14* | LW409 | Springvale | 265 | 384 | 201 | 70 | 55 | 133 | 0.27 | 78 | 74 | 22 | 108 | 26 |
| 15 | LW9(11) | Mandalong | 160 | 220 | 160 | 67 | 30 | 160 | 0.73 | 30 | 29 | 14 | - | - |
| 16 | LW11 | Angus Place | 211 | 263 | 211 | 70 | 100 | *253* | 0.96 | 30 | 15 | 24 | - | - |
| *17* | 411 | Springvale | 315 | 368 | 242 | 70 | 100 | 139 | 0.38 | 42 | 85 | 31 | 142 | 20 |
| 18 | LW5 | Mandalong | 160 | 179 | 97 | 67 | 25 | 83 | 0.46 | 14.5 | 18 | 5 | 51 | 23 |
| 19 | LW5 | Dendrobium | 245 | 255 | 177 | 70 | 80 | 123 | 0.48 | 32 | 47 | 17 | 75 | 28 |
| 20 | LW1 | Wyee | 216 | 206 | 143 | 70 | 30 | 126 | 0.61 | 18.2 | 30 | 11 | 92 | 18 |
| **21** | **LW1** | **Invincible** | **145** | **116** | **83** | **70** | **15** | **106** | **0.91** | 8.5 | 9 | **4** | 36 | 15 |
| 22 | TE 1 | Abel | 120 | 95 | 91 | 30 | 15 | 41 | 0.43 | 18 | 23 | 10 | 24 | 20 |
| 23 | LWs | Ashton | 216 | 154 | 158 | 30 | 30 | 82 | 0.53 | 25.5 | 47 | 31 | 52 | 10 |
| 24 | LW40 | WWD | 179 | 113 | 102 | 30 | 20 | 80 | 0.71 | 21 | 21 | 13 | 15 | 22 |
| **25** | **LWE1** | **Sth Bulga** | **259** | **155** | **115** | **30** | **20** | **145** | **0.94** | 6.2 | 13 | **17** | 65 | 2 |
| 26 | LW41 | WWD | 179 | 105 | 97 | 30 | 20 | 72 | 0.69 | 23 | 20 | 12 | 11 | 28 |
| 27 | LW9 | Crinum | 280 | 155 | 157 | 130 | 35 | 105 | 0.68 | 34 | 22 | 7 | 28 | 79 |
| 28 | LW39 | WWD | 179 | 97 | 88 | 30 | 20 | 68 | 0.70 | 22.5 | 17 | 10 | 8 | 32 |
| 29 | TE (3D) | Wyee North | 355 | 185 | 215 | 70 | 50 | 63 | 0.34 | 54 | 55 | 25 | 36 | 28 |
| 30 | TE(LW4) | Wyee North | 355 | 180 | 224 | 70 | 50 | 40 | 0.22 | <u>156</u> | 61 | 27 | 37 | 34 |
| 31 | TE | Abel | 150 | 76 | 75 | 30 | 15 | 33 | 0.43 | 15.5 | 15 | 7 | 14 | 18 |
| 32 | TE(NthB) | Cooranbong | 150 | 75 | 64 | 67 | 20 | 58 | 0.77 | 12.5 | 8 | 2 | 8 | 47 |
| 33 | LW1 | Oaky ck | 205 | 95 | 94 | 30 | 30 | 55 | 0.58 | 29 | 21 | 11 | 8 | 37 |
| **34** | **LW9/9a** | **Homestead** | **200** | **80** | 63 | **30** | **15** | **65** | **0.81** | 11 | 8 | 5 | 6 | 18 |

W' = minimum (W, 1.4H); $t_{min}$ - minimum beam thickness values at A-Horizon based on subsidence and borehole extensometer data; t' = effective beam thickness above A-Zone derived from back analysis techniques;
**Bold** - surface to seam fracturing reported by others;
<u>Underlined</u> - Conservative estimate of t' returned.
*italics* - Continuous Fracture Zone heights (A-Zone) was originally reported and included the Discontinuous Fracture and Dilated Zone (B-Zone). The A and B- Zone heights were re-assessed by DgS based on a review of available measured vertical strains and piezometric data (see **Figure A40i** and **A40j**).

### A11.5.8 Pi-Term Model for Predicting Heights of Discontinuous Fracturing (B) Above Longwalls without using the Geology Pi-Term (Geometry Model)

Based on the empirical database presented in **Table A6.1**, the statistics software XLSTAT® was used to complete a multi-nonlinear regression analysis as follows for estimating the height of the dilated B-Zone :

$\underline{\text{Mean } B/W' = 1.621\ (H'/W')^{0.55}(T/W')^{0.175}}$ $R^2 = 0.86$ & rsme = 0.12W' (13%)

U95% B/W' = Mean B/W' + b

where b = 0.16 for subcritical panels, 0.16-0.085(W/H-0.7) for critical panels and 0.10 for supercritical panels.

H' = Goaf Load Height = H

W' = Effective Panel Width = minimum of W and 1.4H.

T = Mining Height.

Re-arranging the above equation in terms of B gives:

$\underline{B = 1.621\ W'^{0.275}H^{0.55}T^{0.175}\ \ +/-\ bW'}$

The predicted v. observed B/W' and B' values are presented in **Figure A42k** and **Figure A42l** respectively. The residual errors follow a normal probability distribution about the regression curve as expected according to Central Limit Theory in statistics (see **Figure A42m**). The regression indicates a relatively weaker relationship exists between the height of B-Zone fracturing and the mining height compared to the A-Zone relationship.

### A11.5.9 Pi-Term Model for Predicting Heights of Discontinuous Fracturing (B) Above Longwalls using the Geology Pi-Term

Based on the empirical database presented in **Table A6.1**, the statistics software XLSTAT® was used to complete a multi-nonlinear regression analysis as follows for estimating the height of the dilated B-Zone :

$\underline{\text{Mean } B/W' = 1.873\ (H'/W')^{0.635}(T/W')^{0.257}(t'/W')^{-0.097}}$ $R^2 = 0.86$ & rmse = 0.13W'(15%)

$\underline{\text{U95\% } B/W' = \text{Mean } B/W' + b}$

where b = 0.15 for subcritical panels; 0.15-0.0714(W/H-0.7) for critical panels and 0.10 for supercritical panels.

H' = Goaf Load Height = H

W' = Effective Panel Width = minimum of W and 1.4H.

T = Mining Height.

t' = Effective strata unit thickness; see **Section A11.5.6**.

Re-arranging the above equation in terms of B gives:

$$B = 1.873\, W'^{0.205} H^{0.635} T^{0.257} t'^{-0.097} \quad +/- \; bW'$$

The predicted v. observed B/W' and B' values are presented in **Figure A42n** and **Figure A42o** respectively. The residual errors follow a normal probability distribution about the regression curve as expected according to Central Limit Theory in statistics (see **Figure A42p**). The regression indicates a relatively weaker relationship exists between the height of B-Zone fracturing, the mining height and strata unit thickness compared to the A-Zone relationship.

### A11.5.10 Pi-Term Model Validation

Validation of the proposed Pi-Term model has been completed as follows:

(i) A review of the range of independent variables within the database to check if the model is likely to be biased towards a particular parameter or mining geometry.

(ii) Comparison of predicted v. measured A and B-Horizons for each model to check model reliability.

(iii) Sensitivity analysis of the model to the assumed input parameters (based on method applied in **Hydrosimulations, 2013**).

(iv) Comparison of model results with other models over a representative range of mining geometries and overburden geologies.

(i) Database Variable Review

In regards to the data base, the following parameters from **Table A6.1** were plotted against the W/H ratio in **Figures A43a** to **43d** to test for sample bias:

- Panel Width (W)
- Cover Depth (H)
- Mining Height (T)
- Height of A-Zone Fracturing (A)
- Height of B-Zone Fracturing/Strata Dilation (B)

It is assessed that the database has sufficient coverage in regards to panel width, cover depth and mining height to reliably estimate HoF Zones above sub-critical to super-critical panels with W/H values ranging from 0.3 to 2.2.

(ii) Model Reliability

In regards to prediction model reliability, the minimum effective strata unit thickness assessed for each site has used to estimate the height of A and B-Zones and the residual areas subjected to a Normality test. The distributions of model residual errors should follow the Central Limit theorem for regression analysis. That is, a normal distribution of errors would be expected to occur about the regression line of 'best-fit'. If the regression lines are deemed to meet this requirement, the assessment of predicted confidence limits will then be possible. It would then be expected that < 5% of measured values would exceed the predicted U95%CL values on average.

The regression results for the A-Zone Geological model are summarised in **Table A6.5** and **Figure A42j**. The results demonstrate the model errors satisfy normality tests with 61% of the measured values below the predicted mean values and 97% of the measured values below the Upper 95%CL predictions. A slightly lower reliability outcome was achieved for the Geometry Model for the B-Zone with 55% of measured values below the mean and 90% below the U95%CL (see **Table A6.6**).

It is therefore considered that the reliability of the Pi-Term geology model is acceptable for worst-case estimates of A-Zone fracture heights at new or existing coal mines in Australia until local performance data either confirms or supersedes it.

The results for the B-Zone geology model checks also indicate the model errors satisfy normality tests as shown in **Figure A42p** and are summarised in **Table A6.7**. The proposed mean and U95%CL model satisfactorily over predicts 52% and 95% of the measured B-Zone data (i.e. within 5% of the expected values). A slightly lower reliability outcome was achieved for the Geometry Model for the B-Zone (see **Table A6.8**).

Overall, it is considered that the reliability of both the Pi-Term Models is acceptable for estimates of B-Zone discontinuous fracture height assessments at new or existing coal mines in the NSW Coalfields and should be confirmed or re-calibrated with local measurement data.

The above results indicate that the model is likely to provide reasonably conservative estimates of the height of continuous fracturing for the full range of mining geometries, based on the effective panel width, effective goaf load height (cover depth), mining height and effective strata unit thickness in the A or B-Zones.

## Table A6.5 - Summary of Measured v. Predicted Height of Continuous Fracture A-Zones for the Geology Model

| **Site** | **Panel** | **Mine** | **Panel Width W (m)** | **Cover Depth H (m)** | **W/H** | **Mining Height T (m)** | **Predicted t' (m)** | **Predicted A (m)** | | **Measured A (m)** | **Pass = 1; Fail = 0** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mean | U95%CL | | m | U95 |
| 1 | MW508 | Bellambi W | 110 | 421 | 0.26 | 2.50 | 49 | 82 | 98 | **92** | 0 | **1** |
| 2 | LW10 | Metropolitan | 140 | 460 | 0.30 | 3.40 | 49 | 109 | 130 | **130** | 0 | **1** |
| 3 | LW1-4 | South Coast | 110 | 325 | 0.34 | 2.50 | 41 | 76 | 93 | **85** | 0 | **1** |
| 4 | LW6 | Kemira | 117 | 335 | 0.35 | 2.75 | 40 | 84 | 102 | **98** | 0 | **1** |
| 5 | LW20 | Metropolitan | 163 | 450 | 0.36 | 3.40 | 70 | 99 | 124 | **100** | 0 | **1** |
| 6 | LWA1 | Austar | 159 | 417 | 0.38 | 6.00 | 78 | 118 | 142 | ***87*** | 1 | **1** |
| 7 | LW514 | Bellambi W | 150 | 400 | 0.38 | 2.70 | 64 | 84 | 106 | **90** | 0 | **1** |
| 8 | LW28 | Appin | 200 | 500 | 0.40 | 2.30 | 103 | 81 | 111 | **90** | 0 | **1** |
| 9 | LW2 | Ellalong | 150 | 368 | 0.41 | 3.50 | 49 | 101 | 123 | **113** | 0 | **1** |
| 10 | LW3 | Tahmoor | 180 | 424 | 0.42 | 2.18 | 74 | 80 | 107 | **-** | - | **-** |
| 11 | LW9 | Teralba | 150 | 350 | 0.43 | 2.70 | 30 | 106 | 128 | ***110*** | 0 | **1** |
| 12 | TE | West Cliff | 200 | 446 | 0.45 | 2.50 | 85 | 86 | 116 | ***101*** | 0 | **1** |
| 13 | TE-SW1 | Berrima | 120 | 176 | 0.68 | 2.3 | 29 | 63 | 81 | ***76*** | 0 | **1** |
| 14 | LW409 | Springvale | 265 | 384 | 0.69 | 3.25 | 32 | 148 | 188 | **133** | 0 | **1** |
| 15 | LW9 | Mandalong | 160 | 220 | 0.73 | 4.50 | 25 | 115 | 139 | **-** | - | **-** |
| 16 | LW11 | Angus Place | 211 | 263 | 0.80 | 2.47 | 16 | 129 | 159 | **-** | - | **-** |
| 17 | 411 | Springvale | 315 | 368 | 0.86 | 3.25 | 32 | 156 | 199 | **139** | 0 | **1** |
| 18 | LW5 | Mandalong | 160 | 179 | 0.89 | 3.70 | 20 | 103 | 125 | **118** | 0 | **1** |
| 19 | LW5 | Dendrobium | 245 | 255 | 0.96 | 3.75 | 55 | 100 | 132 | **123** | 0 | **1** |
| 20 | LW1 | Wyee | 216 | 206 | 1.05 | 3.44 | 20 | 121 | 148 | **126** | 0 | **1** |
| *21* | *LW1* | *Invincible* | *145* | *116* | *1.25* | *2.70* | *15* | 90 | 106 | *96* | **0** | **1** |
| 22 | TE1 | Abel | 120 | 95 | 1.26 | 2.30 | 15 | 59 | 72 | **45** | 1 | **1** |
| 23 | LWs | Ashton | 216 | 154 | 1.40 | 2.55 | 15 | 101 | 123 | **82** | 1 | **1** |
| 24 | LW40 | WWD | 179 | 113 | 1.58 | 3.80 | 20 | 81 | 97 | **80** | 1 | **1** |
| *25* | *LWE1* | *South Bulga* | *259* | *155* | *1.67* | *2.55* | *15* | 120 | 142 | *145* | **0** | **0** |
| 26 | LW41 | WWD | 179 | 105 | 1.70 | 3.80 | 20 | 76 | 91 | **72** | 1 | **1** |
| 27 | LW9 | Crinum | 280 | 155 | 1.81 | 3.50 | 20 | 105 | 127 | **85** | 1 | **1** |
| 28 | LW39 | WWD | 179 | 97 | 1.84 | 3.90 | 20 | 71 | 85 | **68** | 1 | **1** |
| 29 | TE-3D | Wyee North | 355 | 185 | 1.92 | 1.90 | 20 | 60 | 86 | **63** | 0 | **1** |
| 30 | TE-355 | Wyee North | 355 | 180 | 1.97 | 1.90 | 20 | 59 | 84 | **40** | 1 | **1** |
| 31 | Panel2 | Abel | 150 | 76 | 1.97 | 1.88 | 15 | 45 | 56 | **45** | 1 | **1** |
| 32 | TE - North B | Cooranbong | 150 | 75 | 2.00 | 2.80 | 16 | 53 | 64 | **58** | 0 | **1** |
| 33 | LW1 | Oaky Ck | 205 | 95 | 2.16 | 3.20 | 25 | 58 | 71 | **55** | 1 | **1** |
| *34* | *LW9/9a* | *Homestead* | *200* | *80* | *2.50* | *3.30* | *15* | 62 | 73 | ***70*** | 0 | **1** |
| | | | | | | | | | | **Percentage of Measured < Predicted Value** | 39 | 97 |

*italics* - Surface to seam connection reported by authors.

## Table A6.6 - Summary of Measured v. Predicted Height of Continuous Fracture A-Zones for the Geometry Model

| Site | Panel | Mine | Panel Width W (m) | Cover Depth H (m) | W/H | Mining Height T (m) | Predicted A (m) | | Measured A (m) | Pass = 1; Fail = 0 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | mean | U95%CL | | m | U95 |
| 1 | MW508 | Bellambi W | 110 | 421 | 0.26 | 2.50 | 86 | 103 | **92** | 0 | 1 |
| 2 | LW10 | Metropolitan | 140 | 460 | 0.30 | 3.40 | 107 | 130 | **130** | 0 | 1 |
| 3 | LW1-4 | South Coast | 110 | 325 | 0.34 | 2.50 | 80 | 98 | **85** | 0 | 1 |
| 4 | LW6 | Kemira | 117 | 335 | 0.35 | 2.75 | 85 | 104 | **98** | 0 | 1 |
| 5 | LW20 | Metropolitan | 163 | 450 | 0.36 | 3.40 | 113 | 139 | **100** | 1 | 1 |
| 6 | LWA1 | Austar | 159 | 417 | 0.38 | 6.00 | 135 | 161 | ***87*** | 1 | 1 |
| 7 | LW514 | Bellambi W | 150 | 400 | 0.38 | 2.70 | 97 | 121 | **90** | 1 | 1 |
| 8 | LW28 | Appin | 200 | 500 | 0.40 | 2.30 | 108 | 140 | **90** | 1 | 1 |
| 9 | LW2 | Ellalong | 150 | 368 | 0.41 | 3.50 | 105 | 129 | **113** | 0 | 1 |
| 10 | LW3 | Tahmoor | 180 | 424 | 0.42 | 2.18 | 97 | 126 | **-** | - | - |
| 11 | LW9 | Teralba | 150 | 350 | 0.43 | 2.70 | 94 | 118 | ***110*** | 0 | 1 |
| 12 | TE | West Cliff | 200 | 446 | 0.45 | 2.50 | 108 | 140 | ***101*** | 1 | 1 |
| 13 | TE | Berrima | 120 | 176 | 0.68 | 2.3 | 68 | 87 | ***76*** | 0 | 1 |
| 14 | LW409 | Springvale | 265 | 384 | 0.69 | 3.25 | 126 | 169 | **133** | 0 | 1 |
| 15 | LW9 | Mandalong | 160 | 220 | 0.73 | 4.50 | 102 | 128 | **-** | - | - |
| 16 | LW11 | Angus Place | 211 | 263 | 0.80 | 2.47 | 95 | 127 | **-** | - | - |
| 17 | 411 | Springvale | 315 | 368 | 0.86 | 3.25 | 133 | 179 | **139** | 0 | 1 |
| 18 | LW5 | Mandalong | 160 | 179 | 0.89 | 3.70 | 90 | 113 | **118** | 0 | 0 |
| 19 | LW5 | Dendrobium | 245 | 255 | 0.96 | 3.75 | 116 | 150 | **123** | 0 | 1 |
| 20 | LW1 | Wyee | 216 | 206 | 1.05 | 3.44 | 101 | 129 | **126** | 0 | 1 |
| *21* | *LW1* | *Invincible* | *145* | *116* | *1.25* | *2.70* | 69 | 85 | **96** | **0** | **0** |
| 22 | TE1 | Abel | 120 | 95 | 1.26 | 2.30 | 57 | 71 | **45** | 1 | 1 |
| 23 | LWs | Ashton | 216 | 154 | 1.40 | 2.55 | 84 | 105 | **82** | 1 | 1 |
| 24 | LW40 | WWD | 179 | 113 | 1.58 | 3.80 | 80 | 105 | **80** | 0 | 1 |
| *25* | *LWE1* | *South Bulga* | *259* | *155* | *1.67* | *2.55* | 84 | 119 | **145** | **0** | **0** |
| 26 | LW41 | WWD | 179 | 105 | 1.70 | 3.80 | 76 | 100 | **72** | 1 | 1 |
| 27 | LW9 | Crinum | 280 | 155 | 1.81 | 3.50 | 95 | 129 | **85** | 1 | 1 |
| 28 | LW39 | WWD | 179 | 97 | 1.84 | 3.90 | 73 | 95 | **68** | 1 | 1 |
| 29 | TE-3D | Wyee North | 355 | 185 | 1.92 | 1.90 | 84 | 126 | **63** | 1 | 1 |
| 30 | TE-355 | Wyee North | 355 | 180 | 1.97 | 1.90 | 83 | 123 | **40** | 1 | 1 |
| 31 | Panel2 | Abel | 150 | 76 | 1.97 | 1.88 | 48 | 65 | **45** | 1 | 1 |
| 32 | TE-NthB | Cooranbong | 150 | 75 | 2.00 | 2.80 | 55 | 72 | **58** | 0 | 1 |
| 33 | LW1 | Oaky Ck | 205 | 95 | 2.16 | 3.20 | 67 | 88 | **55** | 1 | 1 |
| *34* | *LW9/9a* | *Homestead* | *200* | *80* | *2.50* | *3.30* | 61 | 79 | ***70*** | 0 | 1 |
| **Percentage of Measured < Predicted Value** | | | | | | | | | | 45 | 90 |

*italics* - Surface to seam connection reported by authors.

## Table A6.7 - Summary of Measured v. Predicted Height of Dilated B-Zones for the Geology Model

| Site | Panel | Mine | Panel Width W (m) | Cover Depth H (m) | W/H | Mining Height T (m) | t' (m) | Predicted B (m) | | Measured B (m) | Pass = 1; Fail = 0 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mean | U95%CL | | m | U95 |
| 1 | MW508 | Bellambi West | 110 | 421 | 0.26 | 2.50 | 49 | 198 | 214 | **-** | - | - |
| 2 | LW10 | Metropolitan | 140 | 460 | 0.30 | 3.40 | 49 | 238 | 259 | **-** | - | - |
| 3 | LW1 to 4 | South Coast | 110 | 325 | 0.34 | 2.50 | 41 | 170 | 187 | **-** | - | - |
| 4 | LW6 | Kemira | 117 | 335 | 0.35 | 2.75 | 40 | 181 | 198 | **-** | - | - |
| 5 | LW20 | Metropolitan | 163 | 450 | 0.36 | 3.40 | 70 | 234 | 258 | **-** | - | - |
| 6 | LWA1 | Austar | 159 | 417 | 0.38 | 6.00 | 78 | 254 | 278 | **277** | 0 | 1 |
| 7 | LW514 | Bellambi West | 150 | 400 | 0.38 | 2.70 | 64 | 203 | 225 | **-** | - | - |
| 8 | LW28 | Appin | 200 | 500 | 0.40 | 2.30 | 103 | 227 | 257 | **-** | - | - |
| 9 | LW2 | Ellalong | 150 | 368 | 0.41 | 3.50 | 49 | 211 | 233 | **210** | 1 | 1 |
| 10 | LW3 | Tahmoor | 180 | 424 | 0.42 | 2.18 | 74 | 204 | 231 | **204** | 0 | 1 |
| 11 | LW9 | Teralba | 150 | 350 | 0.43 | 2.70 | 30 | 200 | 223 | **150** | 1 | 1 |
| 12 | TE | West Cliff | 200 | 446 | 0.45 | 2.50 | 85 | 220 | 250 | ***245*** | 0 | 1 |
| 13 | TE SW1 | Berrima | 120 | 176 | 0.68 | 2.3 | 29 | 119 | 137 | **112** | 1 | 1 |
| 14 | LW409 | Springvale | 265 | 384 | 0.69 | 3.25 | 32 | 249 | 289 | ***254*** | 0 | 1 |
| 15 | LW9 | Mandalong | 160 | 220 | 0.73 | 4.50 | 25 | | | **-** | - | - |
| 16 | LW11 | Angus Place | 211 | 263 | 0.80 | 2.47 | 16 | 177 | 208 | ***253*** | 0 | 0 |
| 17 | 411 | Springvale | 315 | 368 | 0.86 | 3.25 | 32 | 251 | 295 | **288** | 0 | 1 |
| 18 | LW5 | Mandalong | 160 | 179 | 0.89 | 3.70 | 20 | 150 | 171 | **154** | 0 | 1 |
| 19 | LW5 | Dendrobium | 245 | 255 | 0.96 | 3.75 | 55 | 186 | 218 | **-** | - | - |
| 20 | LW1 | Wyee | 216 | 206 | 1.05 | 3.44 | 20 | 171 | 198 | **-** | - | - |
| *21* | LW1 | Invincible | 145 | 116 | 1.25 | 2.70 | **10** | 110 | 116 | ***111*** | **0** | **1** |
| 22 | TE1 | Abel | 120 | 95 | 1.26 | 2.30 | 15 | 86 | 95 | ***75*** | 1 | 1 |
| 23 | LWs | Ashton | 216 | 154 | 1.40 | 2.55 | 15 | 135 | 154 | ***130*** | 1 | 1 |
| 24 | LW40 | WWD | 179 | 113 | 1.58 | 3.80 | 20 | 112 | 113 | ***108*** | **1** | 1 |
| *25* | LWE1 | South Bulga | 259 | 155 | 1.67 | 2.55 | **10** | 141 | 155 | **150** | **0** | **1** |
| 26 | LW41 | WWD | 179 | 105 | 1.70 | 3.80 | 20 | 100 | 105 | **100** | 1 | 1 |
| 27 | LW9 | Crinum | 280 | 155 | 1.81 | 3.50 | 20 | 143 | 155 | ***150*** | 0 | 1 |
| 28 | LW39 | WWD | 179 | 97 | 1.84 | 3.90 | 20 | 92 | 97 | **92** | 0 | 1 |
| 29 | TE-3D | Wyee North | 355 | 185 | 1.92 | 1.90 | 60 | 128 | 154 | ***143*** | 0 | 1 |
| 30 | TE-355 | Wyee North (LW4) | 355 | 180 | 1.97 | 1.90 | 60 | 125 | 150 | **-** | - | - |
| 31 | Panel2 | Abel | 150 | 76 | 1.97 | 1.88 | 15 | 69 | 76 | **71** | 0 | 1 |
| 32 | TE-North B | Cooranbong | 150 | 75 | 2.00 | 2.80 | 16 | 70 | 75 | ***70*** | 1 | 1 |
| 33 | LW1 | Oaky Ck | 205 | 95 | 2.16 | 3.20 | 25 | 91 | 95 | ***90*** | 1 | 1 |
| *34* | LW9/9a | Homestead | 200 | 80 | 2.50 | 3.30 | 15 | 75 | 80 | **75** | **1** | 1 |
| **Percentage of Measured < Predicted Value** | | | | | | | | | | | **43** | **96** |

### Table A6.8 - Summary of Measured v. Predicted Height of Dilated B-Zones for the Geometry Model

| Site | Panel | Mine | Panel Width W (m) | Cover Depth H (m) | W/H | Mining Height T (m) | Predicted B (m) | | Measured B (m) | Pass = 1; Fail = 0 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | mean | U95%CL | | m | U95 |
| 1 | MW508 | Bellambi West | 110 | 421 | 0.26 | 2.50 | 192 | 210 | **-** | - | - |
| 2 | LW10 | Metropolitan | 140 | 460 | 0.30 | 3.40 | 228 | 250 | **-** | - | |
| 3 | LW1 to 4 | South Coast | 110 | 325 | 0.34 | 2.50 | 167 | 184 | **-** | - | - |
| 4 | LW6 | Kemira | 117 | 335 | 0.35 | 2.75 | 175 | 194 | **-** | - | - |
| 5 | LW20 | Metropolitan | 163 | 450 | 0.36 | 3.40 | 235 | 261 | **-** | - | - |
| 6 | LWA1 | Austar | 159 | 417 | 0.38 | 6.00 | 247 | 272 | **277** | 0 | 0 |
| 7 | LW514 | Bellambi West | 150 | 400 | 0.38 | 2.70 | 206 | 230 | **-** | - | - |
| 8 | LW28 | Appin | 200 | 500 | 0.40 | 2.30 | 246 | 278 | **-** | - | - |
| 9 | LW2 | Ellalong | 150 | 368 | 0.41 | 3.50 | 206 | 230 | **210** | 0 | 1 |
| 10 | LW3 | Tahmoor | 180 | 424 | 0.42 | 2.18 | 216 | 245 | **204** | 1 | 1 |
| 11 | LW9 | Teralba | 150 | 350 | 0.43 | 2.70 | 192 | 216 | **150** | 1 | 1 |
| 12 | TE | West Cliff | 200 | 446 | 0.45 | 2.50 | 234 | 266 | ***245*** | 0 | 1 |
| 13 | TE SW1 | Berrima | 120 | 176 | 0.68 | 2.3 | 120 | 139 | **112** | 1 | 1 |
| 14 | LW409 | Springvale | 265 | 384 | 0.69 | 3.25 | 244 | 286 | ***254*** | 0 | 1 |
| 15 | LW9 | Mandalong | 160 | 220 | 0.73 | 4.50 | 165 | 191 | **-** | - | - |
| 16 | LW11 | Angus Place | 211 | 263 | 0.80 | 2.47 | 177 | 209 | ***253*** | 0 | 0 |
| 17 | 411 | Springvale | 315 | 368 | 0.86 | 3.25 | 250 | 296 | **288** | 0 | 1 |
| 18 | LW5 | Mandalong | 160 | 179 | 0.89 | 3.70 | 143 | 166 | **154** | 0 | 1 |
| 19 | LW5 | Dendrobium | 245 | 255 | 0.96 | 3.75 | 195 | 229 | **-** | - | - |
| 20 | LW1 | Wyee | 216 | 206 | 1.05 | 3.44 | 165 | 193 | **-** | - | - |
| *21* | LW1 | Invincible | 145 | 116 | 1.25 | 2.70 | 104 | 116 | ***111*** | 0 | 1 |
| 22 | TE1 | Abel | 120 | 95 | 1.26 | 2.30 | 86 | 95 | ***75*** | 1 | 1 |
| 23 | LWs | Ashton | 216 | 154 | 1.40 | 2.55 | 134 | 154 | ***130*** | 1 | 1 |
| 24 | LW40 | WWD | 179 | 113 | 1.58 | 3.80 | 111 | 113 | ***108*** | 1 | 1 |
| *25* | LWE1 | South Bulga | 259 | 155 | 1.67 | 2.55 | 134 | 155 | **150** | 0 | 1 |
| 26 | LW41 | WWD | 179 | 105 | 1.70 | 3.80 | 104 | 105 | **100** | 1 | 1 |
| 27 | LW9 | Crinum | 280 | 155 | 1.81 | 3.50 | 142 | 155 | ***150*** | 0 | 1 |
| 28 | LW39 | WWD | 179 | 97 | 1.84 | 3.90 | 92 | 97 | **92** | 0 | 1 |
| 29 | TE-3D | Wyee North | 355 | 185 | 1.92 | 1.90 | 148 | 174 | ***143*** | 1 | 1 |
| 30 | TE-355 | Wyee North (LW4) | 355 | 180 | 1.97 | 1.90 | 144 | 170 | - | - | - |
| 31 | Panel2 | Abel | 150 | 76 | 1.97 | 1.88 | 71 | 76 | **71** | 0 | 1 |
| 32 | TE-North B | Cooranbong | 150 | 75 | 2.00 | 2.80 | 70 | 75 | ***70*** | 1 | 1 |
| 33 | LW1 | Oaky Ck | 205 | 95 | 2.16 | 3.20 | 93 | 95 | ***90*** | 1 | 1 |
| *34* | LW9/9a | Homestead | 200 | 80 | 2.50 | 3.30 | 75 | 80 | **75** | 1 | 1 |
| **Percentage of Measured < Predicted Value** | | | | | | | | | | **48** | **91** |

(iv) Parameter Sensitivities

A review of the sensitivity of the Pi-Term Models has been completed in **Merrick, 2014** and demonstrates that the model is not overly sensitive to changes to the input parameters, W, H and T. The influence of the effective strata thickness t' has a greater impact on the height of fracturing for values < 20 m than the cases with t'> 20 m. This is not surprising as the spanning capabilities of the strata units will probably decrease rapidly below this thickness range as it corresponds with the point where the bending beam stress starts to exceed the UCS of the rock mass.

The model variable sensitivity charts are presented in **Figures A43e** to **A43h**.

(v) Comparison with other models

Three critical cases were identified in the analysis where the A-Zone extended to within 10 m of the surface (Invincible, South Bulga, and Homestead Mines) with a minimum t' value of 10 m assumed. Adopting a minimum beam thickness of 10 m will generally indicate the maximum likely height of continuous fracturing for all cases in the database (see **Figure A42g**).

For completeness, four case studies have been selected from the sub-critical, critical and supercritical panel geometries and plotted with varying panel widths in **Figures A43i** to **A43l** to demonstrate the sensitivity of the models to changes in mining geometry. Several sub-surface fracture height models (**Foster, 1995; SCT, 2008; ACARP, 2007** and **Tammetta, 2013**) that have been referred to by OEH and PACs during recent project approval applications are also plotted with the Pi-term model results. It is apparent that the models are based on a smaller number of key variables and some were developed from data in a particular coalfield only. The application of the models in other coalfields with significantly different geological conditions and mining geometries are considered to have resulted in a larger range of 'error' compared to the Pi-term models.

Finally, the width-based models also do not consider the effect of cover depth or mining height and assume the A-Zone will continue to increase above *supercritical* panel geometries. This usually means that surface to seam connectivity will always be predicted for critical and supercritical panel widths. It is noted that only 2 or 3 cases out of 14 (15% - 20%) or 1 in 5 supercritical longwalls have resulted in surface to seam connectivity; see **Figure 43m**.

This outcome suggests that other factors such as cover depth, mining height and geological conditions should also be considered than just the panel width alone when estimating heights of fracturing above longwall panels.

### A11.5.11 Definition of Surface Cracking Zone

During the development of the Pi-term model it has also been necessary to better define the surface cracking zone depth. The depth of the surface cracking zone has been estimated from subsidence data, surface crack observations and published measurements as follows:

- The literature review findings presented in **Section A11.3** indicate that surface cracking depths above longwalls are likely to be < 15 m generally.

- The Mean and median strain/curvature ratios of 5.3 m and 7.4 m mentioned earlier in Section derived from subsidence data measurements for Newcastle Coalfield (see **Figures A43n** and **A43o**) indicates the ***average surface cracking depth***. The ratio is considered to be a direct measurement of the depth to the neutral axis of bending where tensile strains cross over to compressive strain. This also suggests near surface strata beam thicknesses are twice the depth to the neutral axis of bending or 11 m to 15 m. It is apparent that these values are consistent with near surface beam thicknesses assumed in the Pi-Term Geology Model.

- Borehole measurement devices measured depths of cracking at the base of sandstone valleys in the Southern Coalfield of up to 12 m after mine subsidence effects (refer **Mills, 2007**).

- Measured crack depths of up to 20 m have been measured along the crests of steep slopes above LW41 (ref to **RCA, 2013**).

Based on the above information, it is assessed that the following conservative crack depths presented in **Table A6.9** may be assumed when assessing surface to seam connectivity potential above longwalls beneath varying topography:

**Table A6.9 - Suggested Maximum Cracking Depths for Impact Assessment**

| Location and Topography | Surface Cracking Depth (m) |
|---|---|
| | Newcastle/Hunter Valley - Southern/Western Coalfield |
| Flat Terrain with Moderate Slopes up to 18$^o$ | 7.5 - 12 |
| Bases of Valleys | 12 - 15 |
| Low side of panel beneath steep slopes > 18$^o$ (not valley floor) | 3.5 - 5 |
| Crests or high side of panel beneath steep slopes > 18$^o$ | 15 - 20 |

### A11.5.12 Summary

The geometry and geology Pi-term models presented in **Section A11.5** for estimating the A-Zone and B-Zone fracture horizons are generally consistent with the prevailing view that the panel width, cover depth and mining height will have the greatest influence on fracture development heights above longwall panels. The Pi-term models for A and B-Zone Fracture

Heights are also generally consistent with **Whittaker and Reddish, 1990**, **Singh & Kendorski, 1991** and the analytical models presented earlier.

The spanning or non-spanning capability of strata units in the overburden cannot be ignored however, when assessing the potential fracturing heights above a longwall panel. Where local extensometer and piezometric data are available, the influence of spanning strata may be used to calibrate the Geology Pi-term model to a given site.

Predictions based on the up-dated Strain, Overburden Curvature Index and Fracture Height Angle Models are still also considered relevant and will provide similar, if not more conservative outcomes. These models may be used to provide a range of predictions at a greenfields site for risk assessment purposes. It should be understood however, that only the Geology Pi-term model will allow the influence of strata unit thickness or local site geology to be included directly in the predictions of sub-surface fracture height.

It should be understood that the vagaries of the rock mass do not usually allow the strata unit thickness term to be assessed directly from borehole data without back analysis of overburden performance measurements. The database presented in this appendix has been used to derive a minimum beam thickness of 10 m to estimate worst-case heights of fracturing for adverse rock mass conditions. A thickness of 15 m to 20 m corresponds to the minimum beam thicknesses assessed from surface strain and curvature measurements (and a cracking depth of 7.5 m to 10 m).

Subsequent measurements of continuous heights of fracturing may require a thinner strata unit thickness to be used to calibrate the model. At this stage, there are three cases in the database that have been reported to have fractured through to the surface, which required a beam thickness of 6 to 11 m to match the Pi-term model exactly and intersect the surface cracking zone (or D-Zone). One of the cases (South Bulga LWE1) however, may have included the B-Zone in the interpretation of the 'height of fracturing' at the time it was assessed.

It is assessed that the assumptions that the height of fracturing will be limited when either:

- critical panel widths exceed 1.4H;
- spanning strata exists that can bridge the fractured zone or the presence of plastic, low strength strata that tends to shear along bedding partings when deformed through bending action, rather than crack vertically, may also limit continuous cracking heights.

All of these outcomes are intuitively correct and correlate well with observed behaviour across sub-critical to supercritical mining geometries. It is also noted that the strata unit thickness term enables all of the database and subsequent regression equations to be used with a reasonable level of confidence, such that the predicted worst-case values will not be unduly biased by the database itself. The geology Pi-term t'/W' was back analysed for each of the 34 case studies to give an exact fit between the predicted and measured fracture heights. The set of measured t' values were correlated with the predicted t' with a high $R^2$ of 0.9. The predicted v. measured heights of continuous fracturing were also correlated and returned an $R^2$ value of 0.8, which is also a good fit.

For estimates of HoF above partial pillar extraction panels, the HoF zones may be based on the effective mining height, $T_e$ (if remnant pillars are likely to fail) or the maximum span between stable remnant pillars.

The use of the Pi-term models for multi-seam mining environments will also require consideration of the interburden thicknesses and cumulative effects of the A-Zones if they likely to intersect overlying longwall goafs. The multi-seam affect may be estimated for an overlying seam by converting the multi-seam subsidence increase to an effective mining height.

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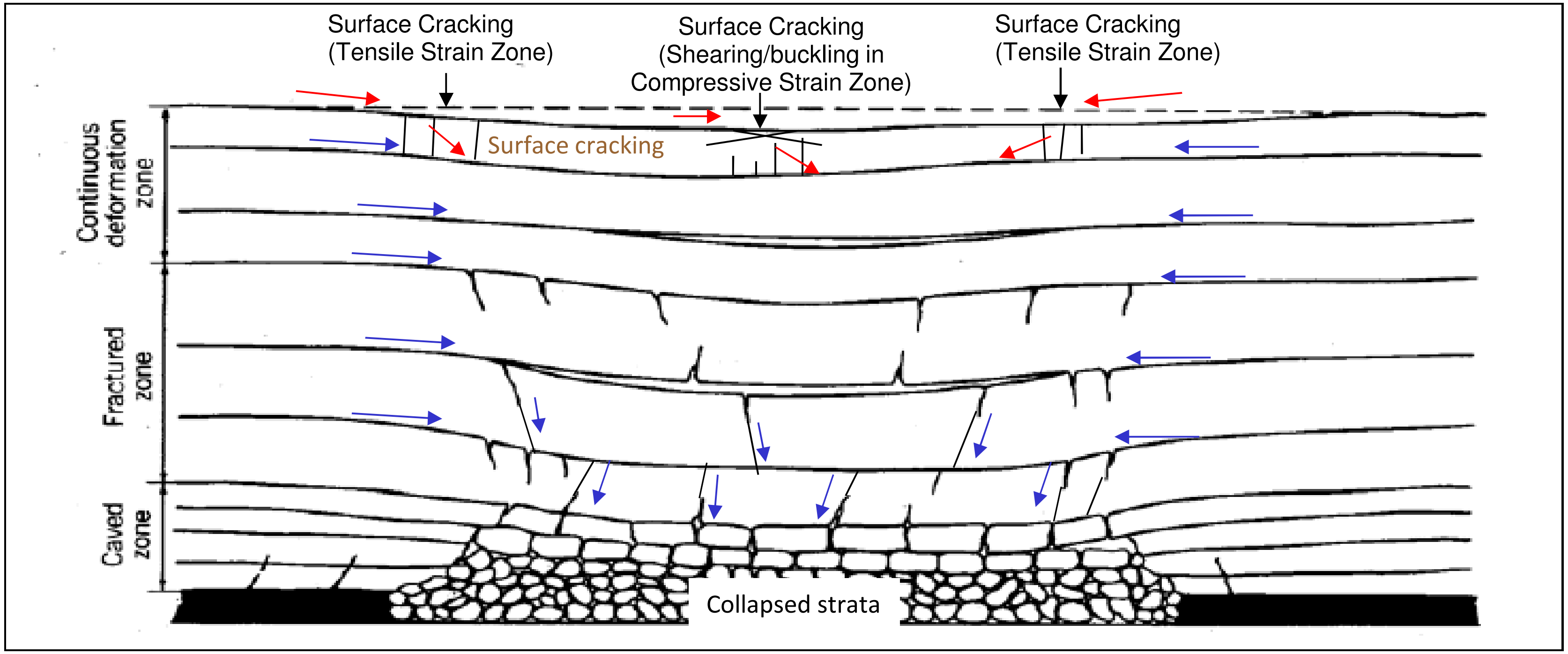


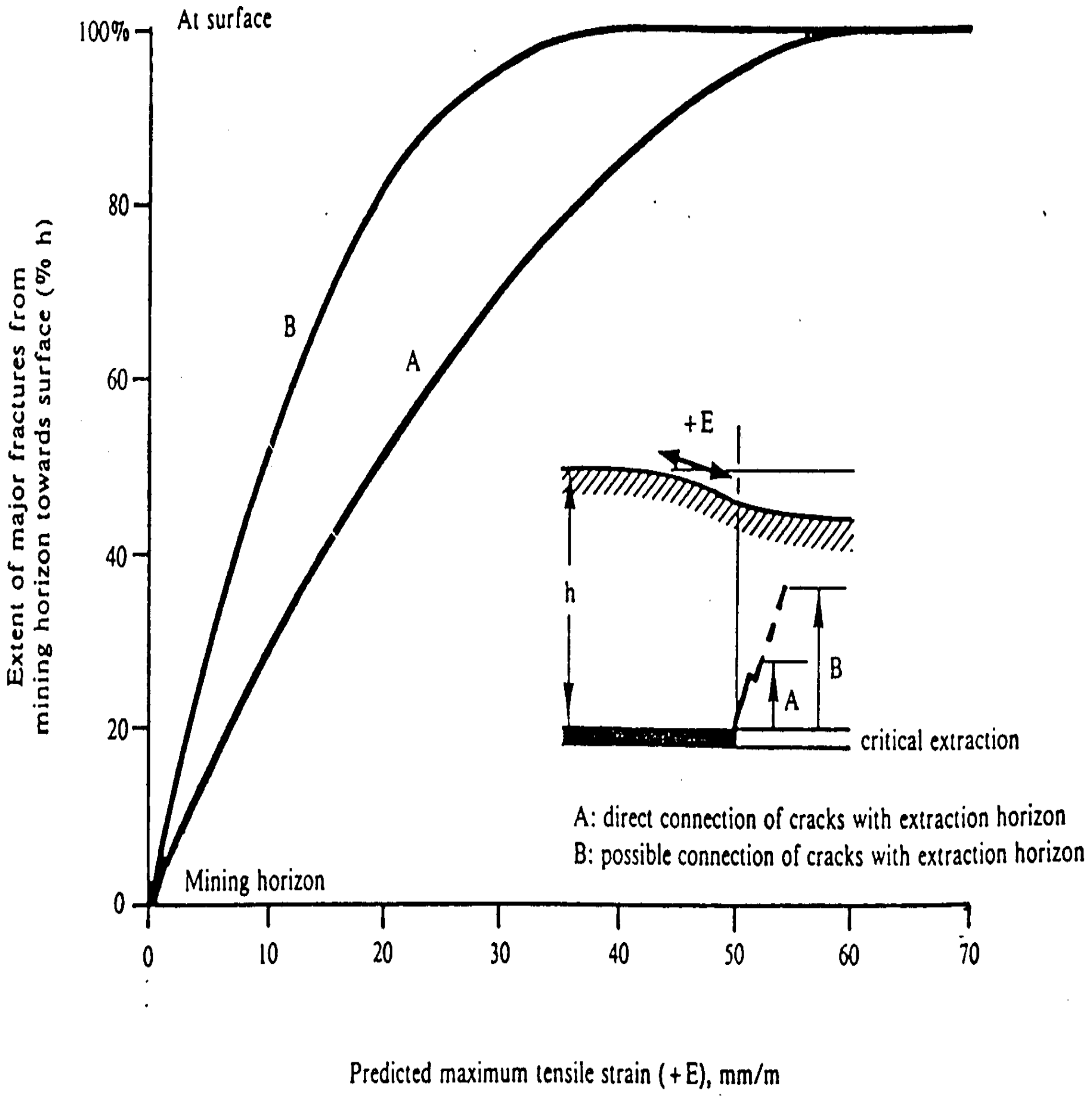
Zones in the Overburden According to Peng and Chiang (1984)

Key

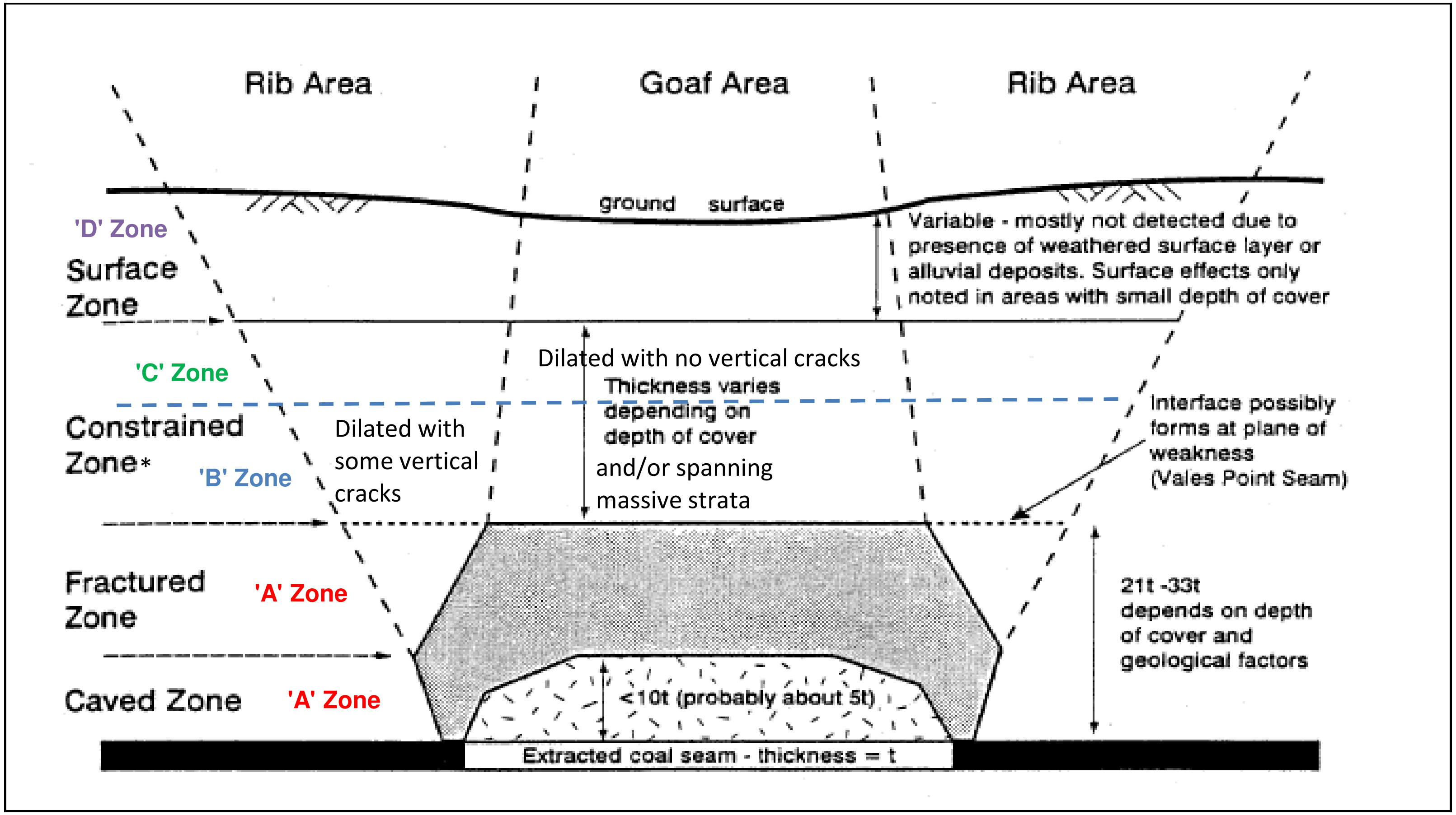
→ Surface water flow path

→ Sub-surface water flow path

| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Appendix A | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 23.11.12 | Title: | Schematic Model of Overburden Fracture Zones Above Longwall Panels | | |
| | Ditton Geotechnical<br>Services Pty Ltd | | | | | |
| | | | Scale: | NTS | Figure No: | A40a |



| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Extract from ACARP, 2003 | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 30.04.07 | Title: | Enpirically Based Sub-Surface Fracturing Model<br>Presented in Whittaker & Reddish, 1989 | | |
| | Ditton Geotechnical<br>Services Pty Ltd | | Scale: | NTS | Figure No: | A40b |



**Zones in the Overburden according to Forster (1995)**

* - Constrained Zone generally means B-Zone, but may include C-Zone , depending on W/H ratio and geology

| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Appendix A | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 23.11.12 | Title: | Schematic Model of Overburden Fracture Zones in **Forster, 1995** Model<br>(based on Piezometric Data Above High Extraction Panels in the Newcastle Coalfield) | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A40c |

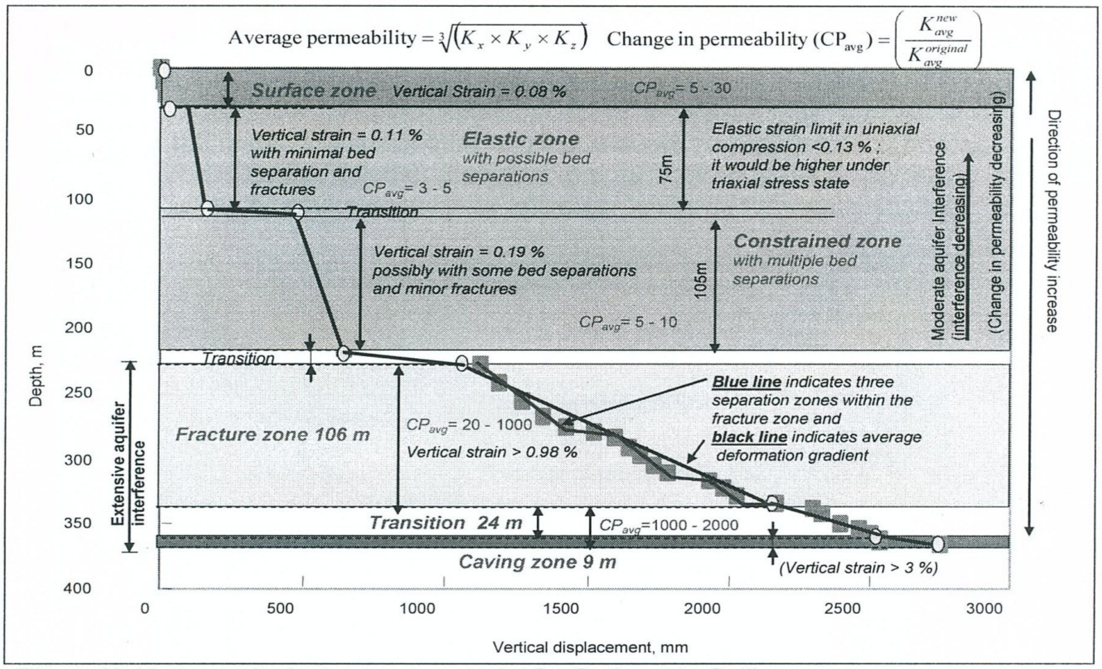


Figure H. Hydrogeological response model for Springvale Colliery

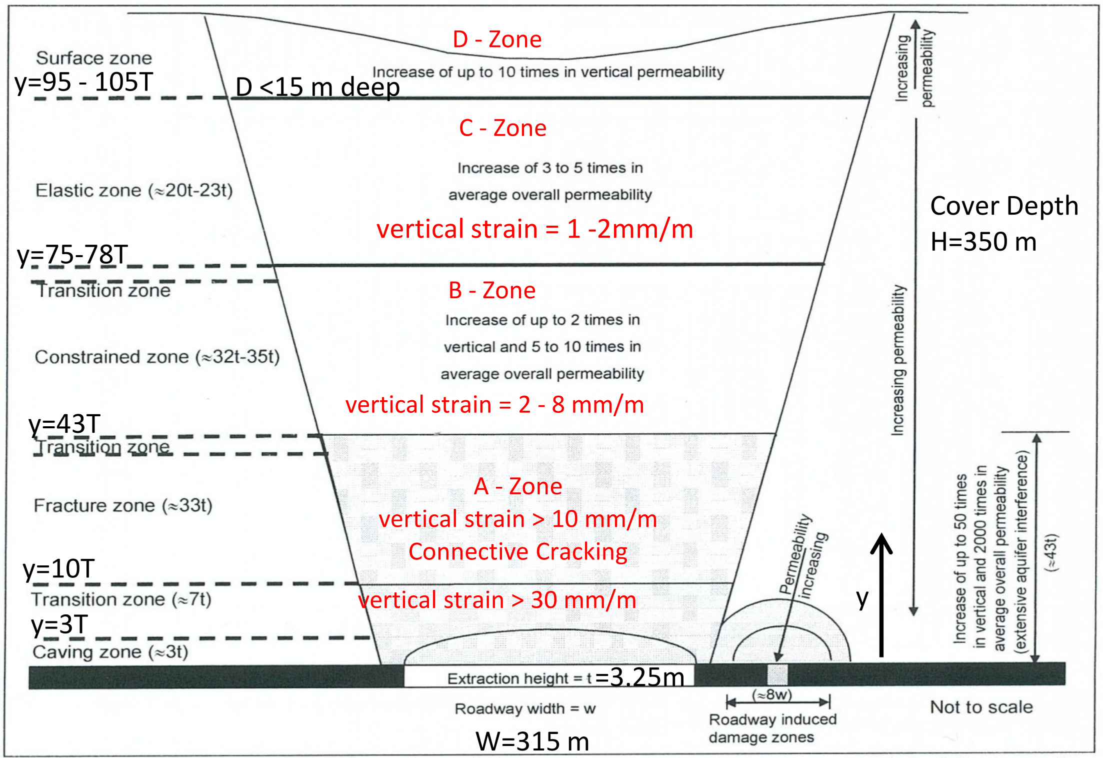


Figure I. A schematic representation of the hydrogeological response model of Springvale Colliery

| DgS | Engineer: | S.Ditton | Client: | Appendix A | | |
|---|---|---|---|---|---|---|
| | Drawn: | S.Ditton | | | | |
| | Date: | 23.11.12 | Title: | Schematic Model of Overburden Fracture Zones **in ACARP, 2007** | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | | Figure No: | A40d |

Figure 6 is a conceptual model that illustrates the type of damage that can be expected within the overburden due to subsidence above a full-extraction panel. Five broad zones can be identified [Singh and Kendorski 1981; Peng and Chiang 1984; Kendorski 1993, 2006]:

1. The *complete caving zone*, in which the roof rock is completely disrupted as it falls into the gob, normally extends two to four times the extracted seam height (h).
2. The *partial caving zone,* in which the beds are completely fractured but never lose contact with one another, extends up to 6–10 h.
3. The *fracture zone,* within which the subsidence strains are great enough to cause new fracturing in the rock and create direct hydraulic connections to the lower seam. The top of this zone can be as high as 24 h above the lower seam.
4. The *dilated zone,* where the permeability is enhanced but little new fracturing is created, extends up to 60 h.
5. The *confined zone,* where subsidence normally causes no change in strata properties other than occasional bed slippage. This zone extends from the top of the dilated zone to about 50 ft below the surface.

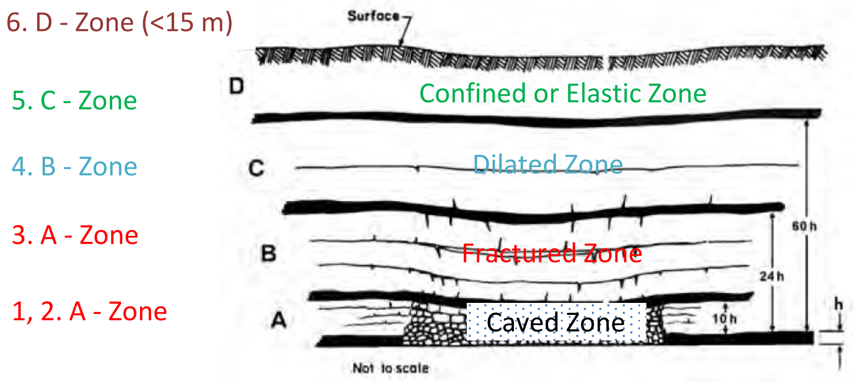
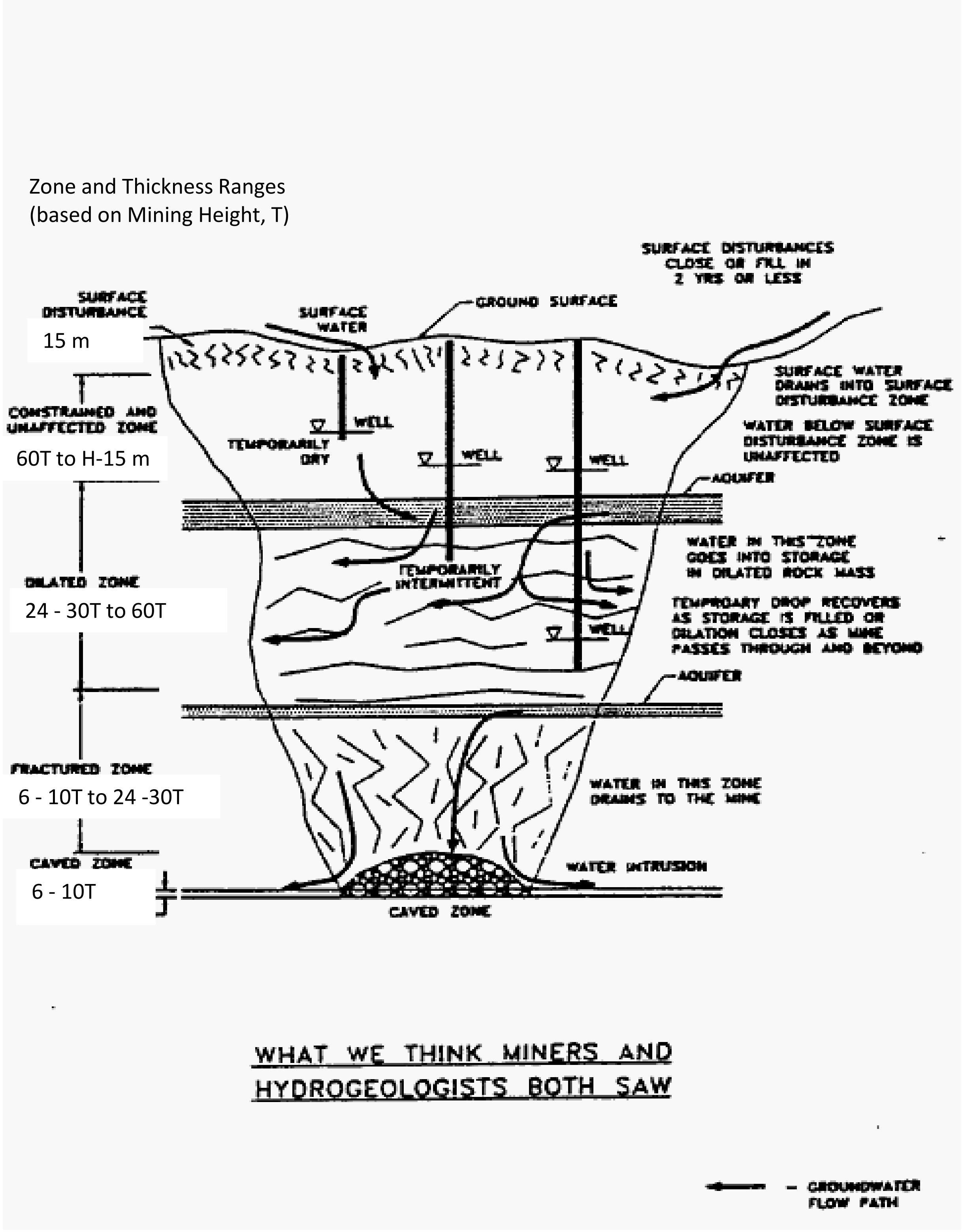


**Figure 6.—Overburden response to full-extraction mining: (A) caving zones, (B) fracture zone, (C) dilated zone, and (D) confined zone.**

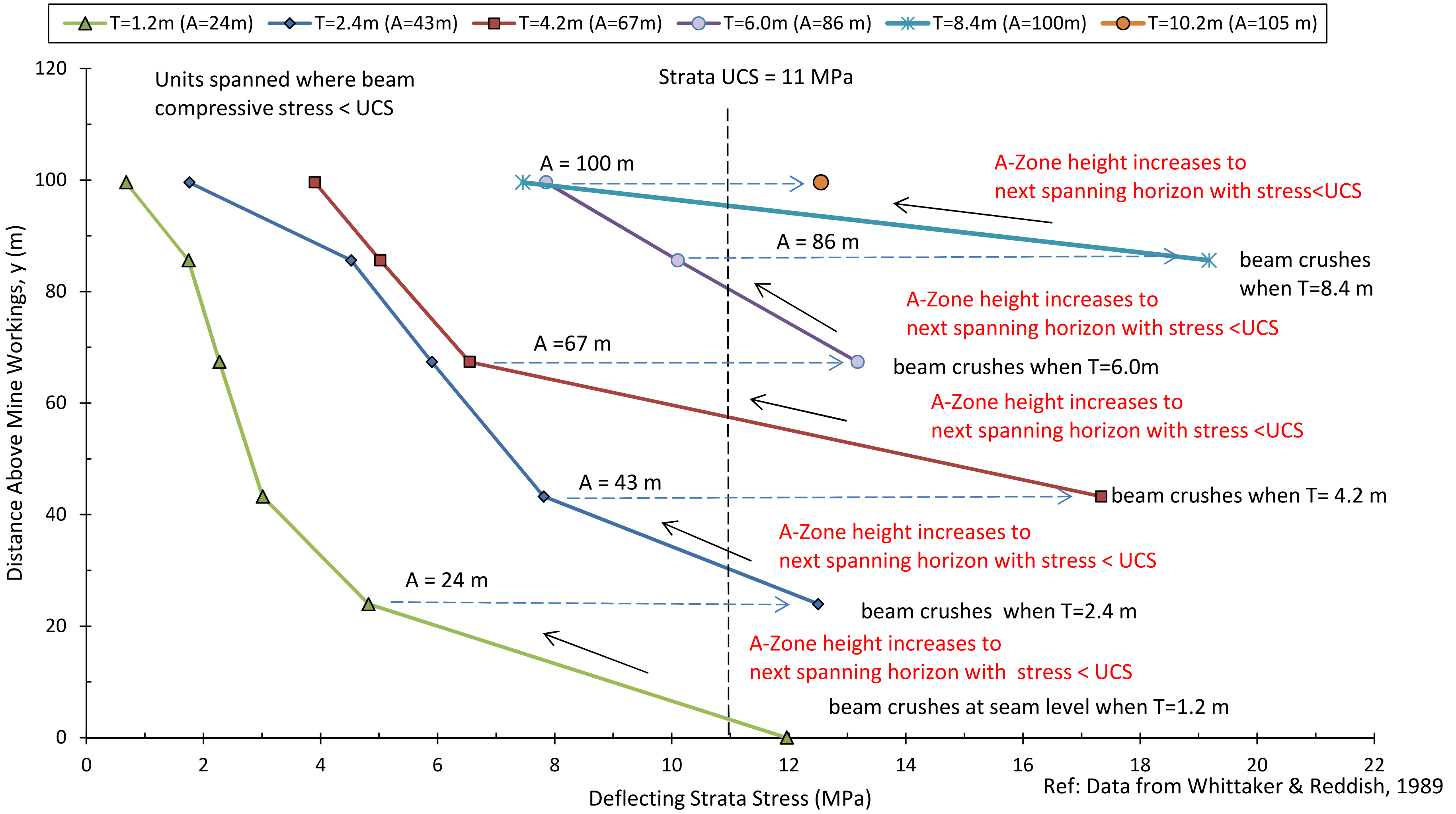
The dimensions of these zones vary from panel to panel because of differences in geology and panel geometry. The implication of this model for multiple-seam mining is that when the interburden thickness exceeds approximately 6–10 times the lower seam thickness, the upper seam should be largely intact, although the roof may be fractured or otherwise damaged.

Note: Equivalent **ACARP, 2007** model zones A to D also shown down the left side.

| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Appendix A | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 03.06.13 | Title: | Model of Overburden Fracture Zones above US Longwall Mines According to Mark, 2007 | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | | Figure No: | A40e |



| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Appendix A | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 03.06.13 | Title: | Model of Overburden Fracture Zones above UK Longwall Mines According to Kendorski, 1993 | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | | Figure No: | A40f |

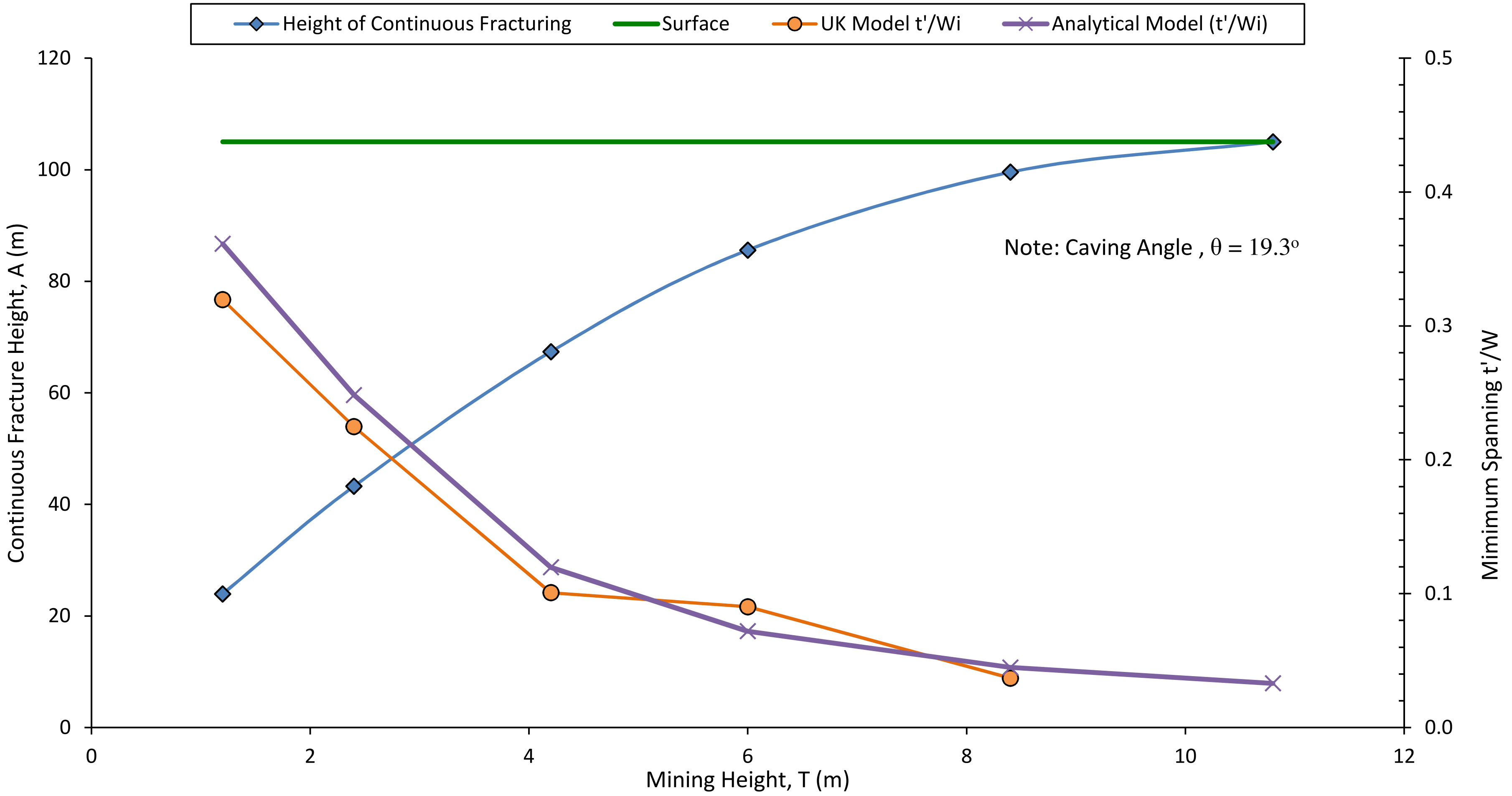


Ref: Data from Whittaker & Reddish, 1989

DgS

Engineer: S.Ditton
Drawn: S.Ditton
Date: 07.06.13
Ditton Geotechnical Services Pty Ltd

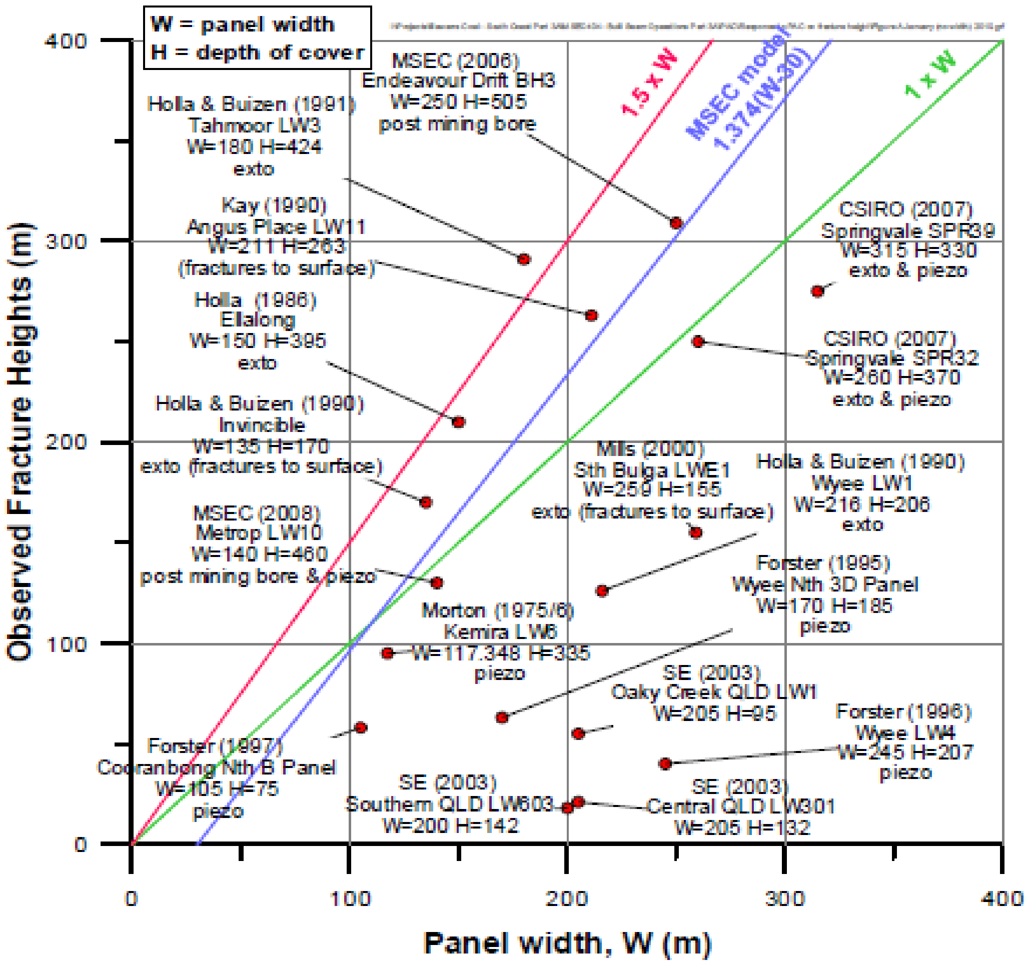
Client: Review of Height of Fracturing Data
Title: Interpreted Beam Stress in Spanning Units of Physical Model of Laminated Overburden above a Longwall
Scale: NTS
Figure No: A40g



Note: Caving Angle , $\theta = 19.3^{o}$

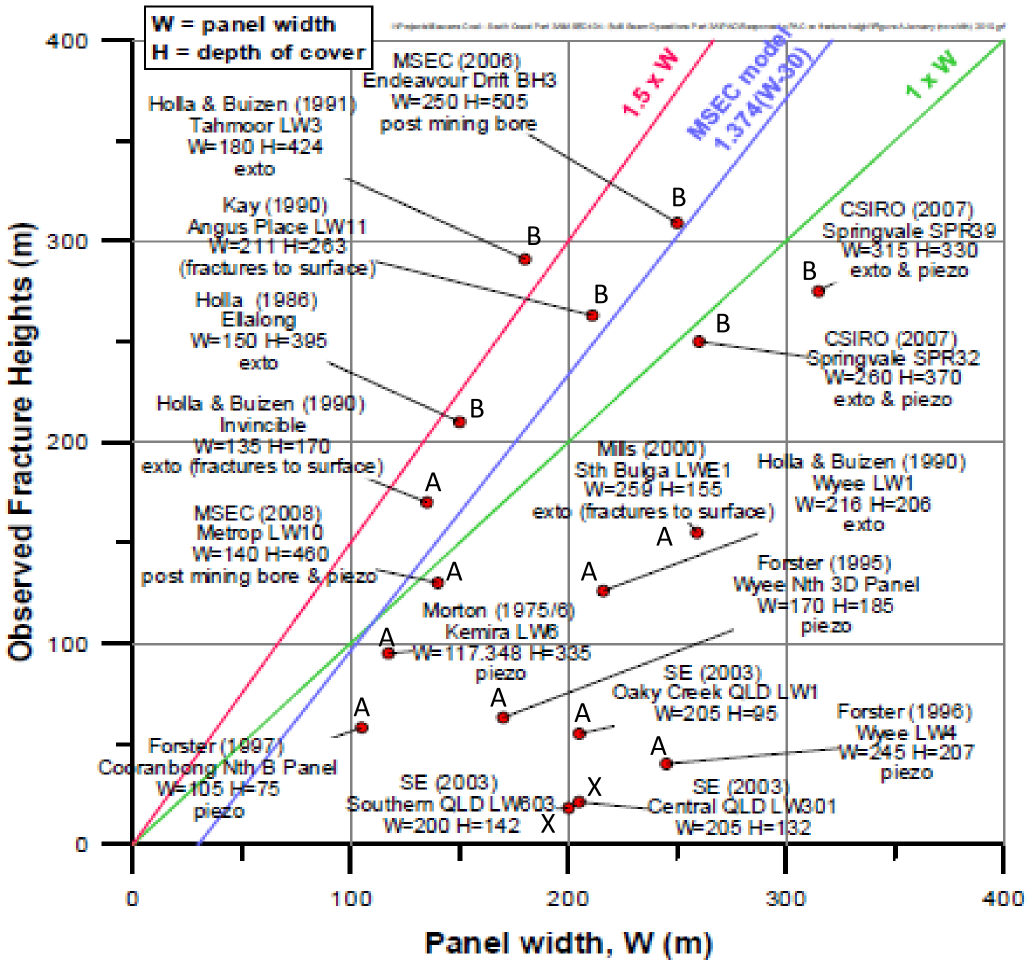
Ref: Data from Whittaker & Reddish, 1989

| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 07.06.13 | Title: | Analytical v. Physical HoF Model Mimimum Beam Thickness Required to Span the Continuous Fracture Zone | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A40h |



**Ref: MSEC, 2011**

| | | | | | |
|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | |
| | Drawn: | S.Ditton | Title: | Observed Fracture Height Models presented by SCT and MSEC | |
| | Date: | 07.06.13 | | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: A40i |



Key

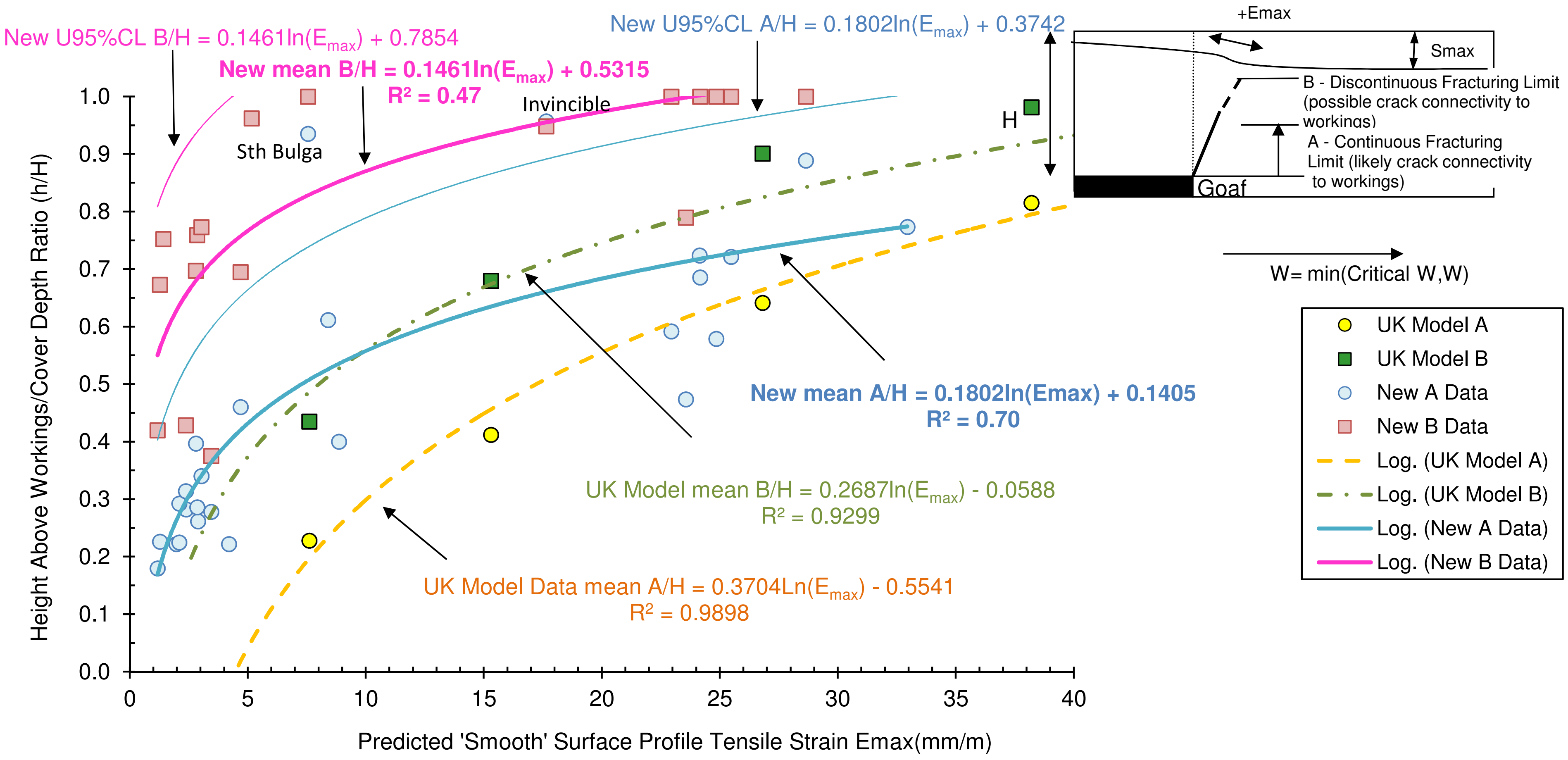
A: A-Zone Horizon

B: B-Zone Horizon

X: In-conclusive data

**Ref: MSEC, 2011**

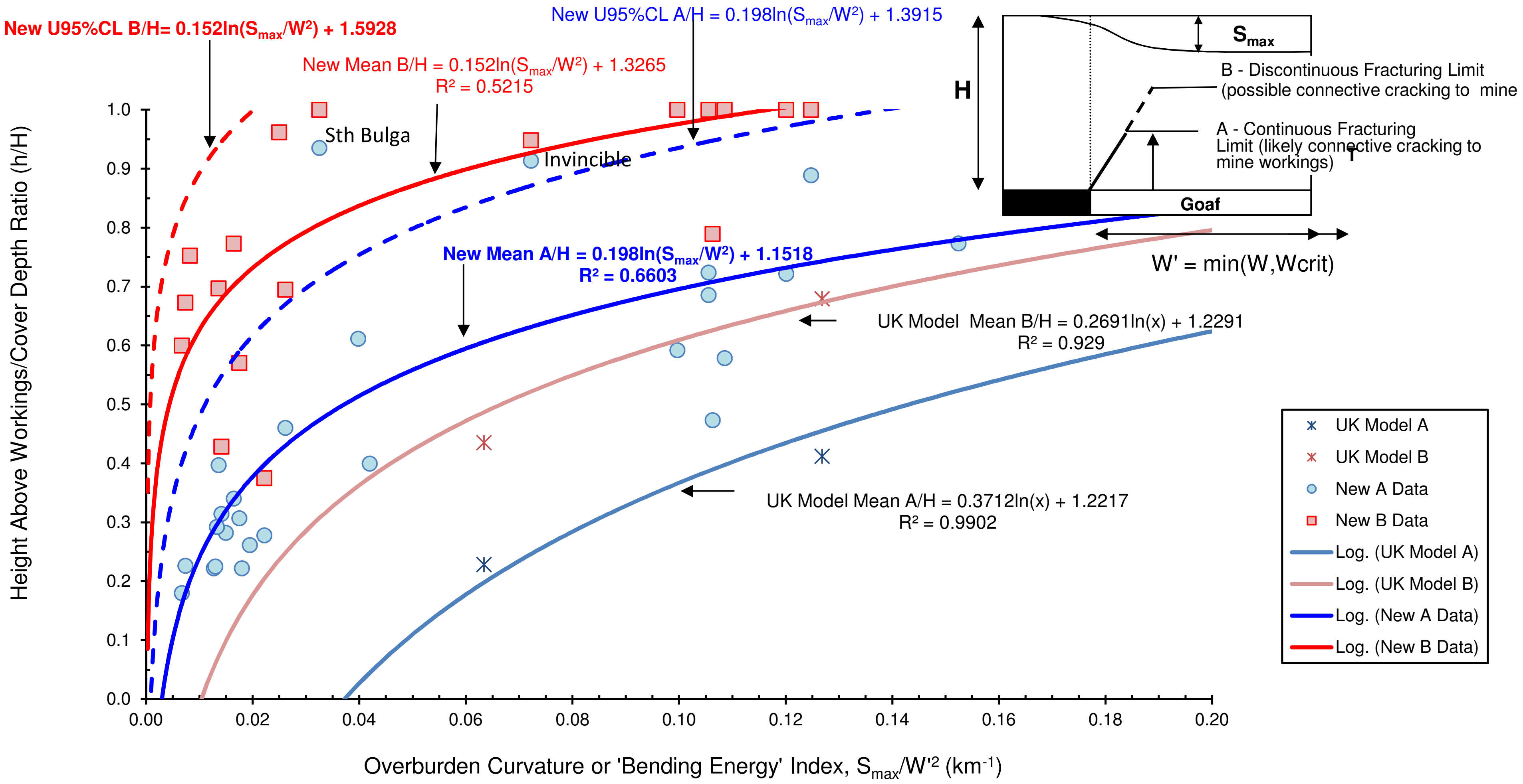
| | | | | | |
|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | |
| | Drawn: | S.Ditton | | | |
| | Date: | 07.06.13 | Title: | Review of Observed Fracture Height Models presented by SCT and MSEC v. Whittaker & Reddish Sub-Surface Fracture Model Zoning | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: A40j |



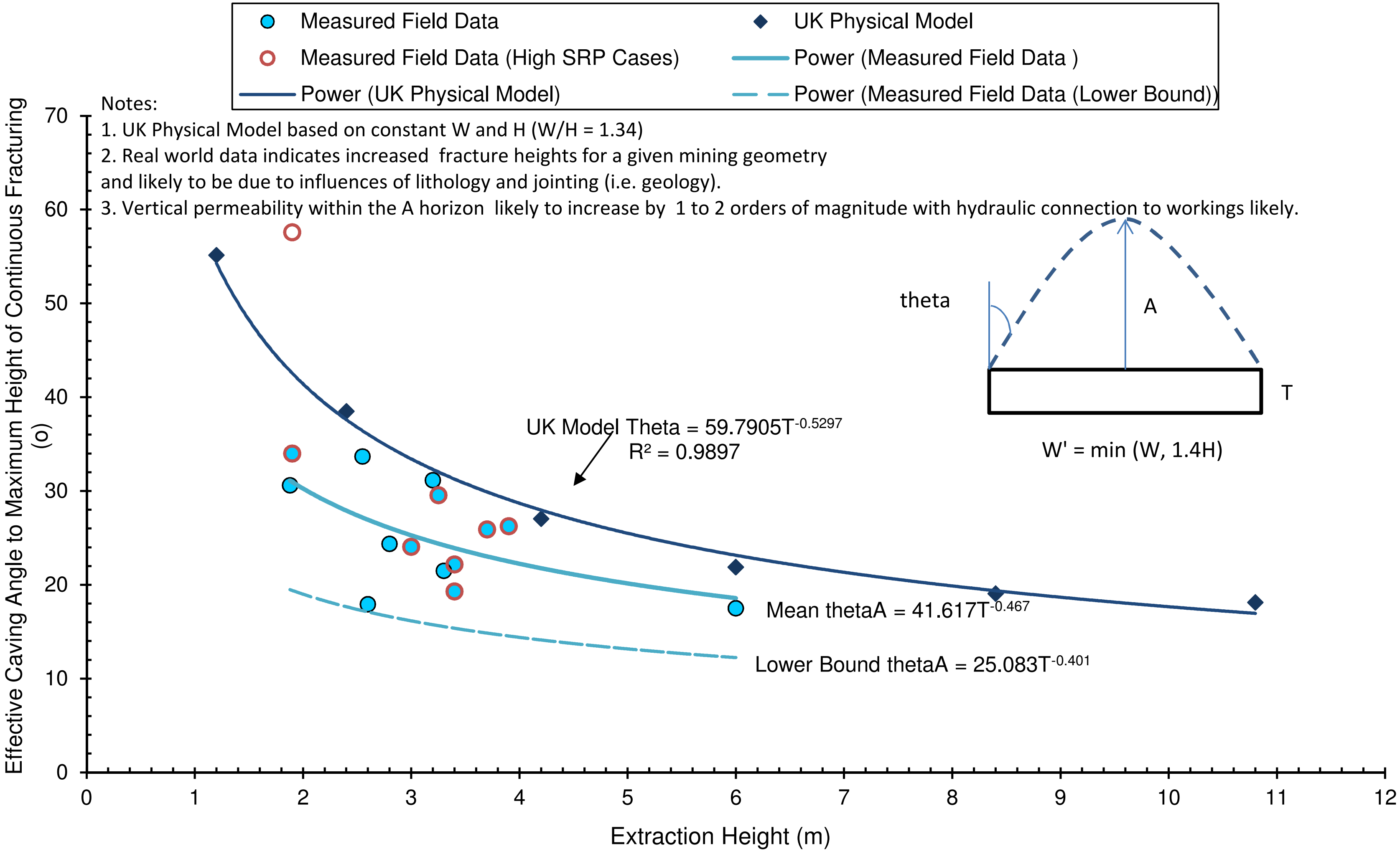
DgS

Engineer: S.Ditton
Drawn: S.Ditton
Date: 18.11.12
Ditton Geotechnical
Services Pty Ltd

Client: Updated Whittaker and Reddish Model presented in ACARP, 2003
Title: Continuous and Discontinuous Sub-Surface Fracture Height Model above Longwalls
using Surface Tensile Strains as the Key Indicator
Scale: NTS
Figure No: A41a



| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Updated from ACARP, 2003 | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 03.12.12 | Title: | Continuous and Discontinuous Sub-Surface Fracture Heights above Longwalls (based on ACARP, 2003) | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A41b |



Notes:

1. UK Physical Model based on constant W and H (W/H = 1.34)

2. Real world data indicates increased fracture heights for a given mining geometry and likely to be due to influences of lithology and jointing (i.e. geology).

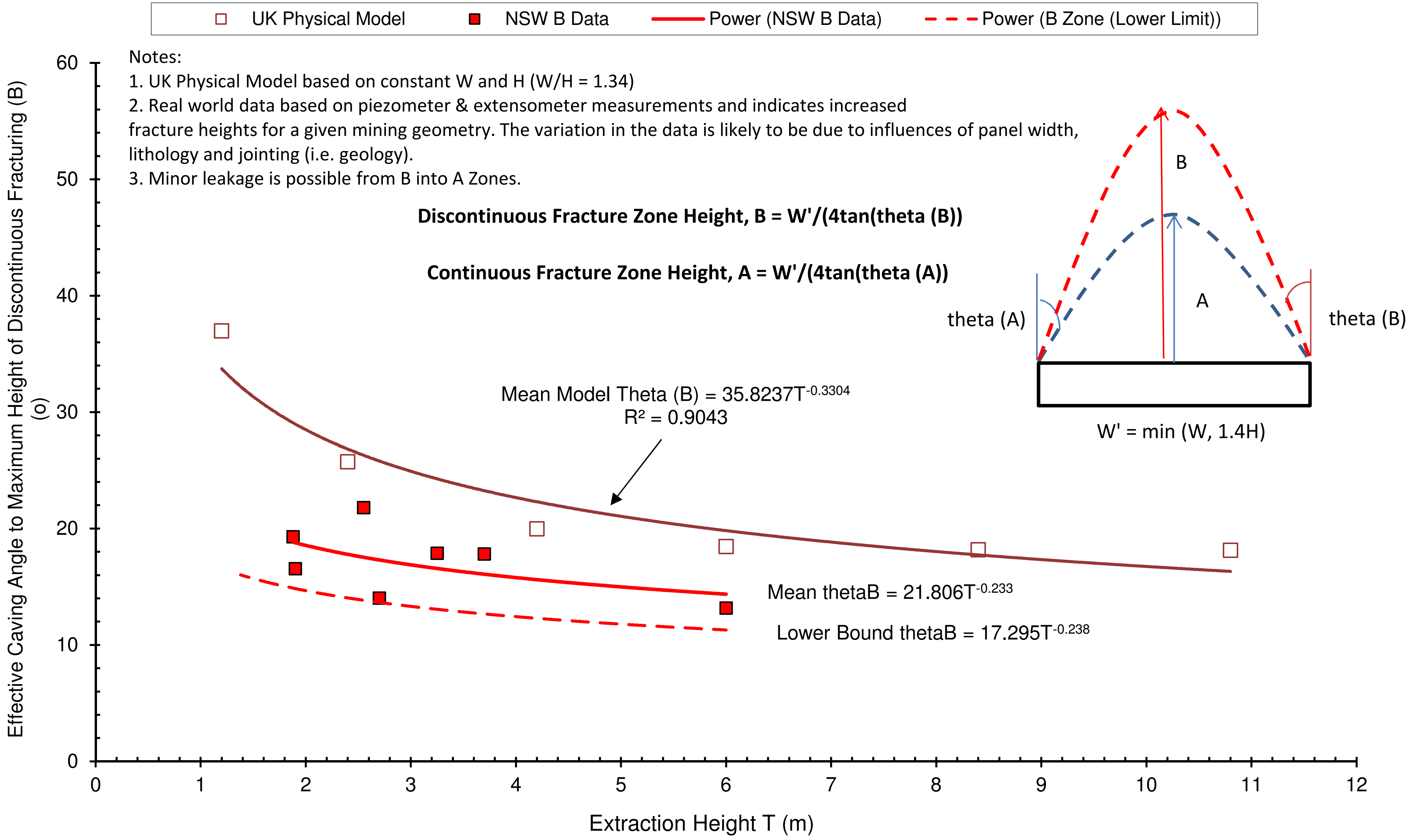
3. Vertical permeability within the A horizon likely to increase by 1 to 2 orders of magnitude with hydraulic connection to workings likely.

UK Model Theta = $59.7905T^{-0.5297}$
$R^2 = 0.9897$

Mean thetaA = $41.617T^{-0.467}$

Lower Bound thetaA = $25.083T^{-0.401}$

| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Modified from ACARP, 2003 (DgS,2012) | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 15.11.12 | Title: | Alternative ACARP, 2003 A-Zone Sub-Surface Fracture Height Model based on Panel Width and Mining Height as Key Parameters | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A41c |

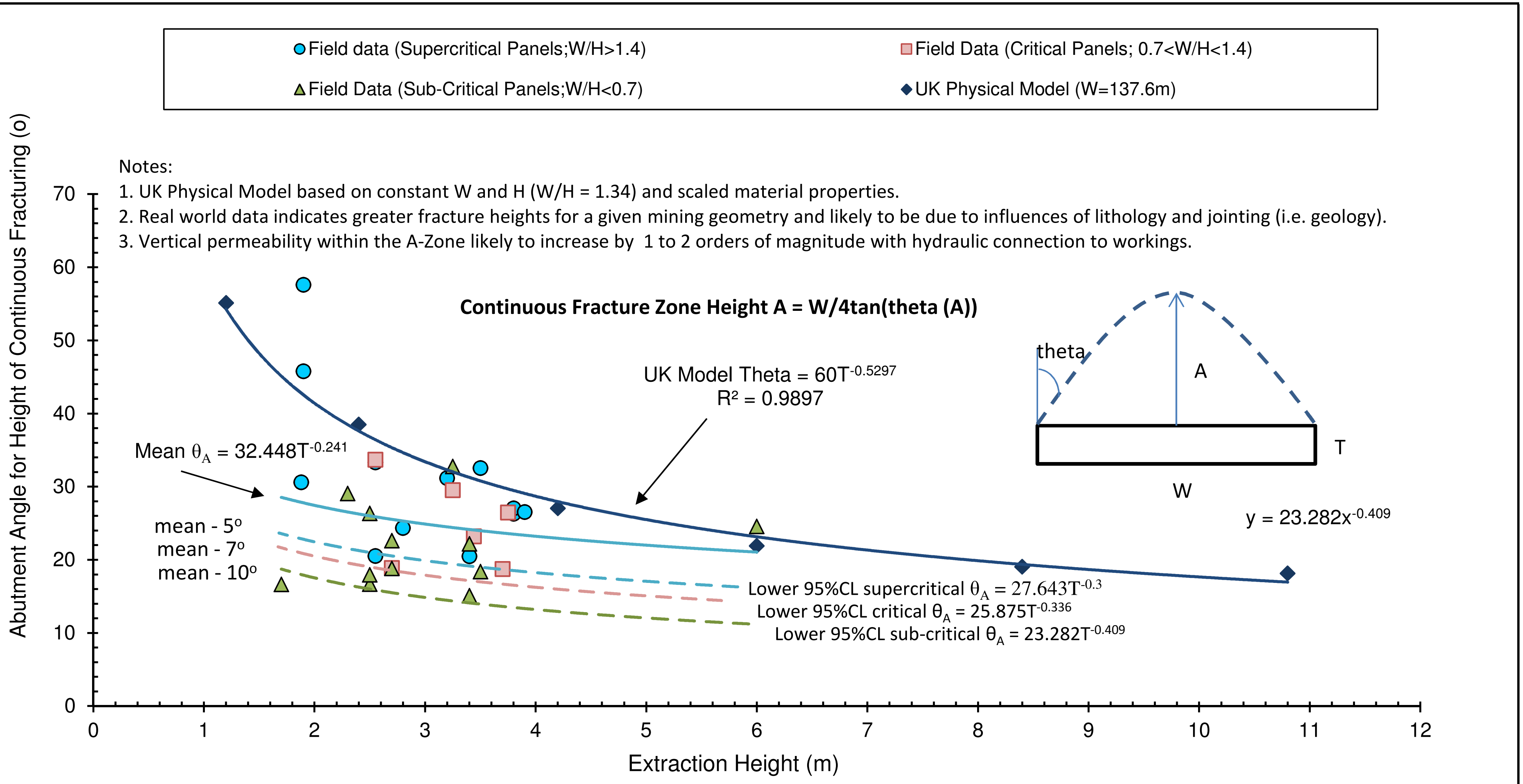


Notes:
1. UK Physical Model based on constant W and H (W/H = 1.34)
2. Real world data based on piezometer & extensometer measurements and indicates increased fracture heights for a given mining geometry. The variation in the data is likely to be due to influences of panel width, lithology and jointing (i.e. geology).
3. Minor leakage is possible from B into A Zones.

**Discontinuous Fracture Zone Height, B = W'/(4tan(theta (B))**

**Continuous Fracture Zone Height, A = W'/(4tan(theta (A))**

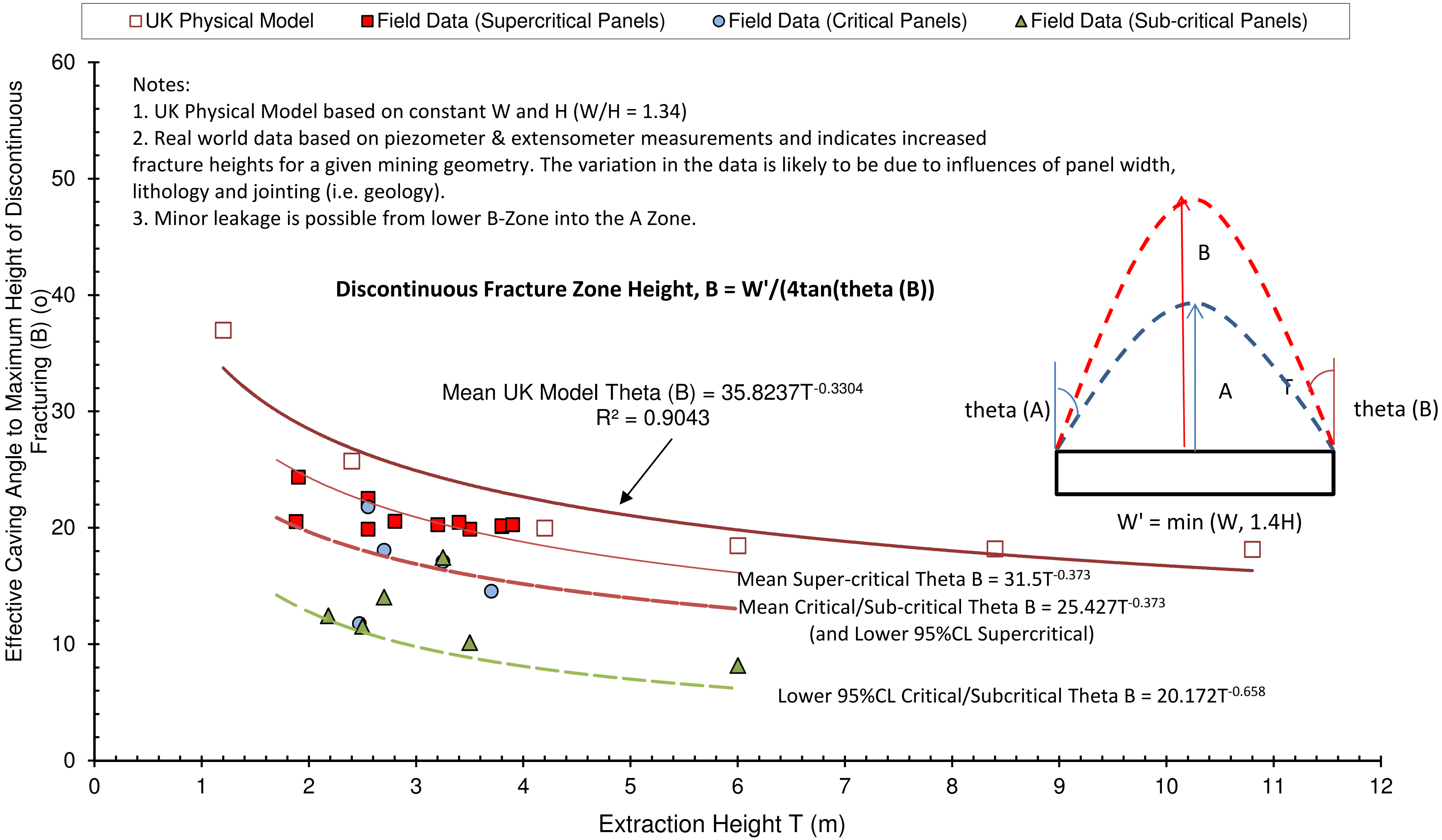
| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Modified from ACARP, 2003 (DgS,2012) | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 15.11.12 | Title: | Alternative ACARP, 2003 B-Zone Sub-Surface Fracture Height Model based on Panel Width and Mining Height as Key Parameters | | |
| | Ditton Geotechnical Services Pty Ltd | | | | | |
| | | | Scale: | NTS | Figure No: | A41d |



Notes:

1. UK Physical Model based on constant W and H (W/H = 1.34) and scaled material properties.
2. Real world data indicates greater fracture heights for a given mining geometry and likely to be due to influences of lithology and jointing (i.e. geology).
3. Vertical permeability within the A-Zone likely to increase by 1 to 2 orders of magnitude with hydraulic connection to workings.

| | | | | |
|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Modified from ACARP, 2003 |
| | Drawn: | S.Ditton | | |
| | Date: | 10.06.13 | Title: | Predicted Height of Continuous Fracturing Based on HoF Angle and Mining Height |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS |
| | | | Figure No: | A41e |



Notes:
1. UK Physical Model based on constant W and H (W/H = 1.34)
2. Real world data based on piezometer & extensometer measurements and indicates increased fracture heights for a given mining geometry. The variation in the data is likely to be due to influences of panel width, lithology and jointing (i.e. geology).
3. Minor leakage is possible from lower B-Zone into the A Zone.

**Discontinuous Fracture Zone Height, B = W'/(4tan(theta (B))**

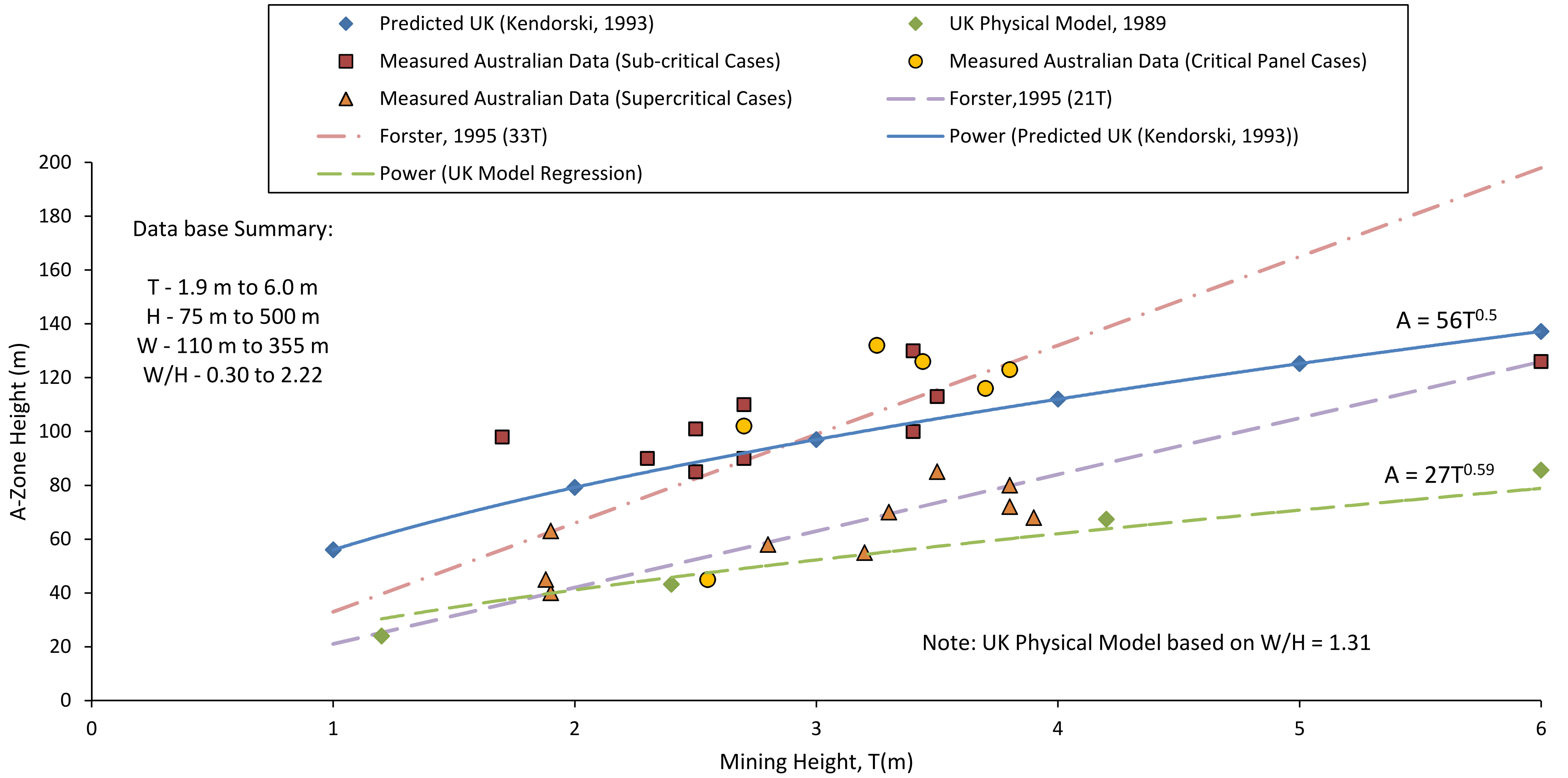
Mean UK Model Theta (B) = $35.8237T^{-0.3304}$
$R^2 = 0.9043$

Mean Super-critical Theta B = $31.5T^{-0.373}$

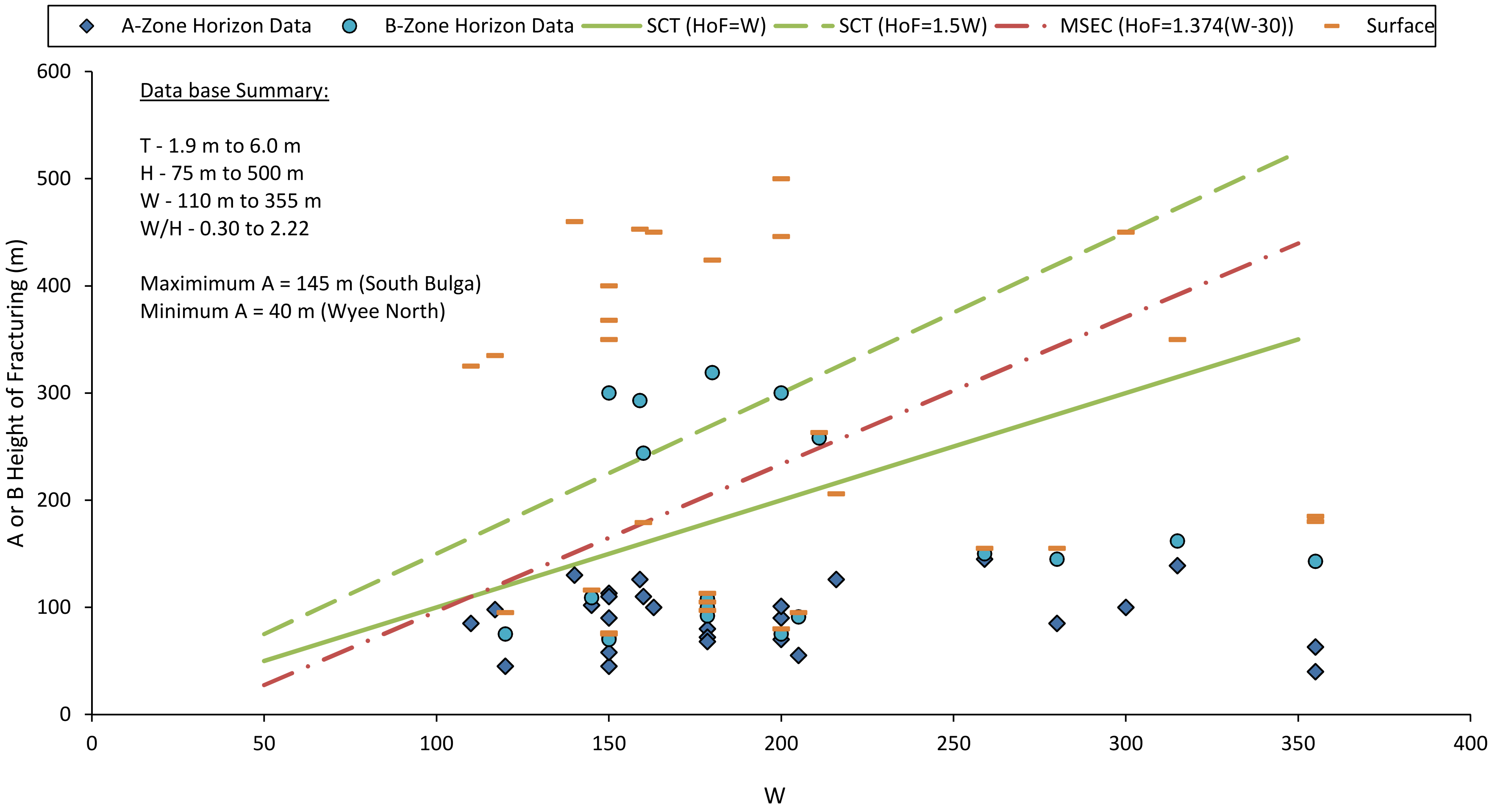
Mean Critical/Sub-critical Theta B = $25.427T^{-0.373}$
(and Lower 95%CL Supercritical)

Lower 95%CL Critical/Subcritical Theta B = $20.172T^{-0.658}$

| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Modified from ACARP, 2003 | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 10.06.13 | Title: | Predicted Height of Discontinuous Fracturing Based on Measured Heights of Discontinuous Fracture Angles and Mining Height | | |
| | Ditton Geotechnical Services Pty Ltd | | | | | |
| | | | Scale: | NTS | Figure No: | A41f |

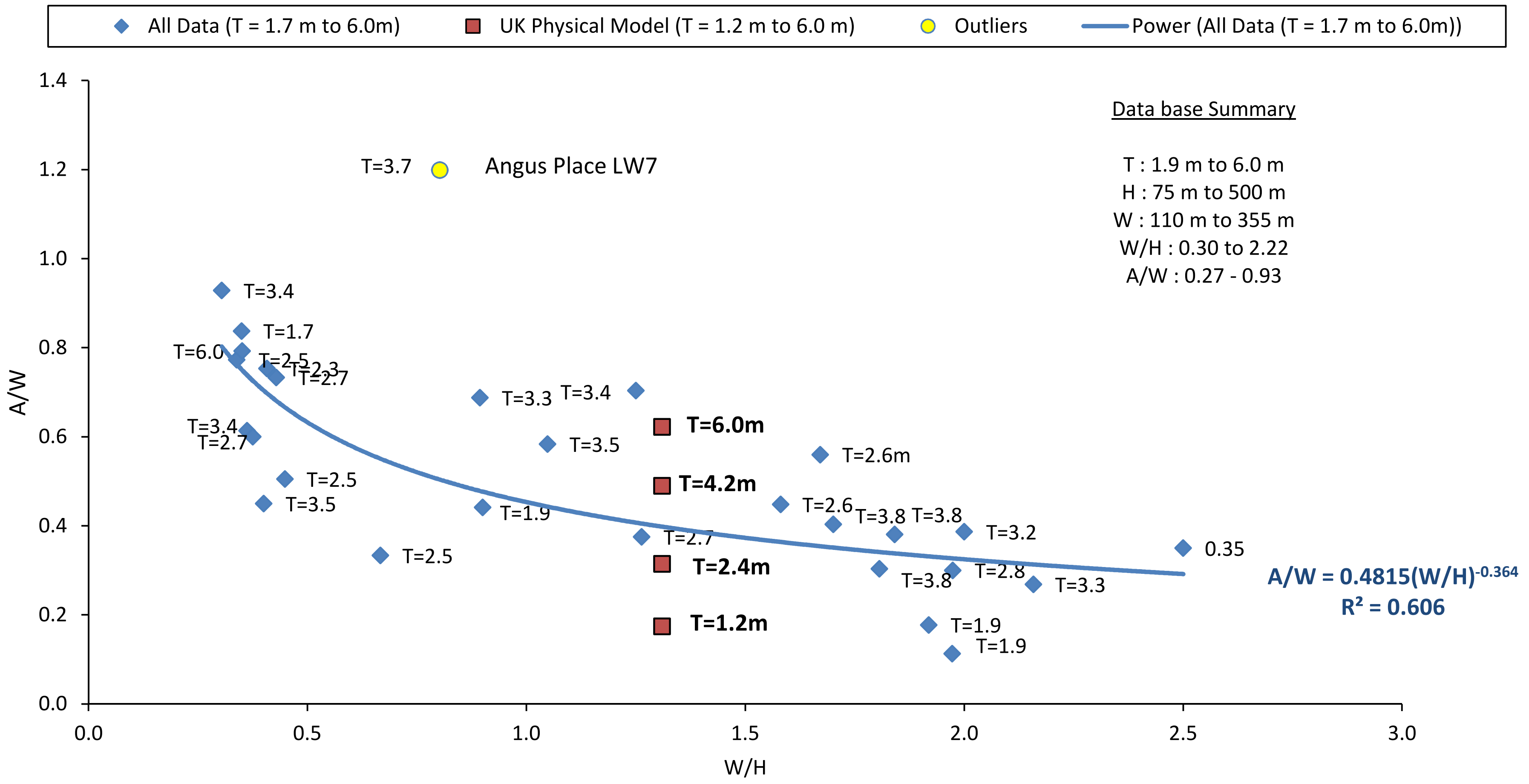


| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 07.06.13 | Title: | Continuous UK Fracture Height Models based on Mining Height Only v. Measured Australian Database | | |
| | Ditton Geotechnical Services Pty Ltd | | | | | |
| | | | Scale: | NTS | Figure No: | A41g |

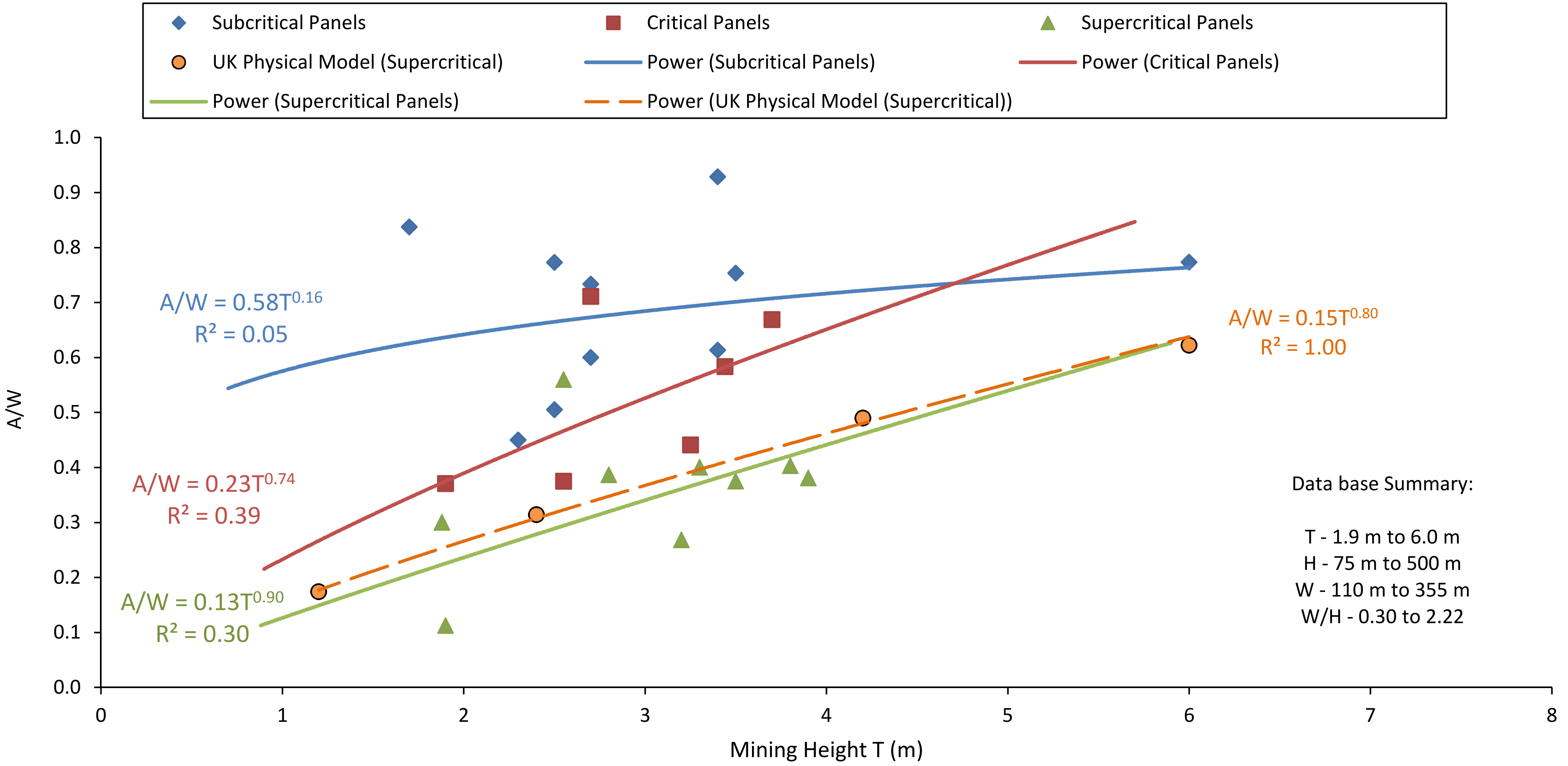


DgS

| | | | | | |
|---|---|---|---|---|---|
| Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | | |
| Drawn: | S.Ditton | | | | |
| Date: | 07.06.13 | Title: | Continuous Australian Fracture Height Model based on Panel Width Only Database | | |
| Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A41h |



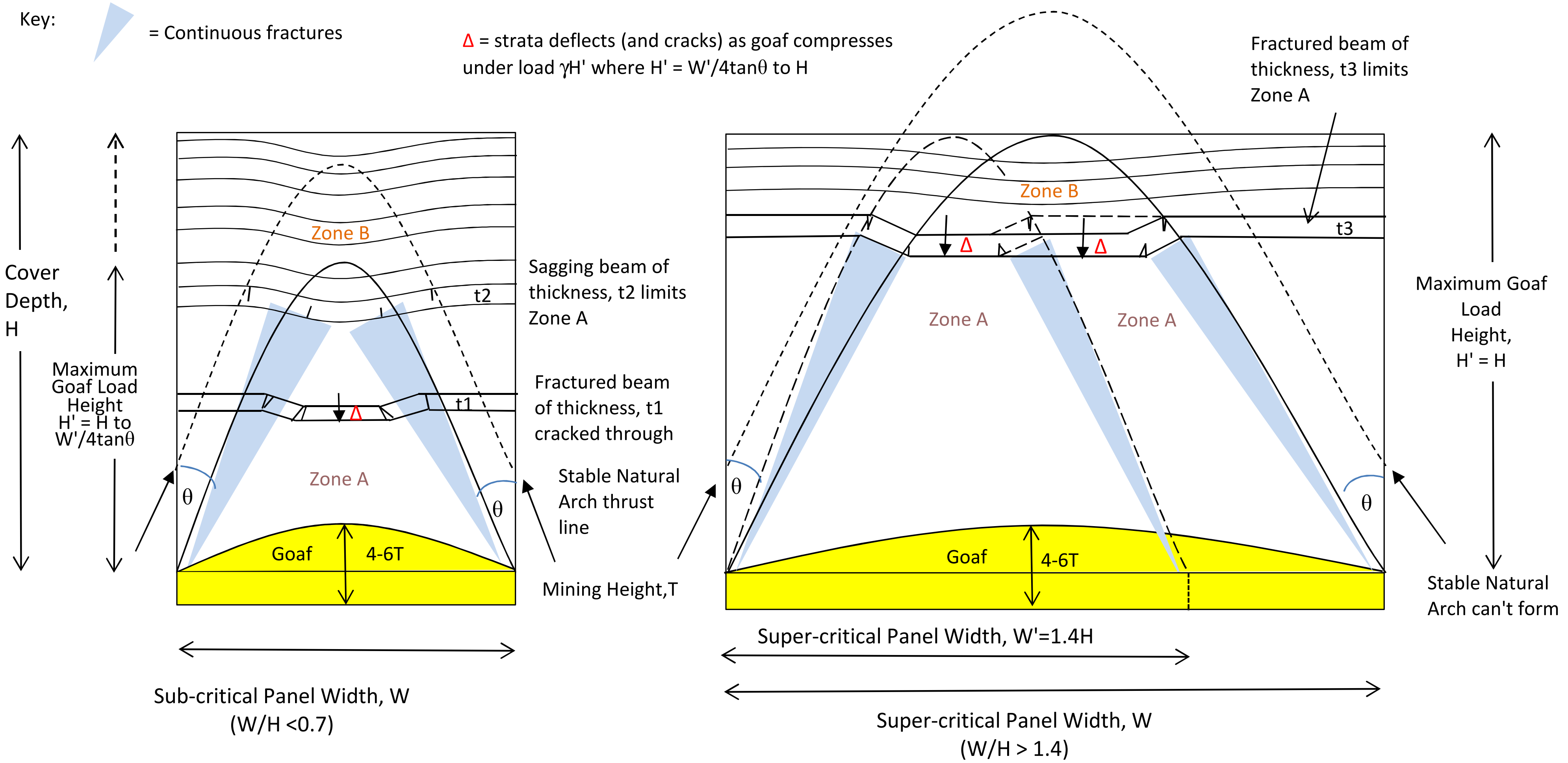
| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 07.06.13 | Title: | Continuous Australian Fracture Height Model based on A normalised to Panel Width with Influence of Mining Height Included | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A41i |



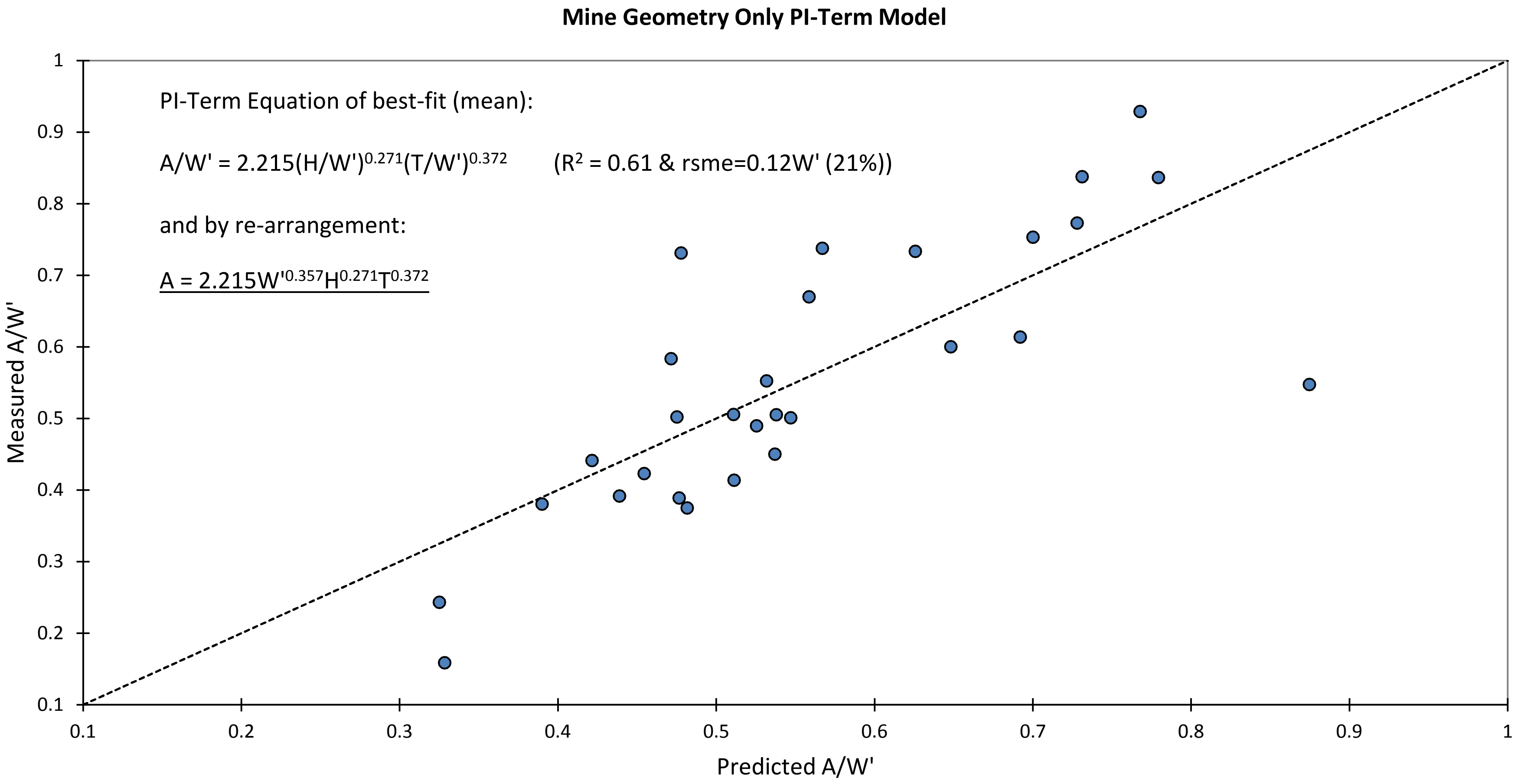
Data base Summary:

T - 1.9 m to 6.0 m
H - 75 m to 500 m
W - 110 m to 355 m
W/H - 0.30 to 2.22

| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 07.06.13 | Title: | Continuous Australian Fracture Height Model based on A normalised to Panel Width v. Mining Height | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A41j |



| | | | | |
|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data |
| | Drawn: | S.Ditton | | |
| | Date: | 26.08.13 | Title: | Conceptual Model for Development of Height of Continuous Fracturing Zone for a range of Longwall Panel Geometries |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS    Figure No: A42a |



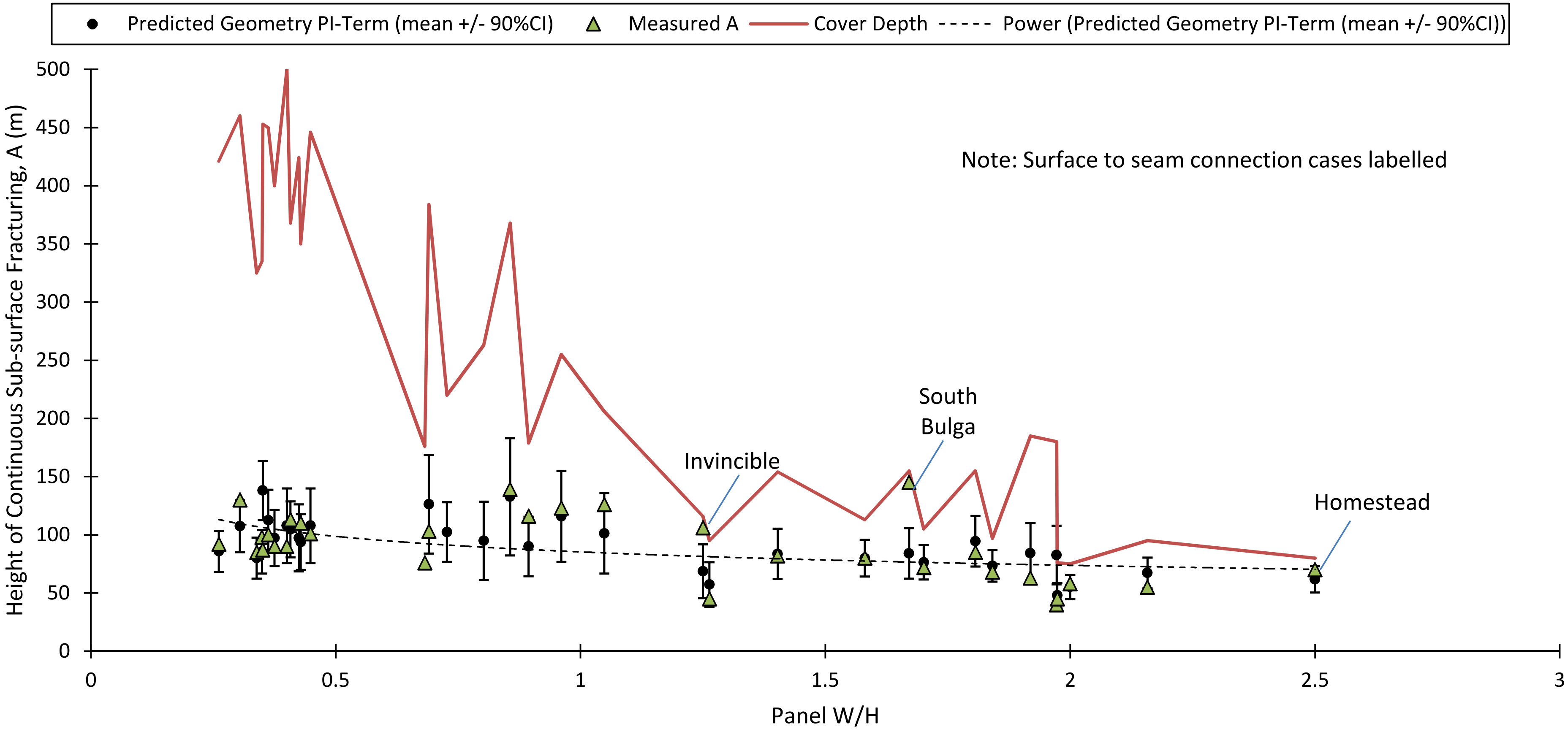
PI-Term Equation of best-fit (mean):

$A/W' = 2.215(H/W')^{0.271}(T/W')^{0.372}$ ($R^2 = 0.61$ & rsme=0.12W' (21%))

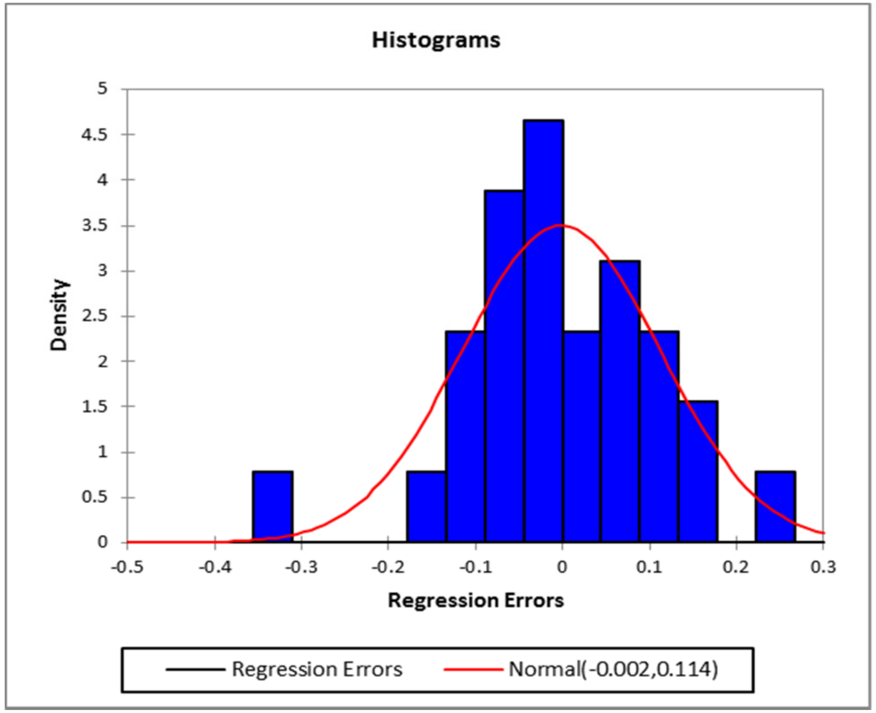
and by re-arrangement:

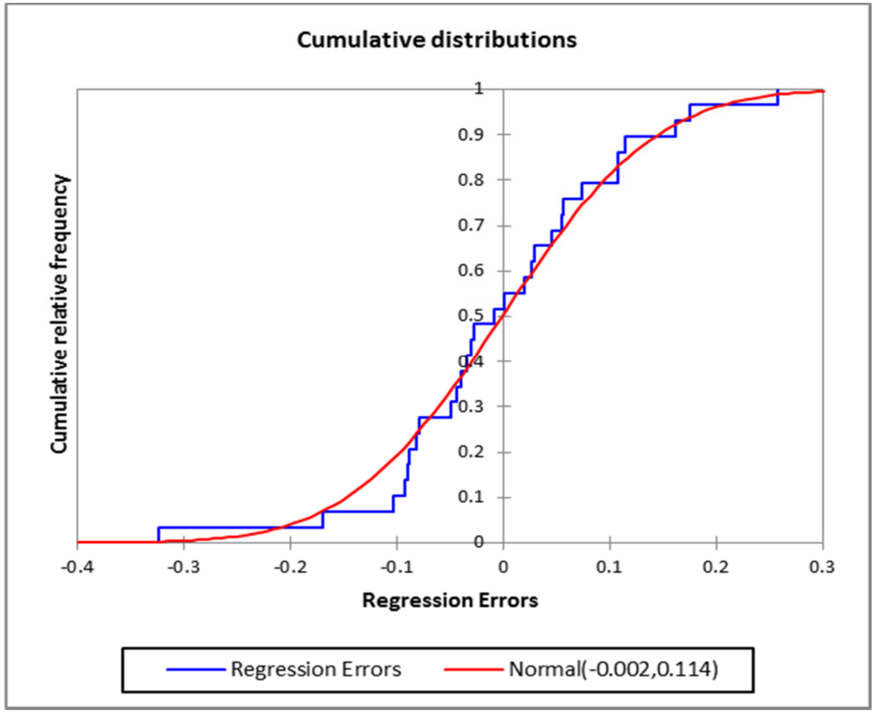
$\underline{A = 2.215W'^{0.357}H^{0.271}T^{0.372}}$

| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 01.05.14 | Title: | Results of Non-Linear Regession Analysis: Predicted v. Measured Value Analysis<br>for Height of A-Zone Fracturing for the Geometry PI-Term Model | | |
| | Ditton Geotechnical<br>Services Pty Ltd | | Scale: | NTS | Figure No: | A42b |



| | | | | | |
|---|---|---|---|---|---|
| **DgS** | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | |
| | Drawn: | S.Ditton | | | |
| | Date: | 01.05.14 | Title: | Results of Non-Linear Regession Error analysis for Geometry PI-Terms Only Height of A-Zone Prediction Model (Geology Pi-Term Not Included) | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: A42c |



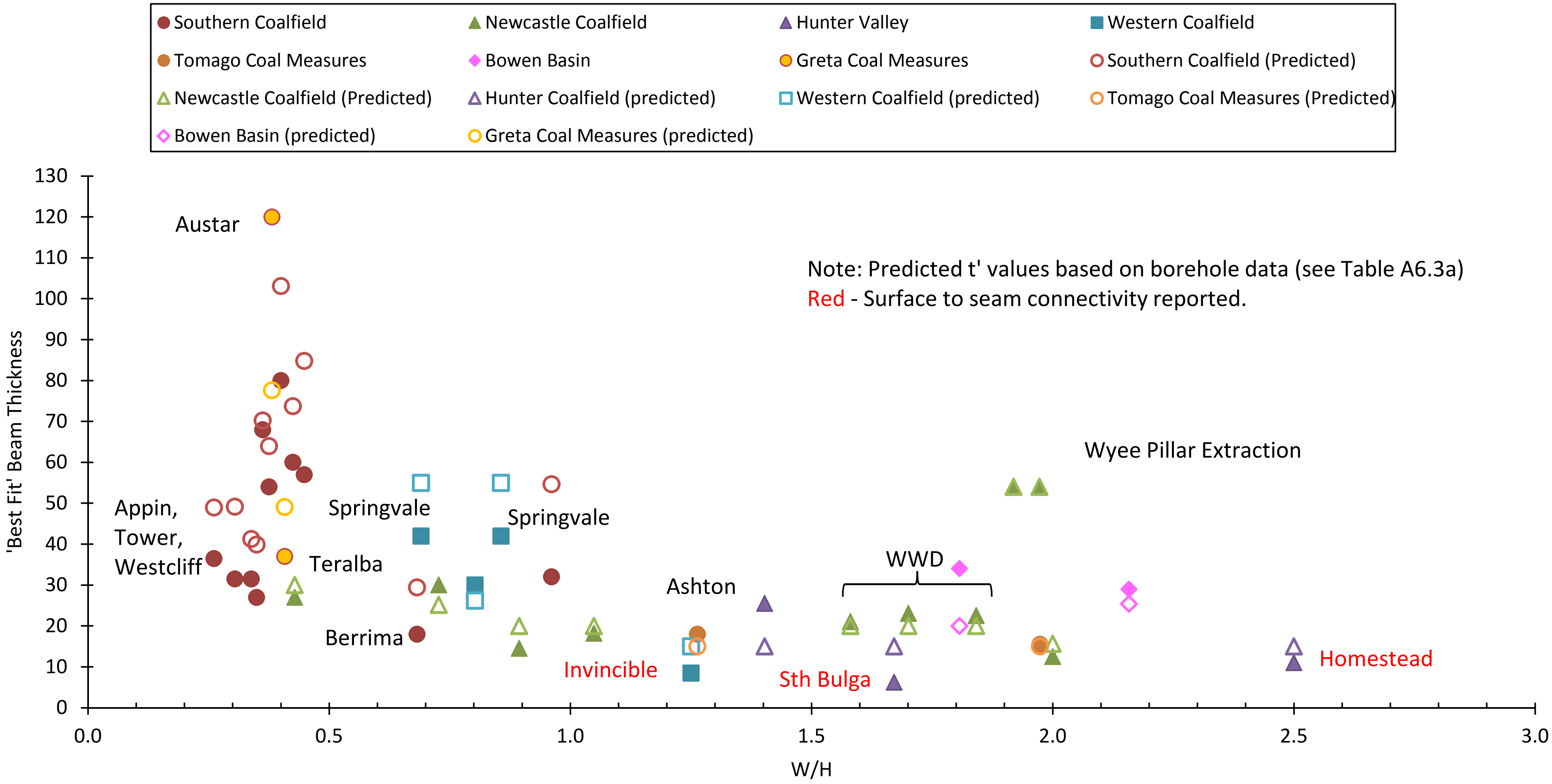


Kolmogorov-Smirnov test:

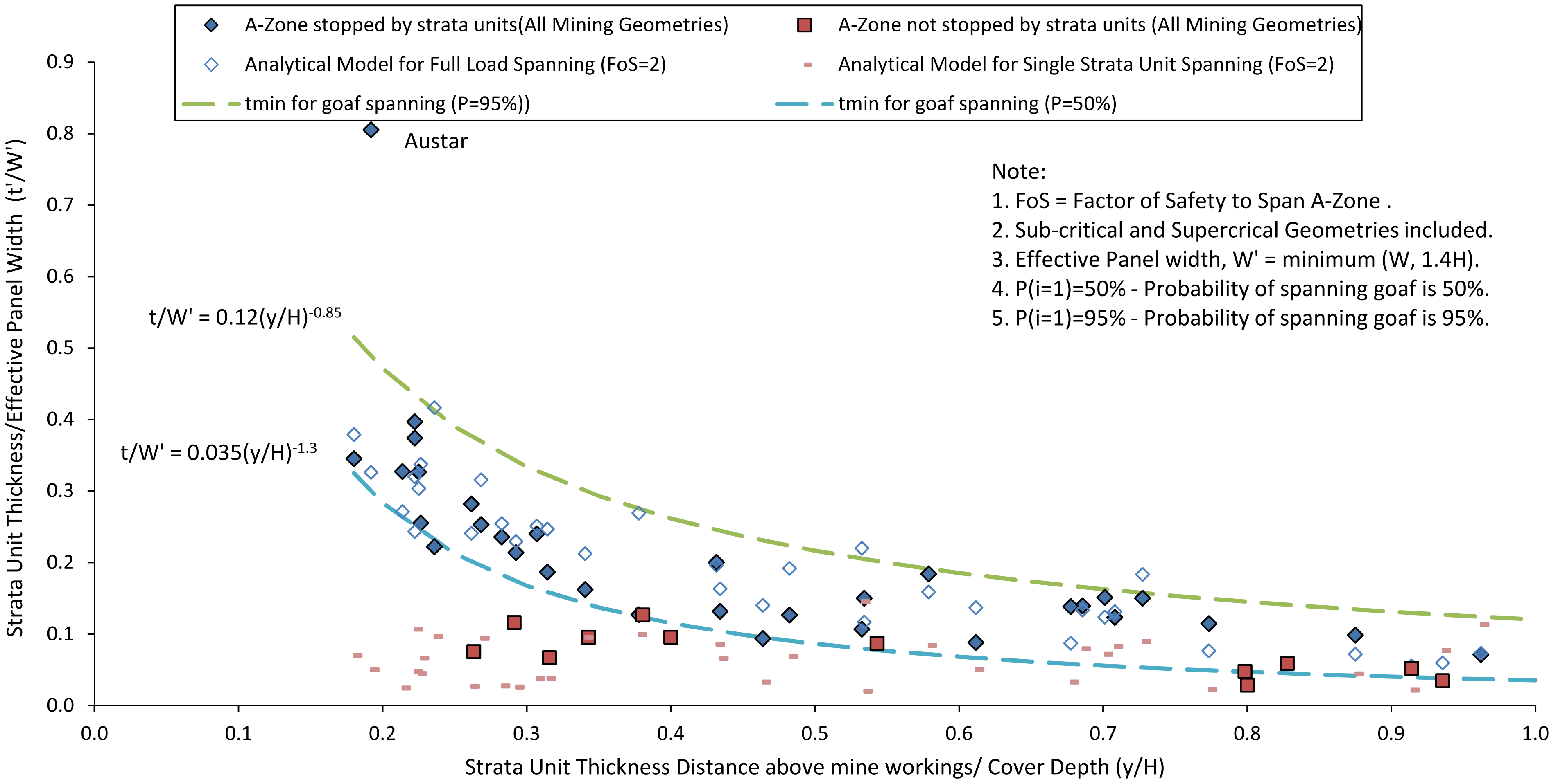
| | |
|---|---|
| D | 0.117 |
| p-value | 0.798 |
| alpha | 0.05 |

Test interpretation:
H0: The sample follows a Normal distribution
Ha: The sample does not follow a Normal distribution
As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.
The risk to reject the null hypothesis H0 while it is true is 79.75%.

| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 01.05.14 | Title: | Results of Non-Linear Regession Error analysis for Geometry Pi-Term Height of A-Zone<br>Prediction Model: Regression Error Normal Distribution Test | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A42d |



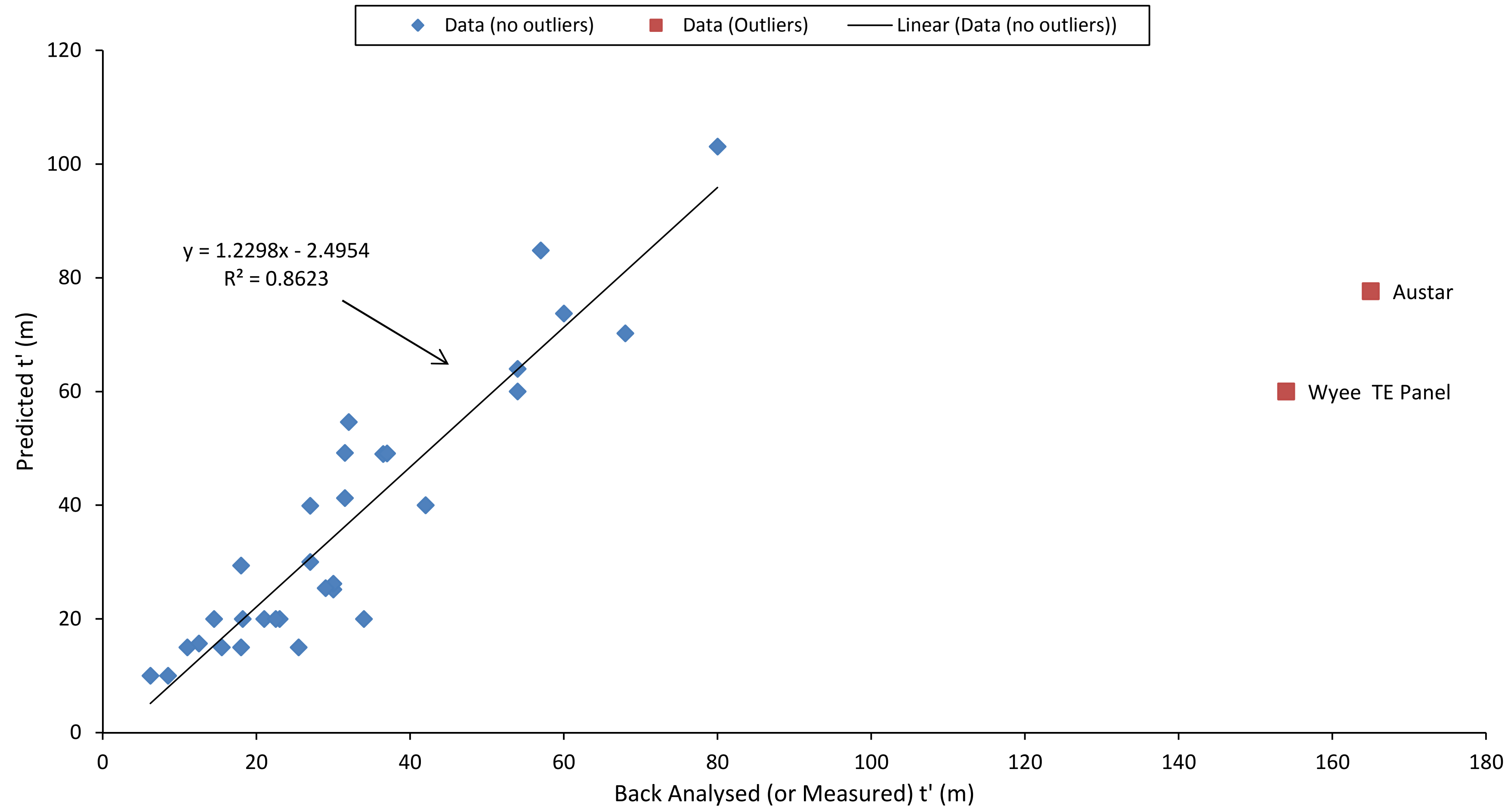
| | | | | | |
|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | |
| | Drawn: | S.Ditton | Title: | Results of Back-analysis of Effective Strata Units required to Match the Observed A-Zone Heights above Longwall Panel Goafs using the Geology Pi-Term Model | |
| | Date: | 01.05.14 | | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: A42e |



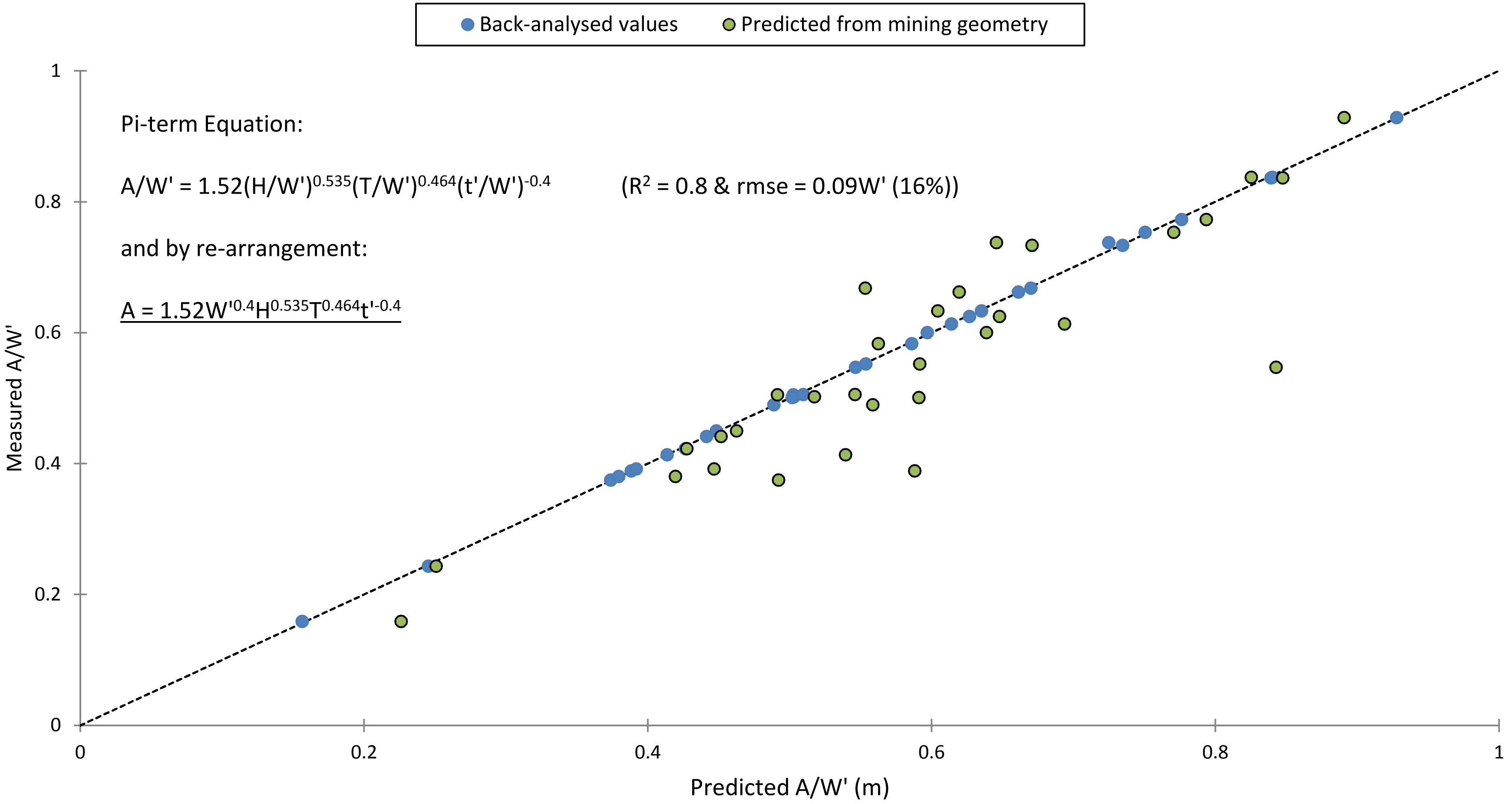
Note:
1. FoS = Factor of Safety to Span A-Zone .
2. Sub-critical and Supercrical Geometries included.
3. Effective Panel width, W' = minimum (W, 1.4H).
4. P(i=1)=50% - Probability of spanning goaf is 50%.
5. P(i=1)=95% - Probability of spanning goaf is 95%.

DgS

| | | | | | |
|---|---|---|---|---|---|
| Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | | |
| Drawn: | S.Ditton | | | | |
| Date: | 01.05.14 | Title: | Minimum Effective beam Thickness Required to Span the A-Zone, based on Back Analysis Results for the Geology Pi-Term Model (see Figure A42e) | | |
| Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A42f |



| | | | | |
|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data |
| | Drawn: | S.Ditton | | |
| | Date: | 01.05.14 | Title: | Comparison of Back-Analysed (or measured (t') v. Predicted t' for the Geological PI-Term |
| | Ditton Geotechnical Services Pty Ltd | | | |
| | | | Scale: | NTS Figure No: A42g |



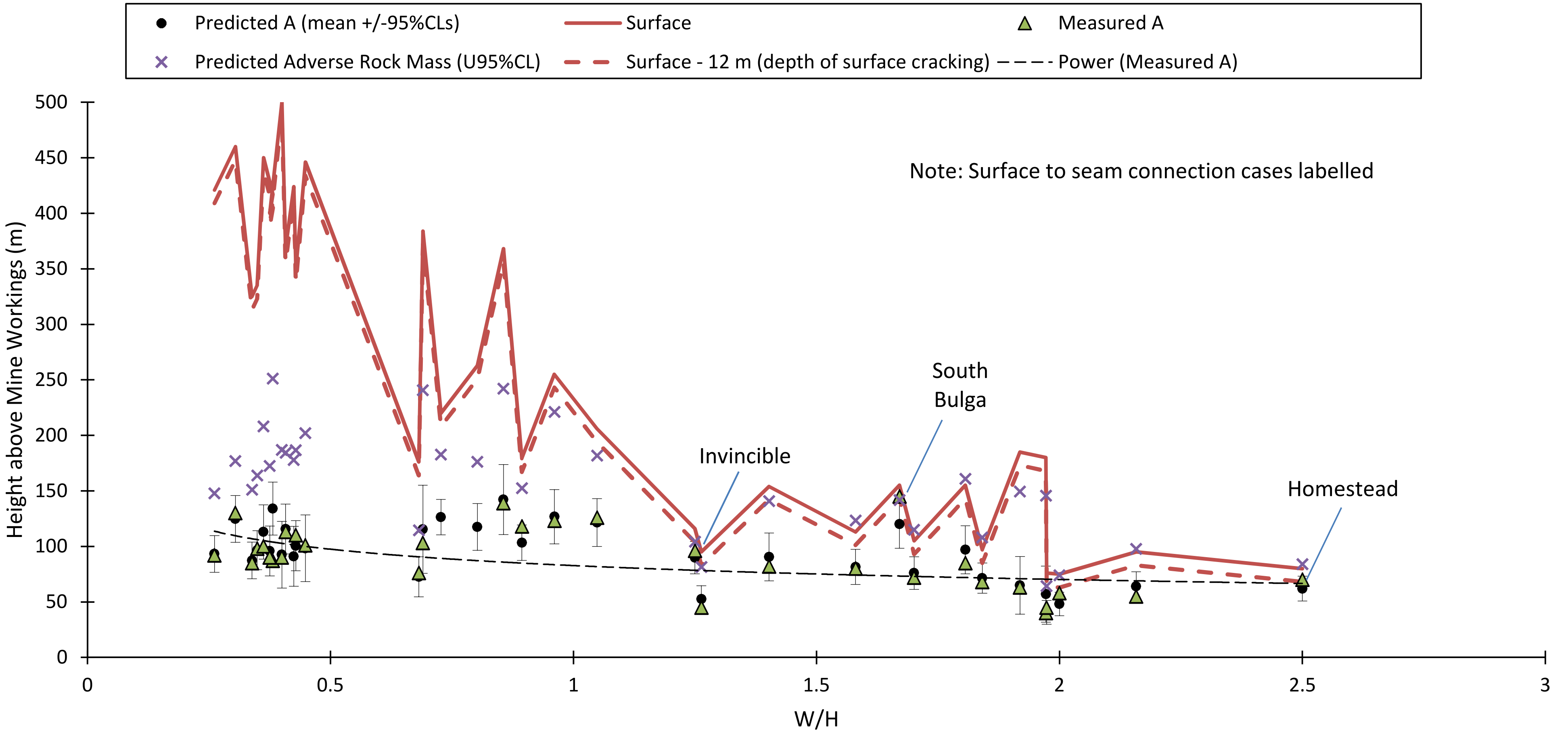
Pi-term Equation:

$A/W' = 1.52(H/W')^{0.535}(T/W')^{0.464}(t'/W')^{-0.4}$ ($R^2 = 0.8$ & rmse = 0.09W' (16%))

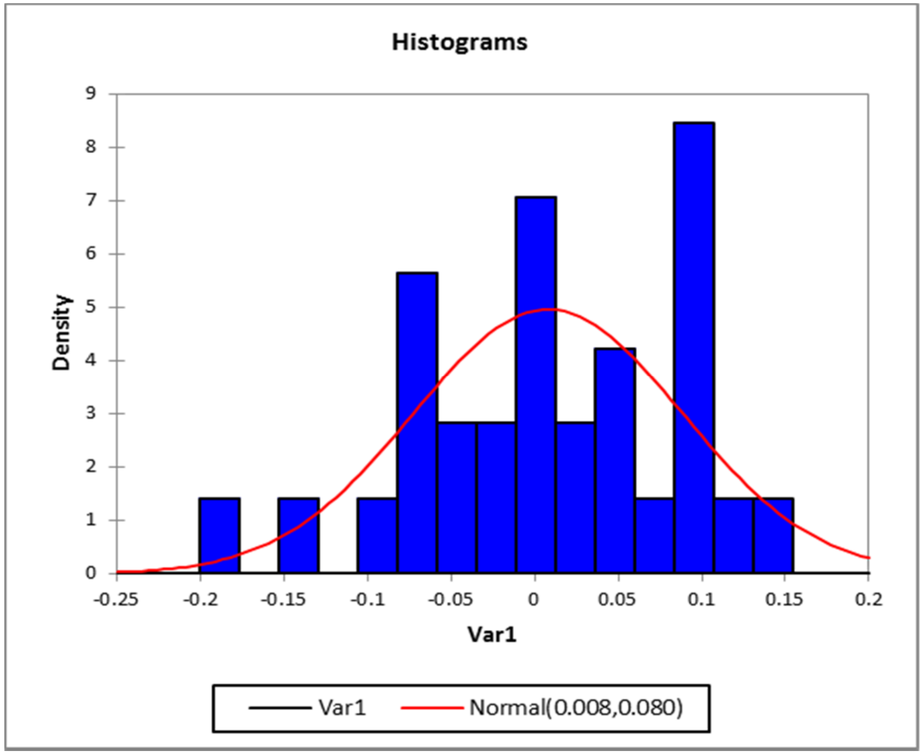
and by re-arrangement:

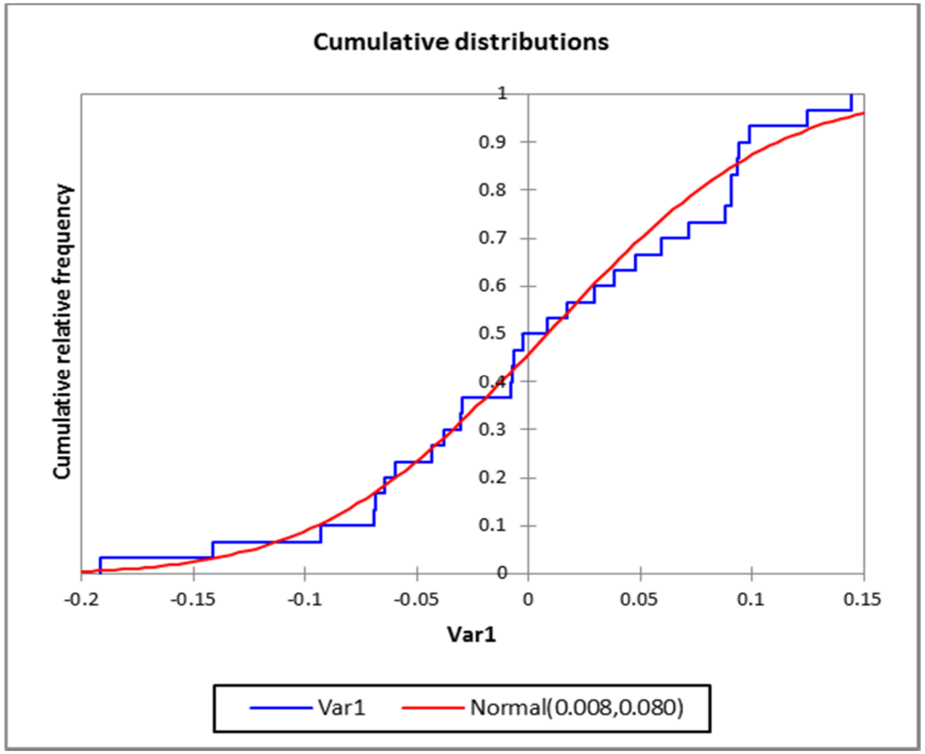
$\underline{A = 1.52W'^{0.4}H^{0.535}T^{0.464}t'^{-0.4}}$

| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 01.05.14 | Title: | Results of Non-Linear Regession Analysis: Predicted v. Measured Value Analysis for Height of A-Zone Fracturing for Geology Pi-Term Model | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A42h |



| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | | |
| | Drawn: | S.Ditton | Title: | Results of Non-Linear Regession Error analysis for Height of A-Zone Prediction Model with Geology Included | | |
| | Date: | 01.05.14 | | | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A42i |



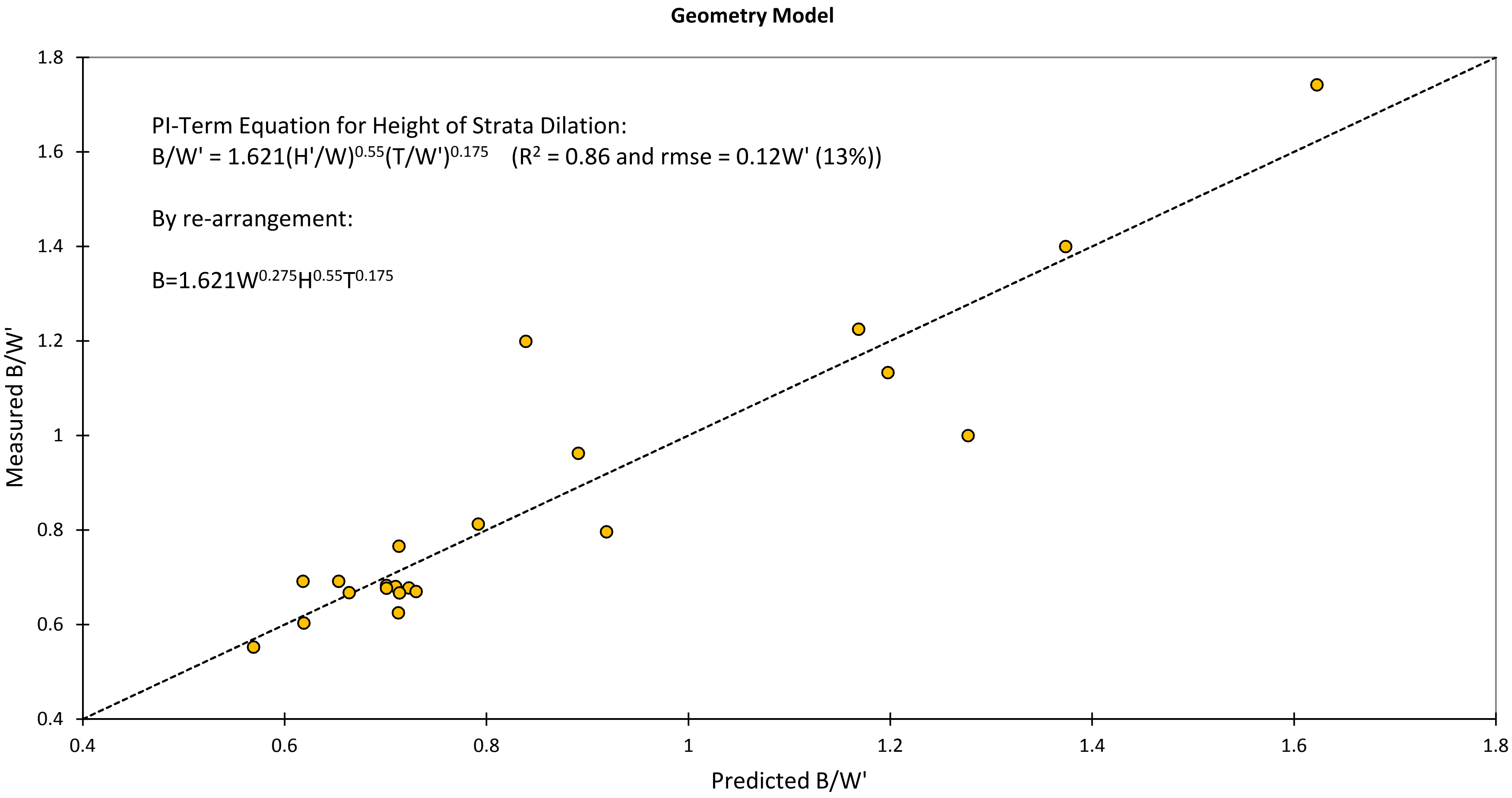


Kolmogorov-Smirnov test:

| | |
|---|---|
| D | 0.107 |
| p-value | 0.866 |
| alpha | 0.05 |

Test interpretation:
H0: The sample follows a Normal distribution
Ha: The sample does not follow a Normal distribution
As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.
The risk to reject the null hypothesis H0 while it is true is 86.6%.

| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 01.05.14 | Title: | Results of Non-Linear Regession Error analysis for Geology Pi-Term Height of A-Zone Prediction Model: Regression Error Normal Distribution Test | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A42j |



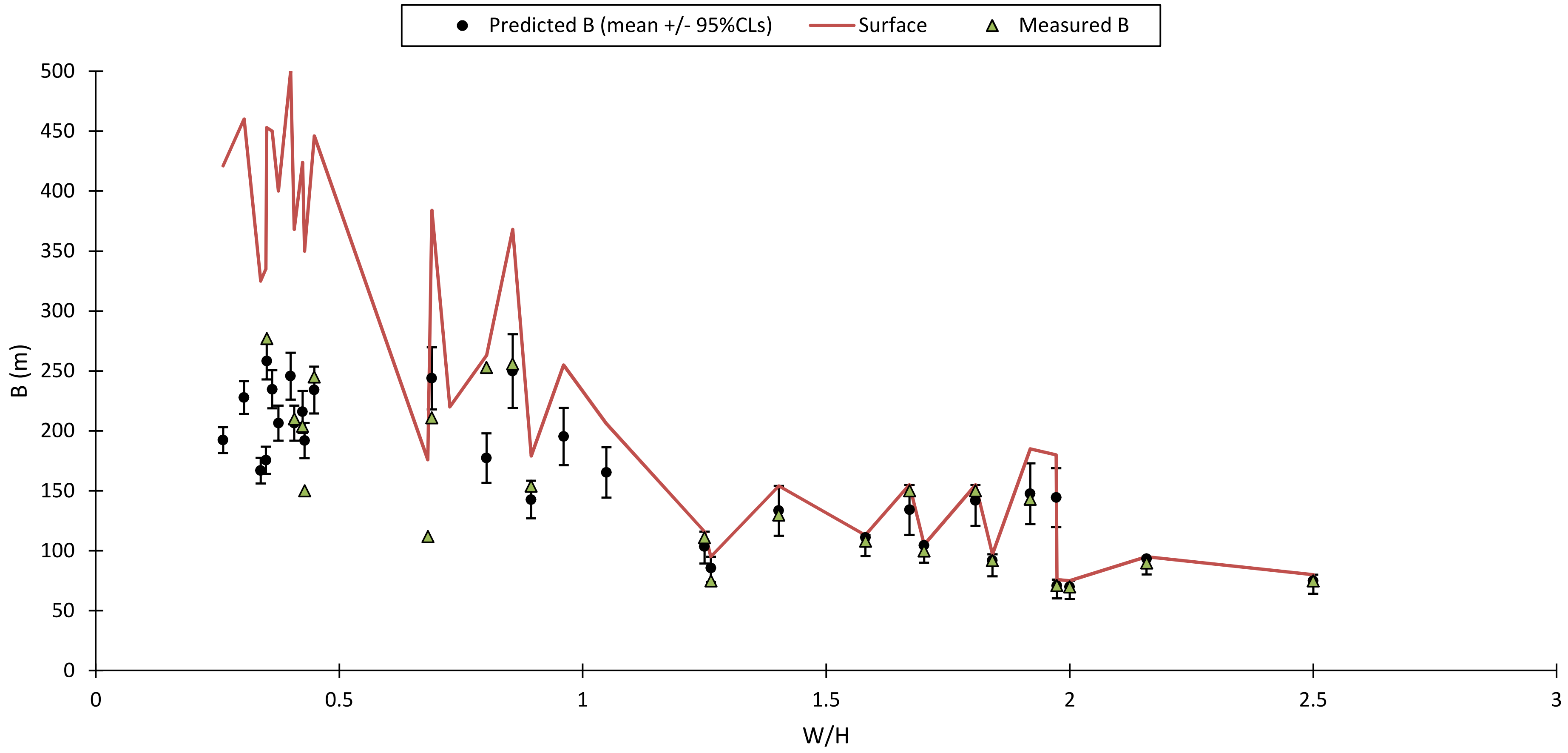
PI-Term Equation for Height of Strata Dilation:

$B/W' = 1.621(H'/W)^{0.55}(T/W')^{0.175}$ ($R^2 = 0.86$ and rmse = 0.12W' (13%))

By re-arrangement:

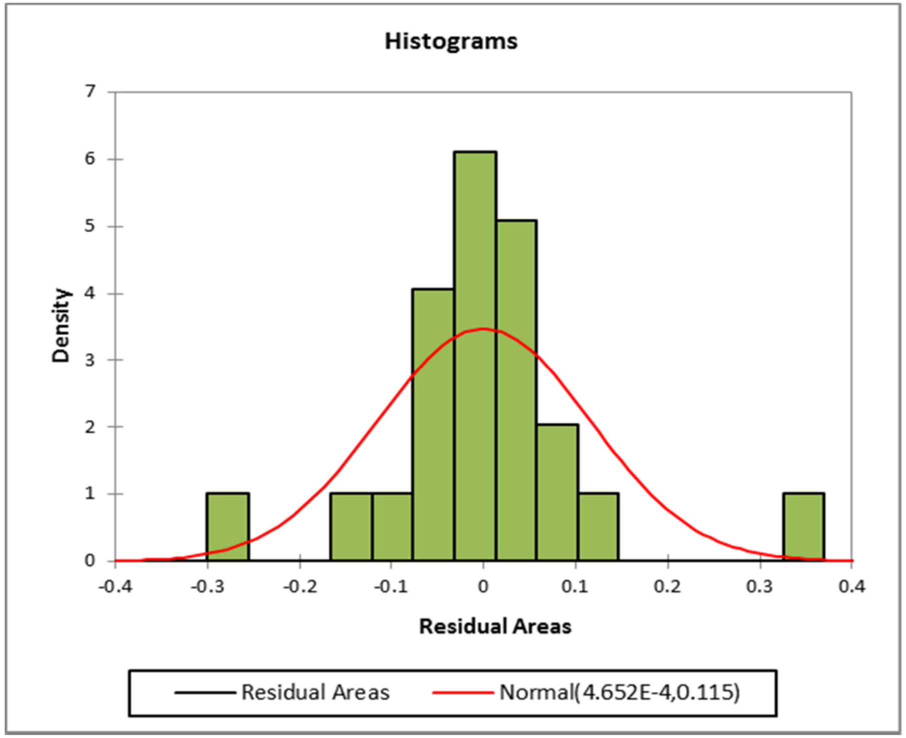
$B=1.621W^{0.275}H^{0.55}T^{0.175}$

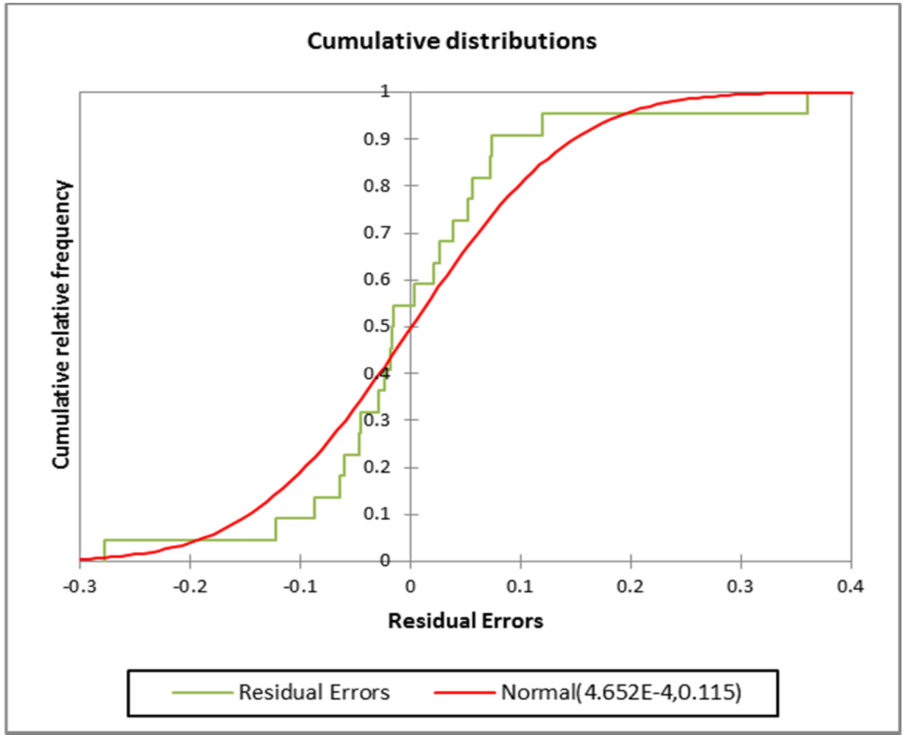
| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 01.02.14 | Title: | Results of Non-Linear Regession Error analysis for Height of B-Zone Predictions<br>for Geometry Only Pi-Term Model | | |
| | Ditton Geotechnical<br>Services Pty Ltd | | | | | |
| | | | Scale: | NTS | Figure No: | A42k |



DgS

|  |  |  |  |
|---|---|---|---|
| Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data |
| Drawn: | S.Ditton |  |  |
| Date: | 01.02.14 | Title: | Results of Non-Linear Regession Error analysis for Height of B-Zone Predictions for Geometry Only Pi-Term Model |
| Ditton Geotechnical Services Pty Ltd |  | Scale: | NTS |
|  |  | Figure No: | A42I |





**Kolmogorov-Smirnov test:**

| | |
|---|---|
| D | 0.173 |
| p-value | 0.487 |
| alpha | 0.05 |

**Test interpretation:**

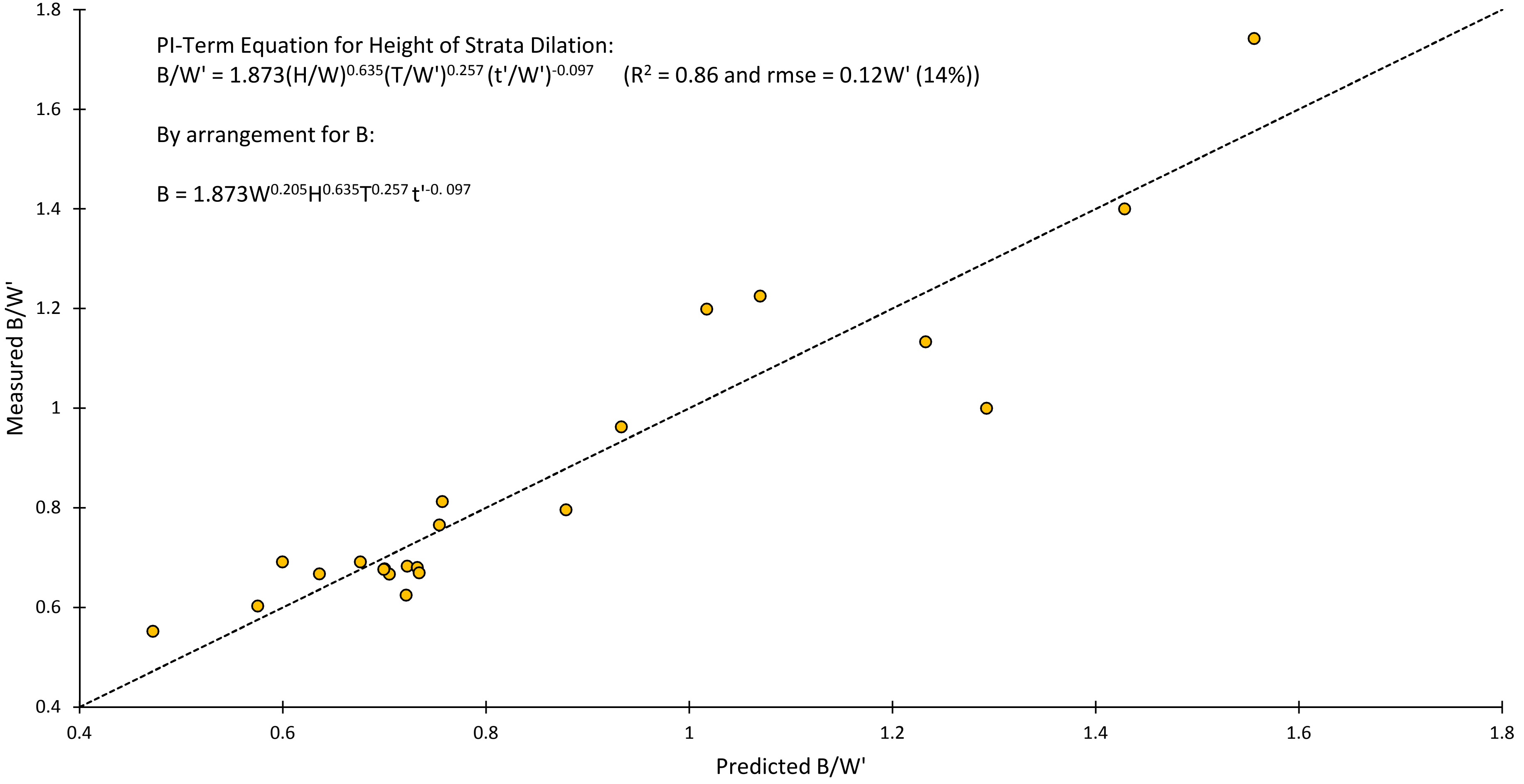
H0: The sample follows a Normal distribution

Ha: The sample does not follow a Normal distribution

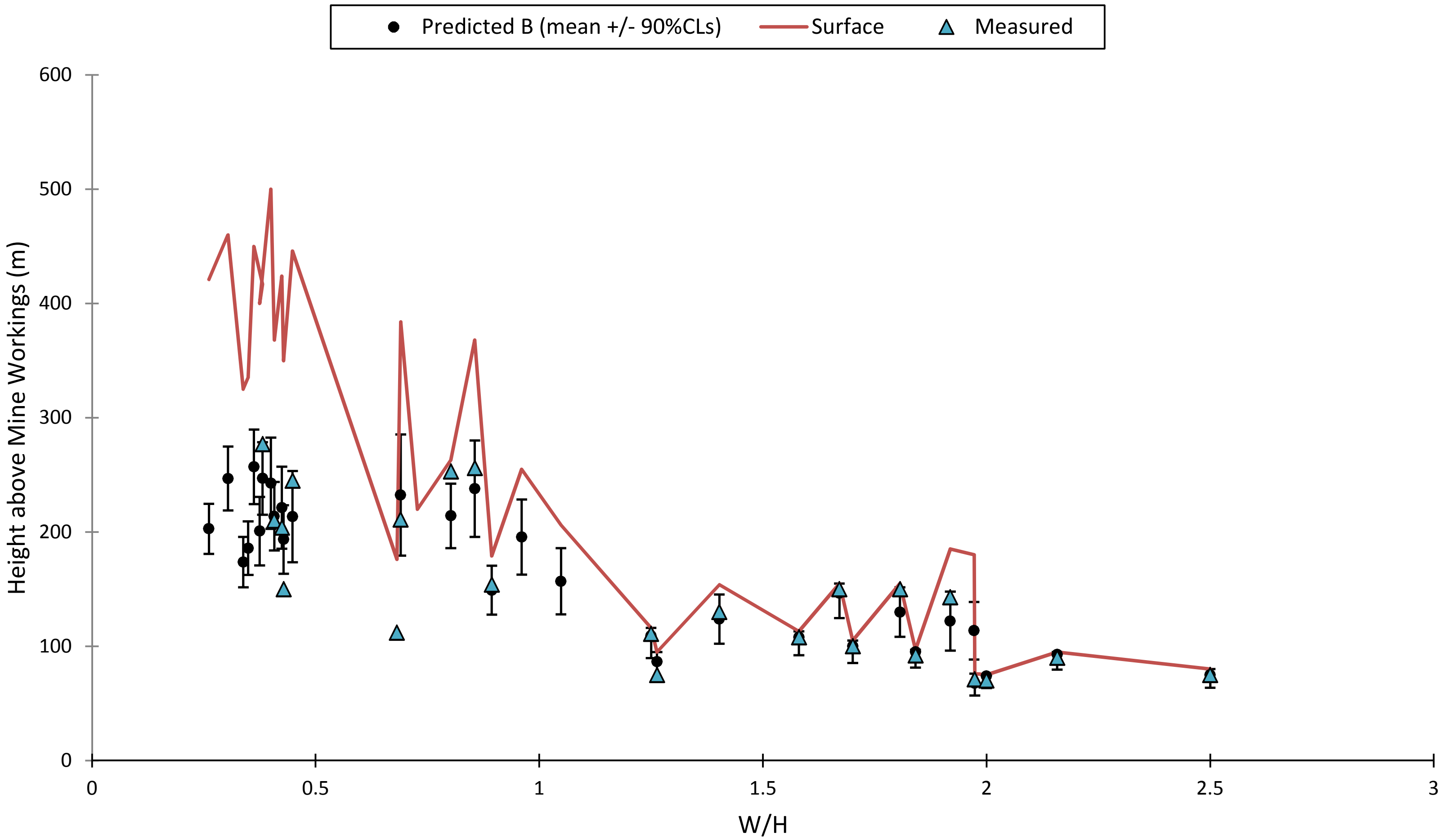
As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.

The risk to reject the null hypothesis H0 while it is true is 48.70%.

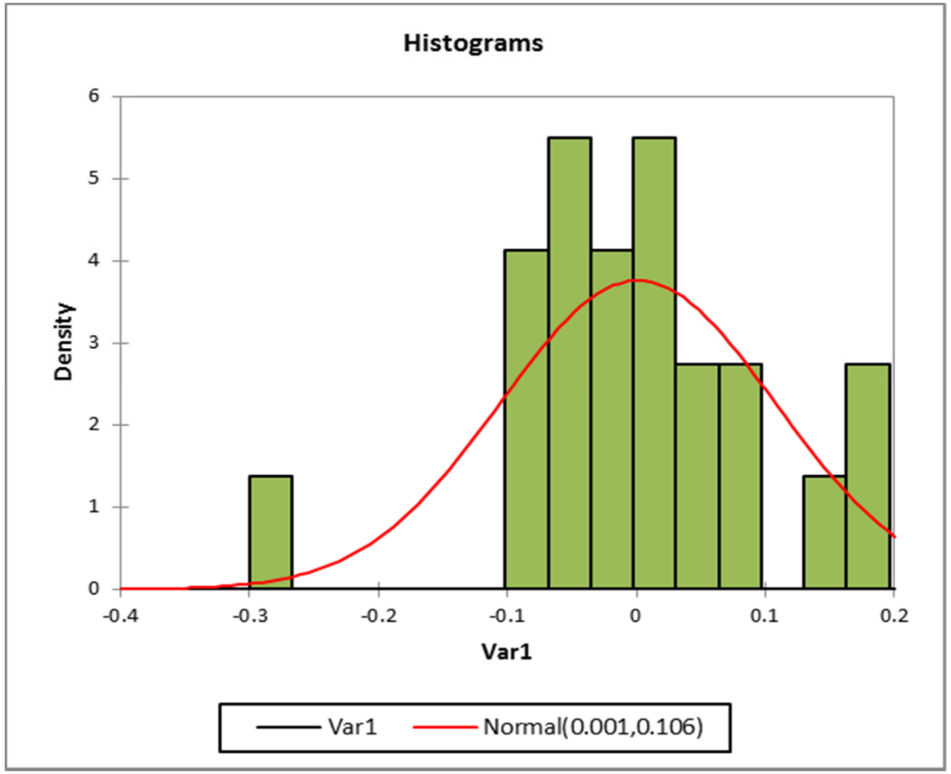
| | | | | |
|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data |
| | Drawn: | S.Ditton | | |
| | Date: | 01.02.14 | Title: | Results of Non-Linear Regession Error analysis for Height of B-Zone Predictions for Geometry Only Pi-Term Model |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS |
| | | | Figure No: | A42m |

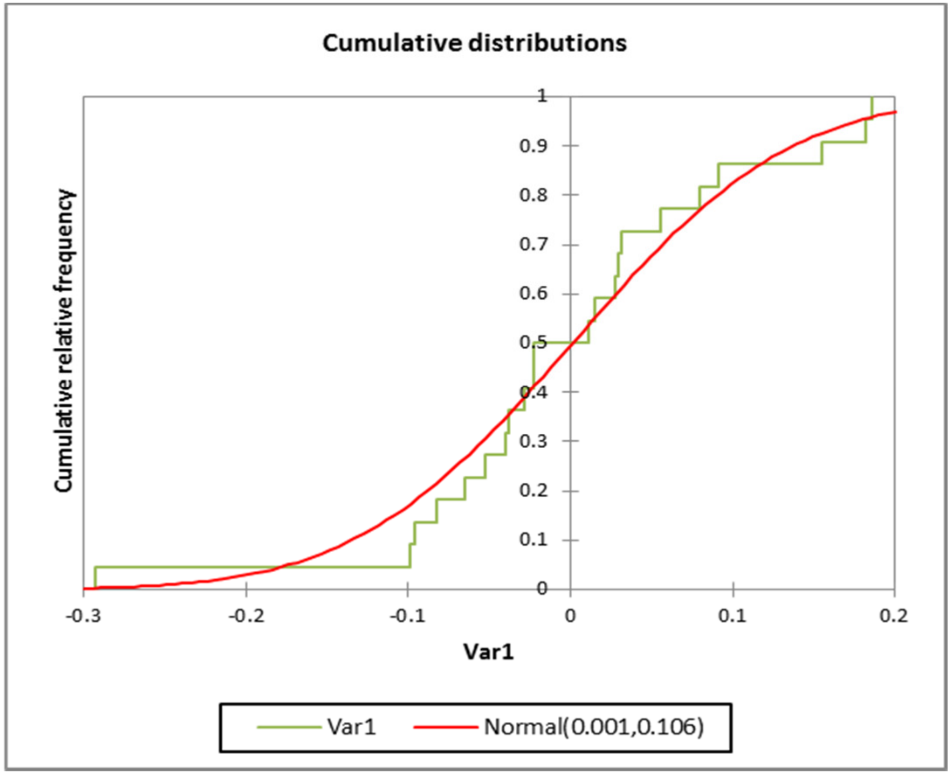


| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 01.02.14 | Title: | Results of Non-Linear Regession Error analysis for Height of B-Zone Predictions for Geology Pi-Term Model | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A42n |



| | | | | |
|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data |
| | Drawn: | S.Ditton | | |
| | Date: | 01.02.14 | Title: | Results of Non-Linear Regession Error analysis for Height of B-Zone Predictions<br>for Geology Pi-Term Model |
| | Ditton Geotechnical<br>Services Pty Ltd | | Scale: | NTS |
| | | | Figure No: | A42o |





**Kolmogorov-Smirnov test:**

| | |
|---|---|
| D | 0.126 |
| p-value | 0.849 |
| alpha | 0.05 |

**Test interpretation:**

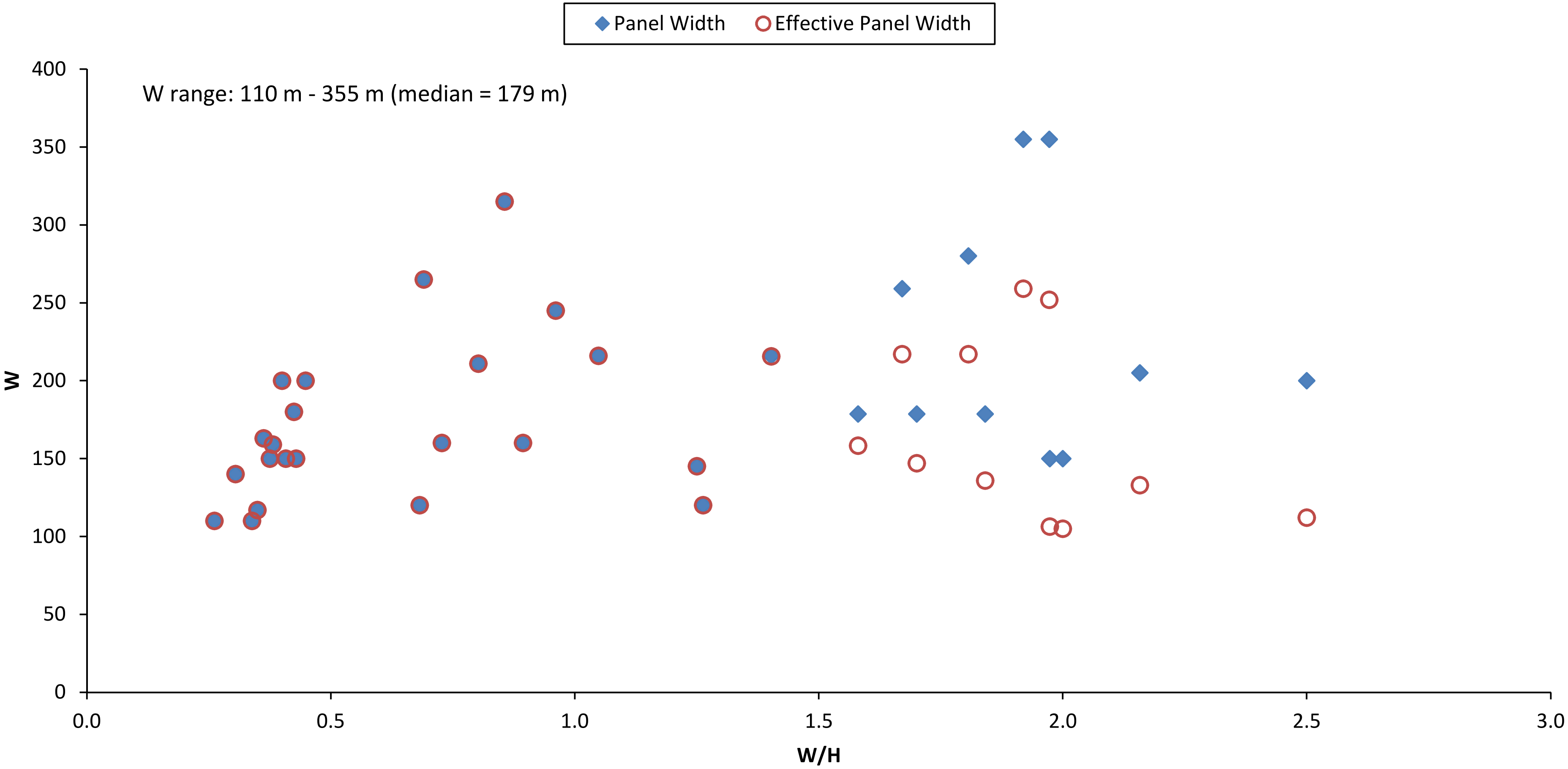
H0: The sample follows a Normal distribution

Ha: The sample does not follow a Normal distribution

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.

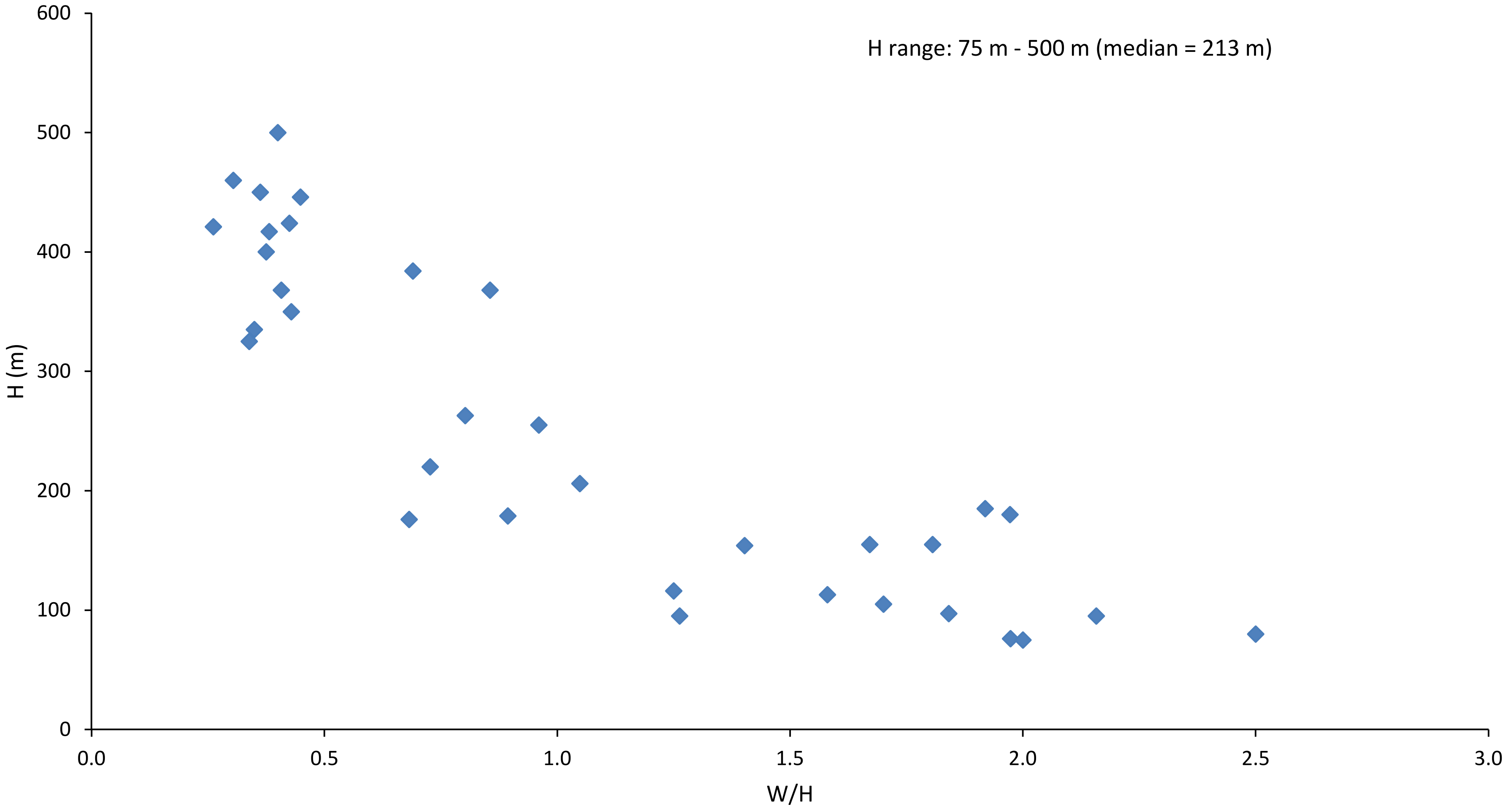
The risk to reject the null hypothesis H0 while it is true is 84.89%.

| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 01.02.14 | Title: | Results of Non-Linear Regession Error analysis for Height of B-Zone Predictions for Geology Pi-Term Model | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A42p |

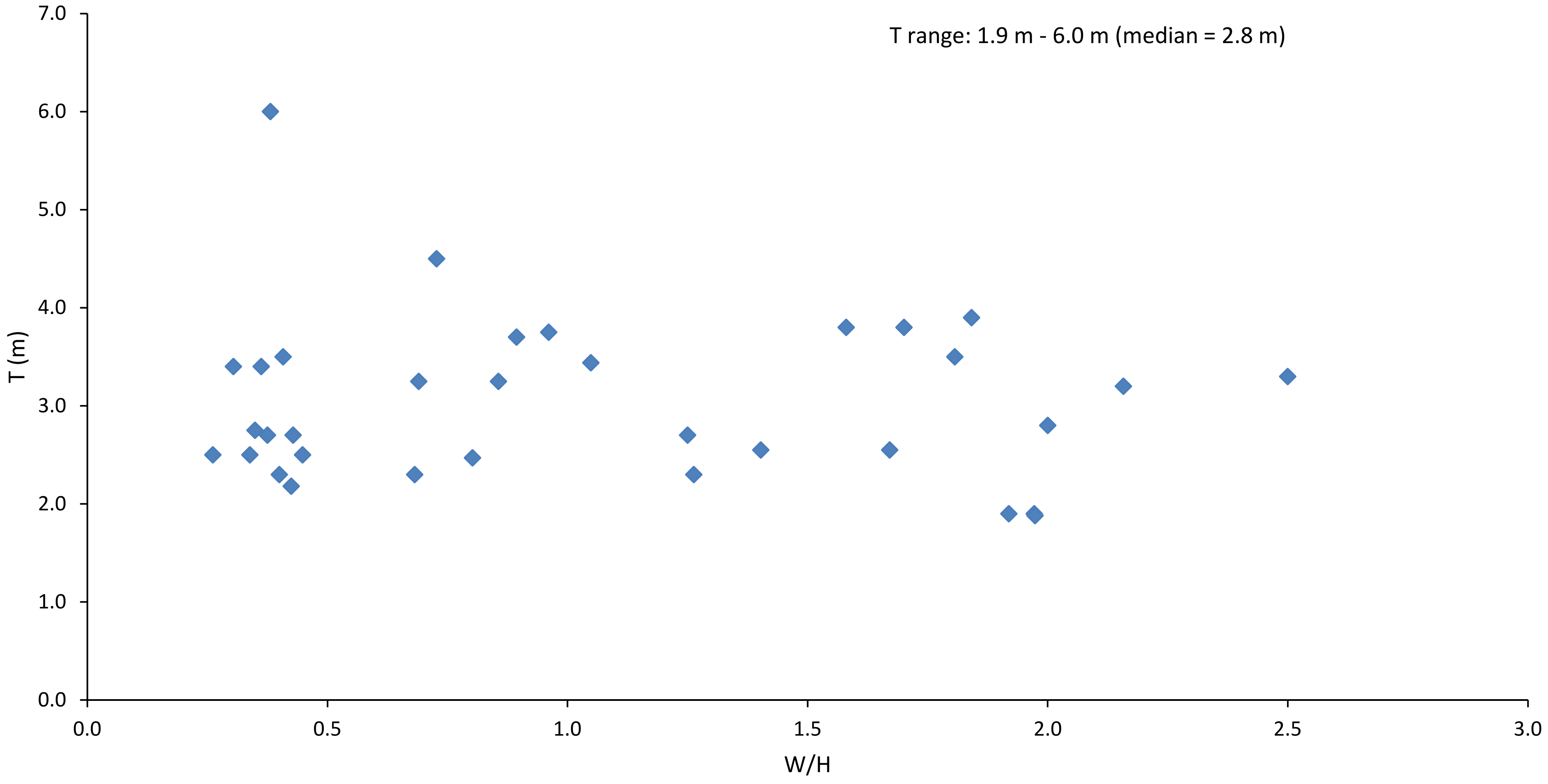


W range: 110 m - 355 m (median = 179 m)

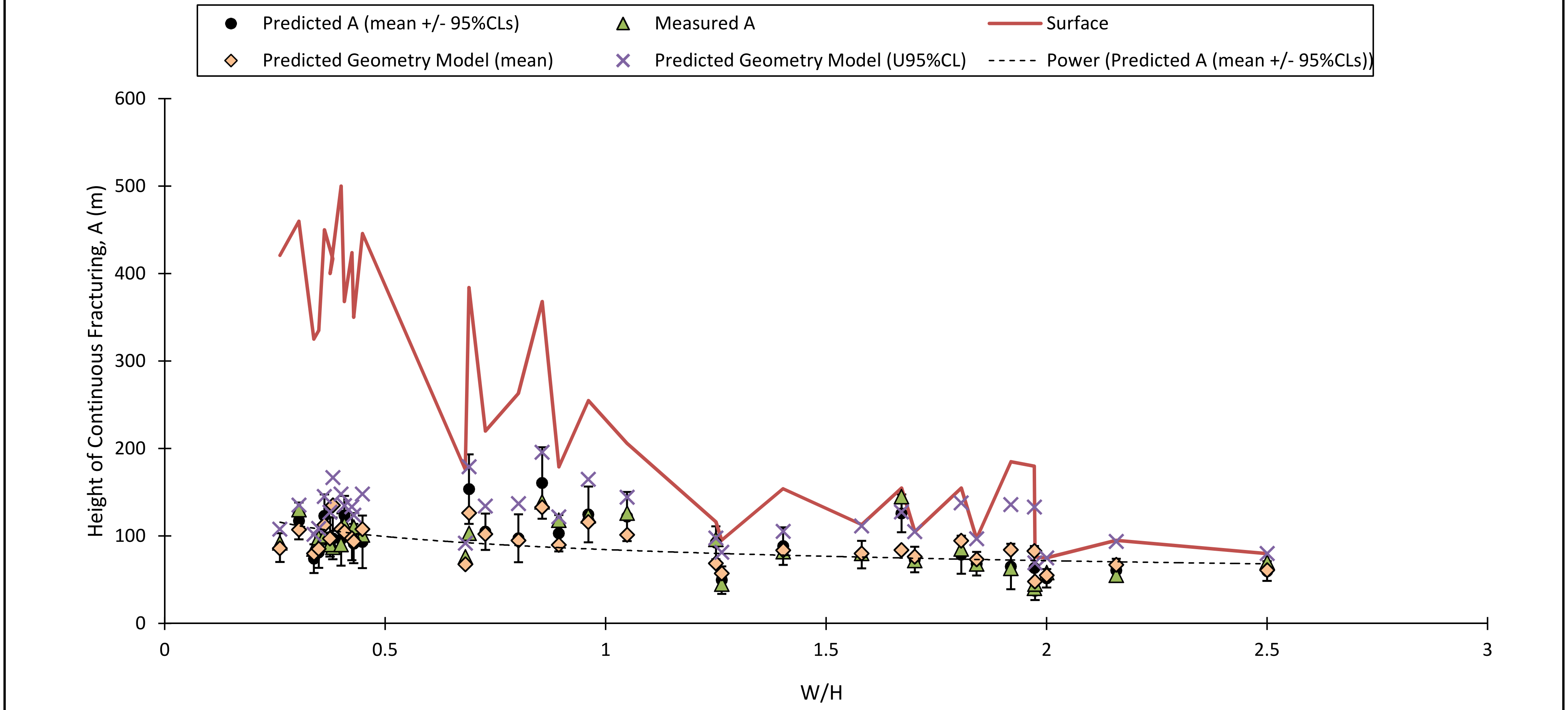
| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Modified from ACARP, 2003 | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 03.12.12 | Title: | Panel Width v. W/H Database for Sub-surface Fracturing Model | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A43a |



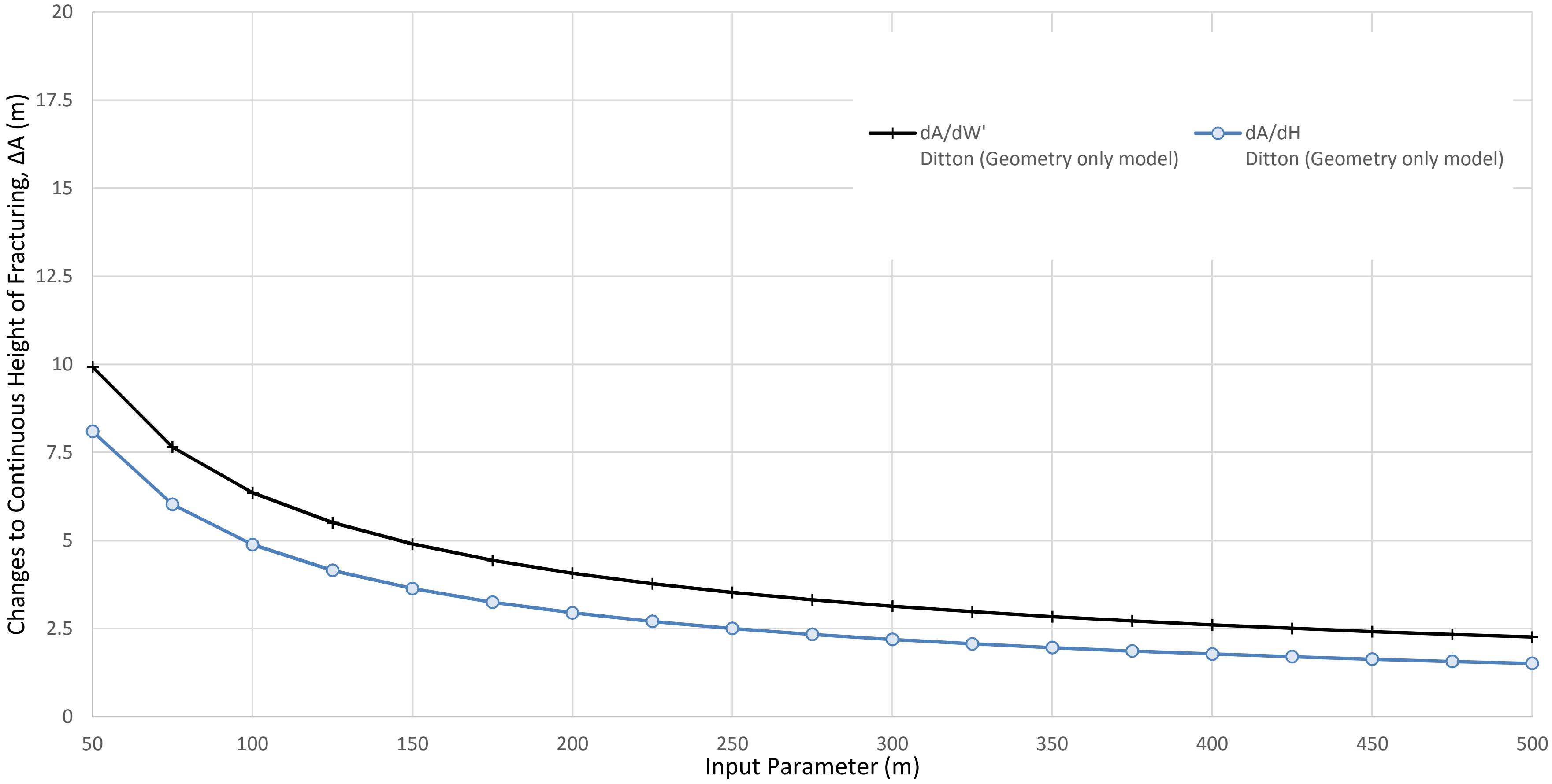
| | | | | | |
|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Modified from ACARP, 2003 | |
| | Drawn: | S.Ditton | | | |
| | Date: | 03.12.12 | Title: | Cover Depth v. W/H Database for Sub-surface Fracturing Model | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: A43b |



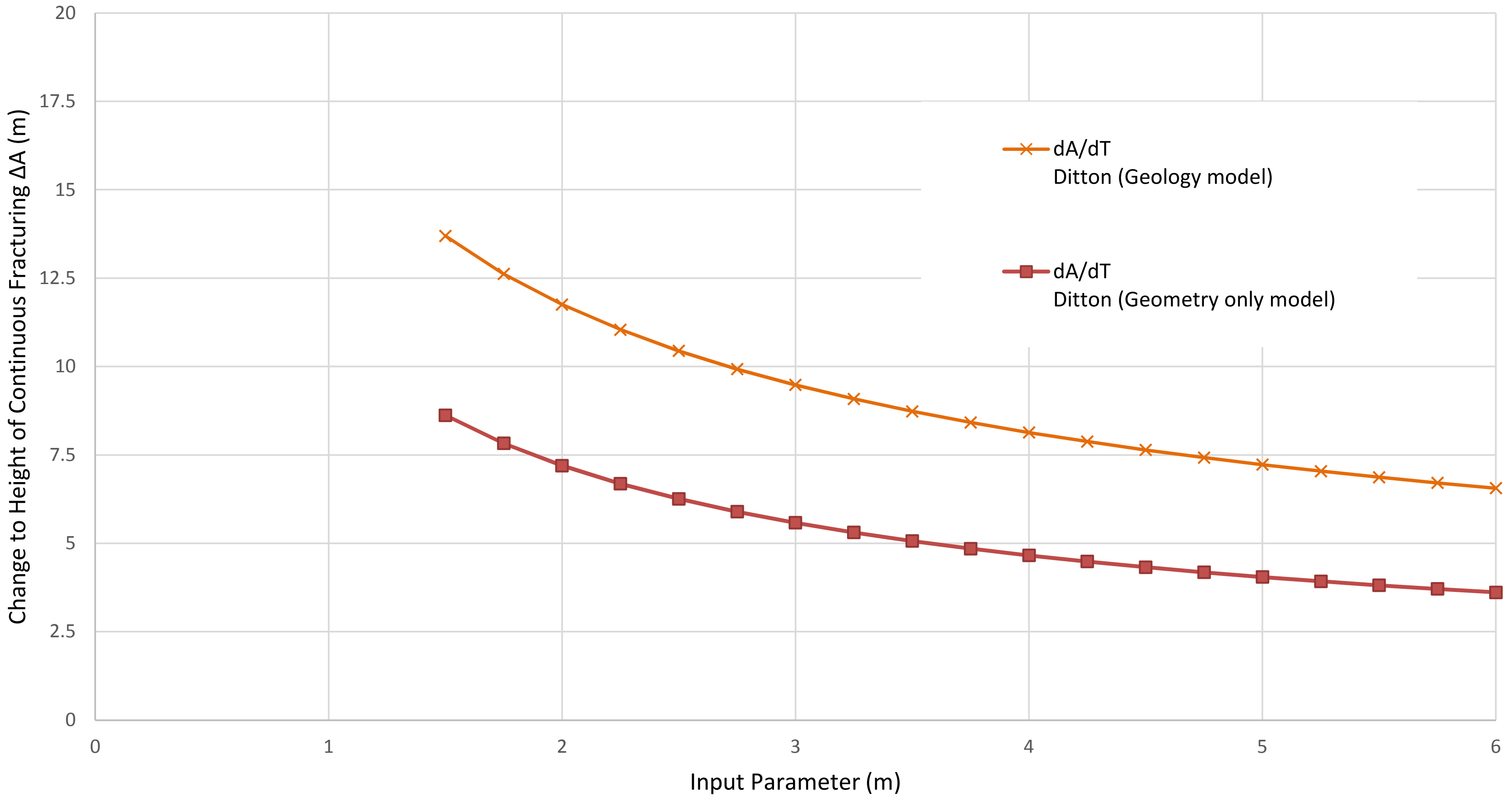
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Modified from ACARP, 2003 | | | |
| | Drawn: | S.Ditton | | | | | |
| | Date: | 03.12.12 | Title: | Mining Height v. W/H Database for Sub-surface Fracturing Model | | | |
| | Ditton Geotechnical Services Pty Ltd | | | | | | |
| | | | Scale: | NTS | | Figure No: | A43c |



| | | | | | |
|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | |
| | Drawn: | S.Ditton | Title: | Heights of Continuous Fracturing Predictions for the Geometry and Geology Pi-Term Models | |
| | Date: | 01.05.14 | | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: A43d |



|  |  |  |  |  |  |
|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Modified from ACARP, 2003 | |
| | Drawn: | S.Ditton | | | |
| | Date: | 25.05.14 | Title: | Sensitivity Analysis of Geometry Only Pi-Term Model Input Parameters on Predicted Height of Continuous Fracturing: W' and H (as per Merrick, 2014) | |
| | Ditton Geotechnical Services Pty Ltd | | | | |
| | | | Scale: | NTS | Figure No: A43e |



DgS

Engineer: S.Ditton
Drawn: S.Ditton
Date: 25.05.14

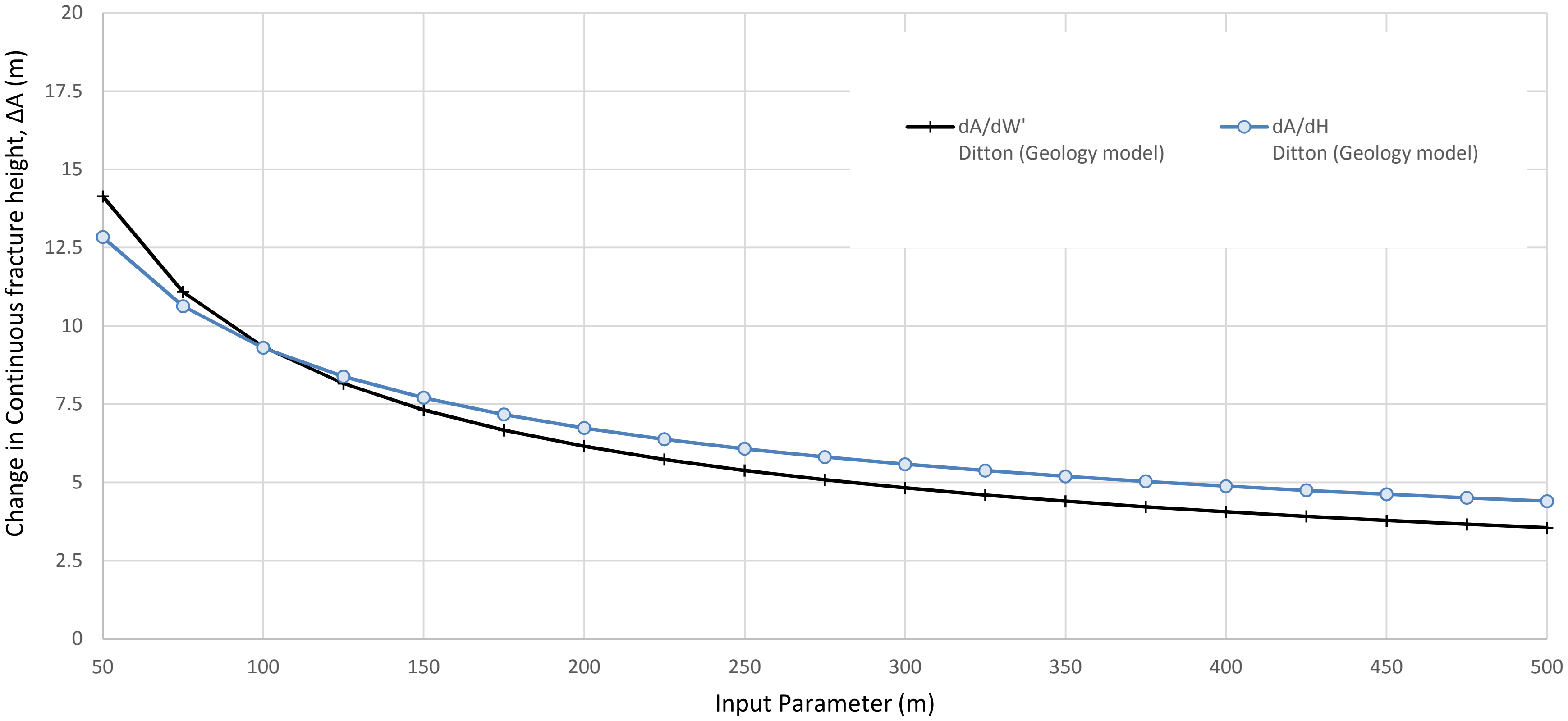
Ditton Geotechnical Services Pty Ltd

Client: Modified from ACARP, 2003

Title: Sensitivity Analysis of Geology & Geometry Pi-Term Model Input Parameters on Predicted Height of Continuous Fracturing: T (as per Merrick, 2014)

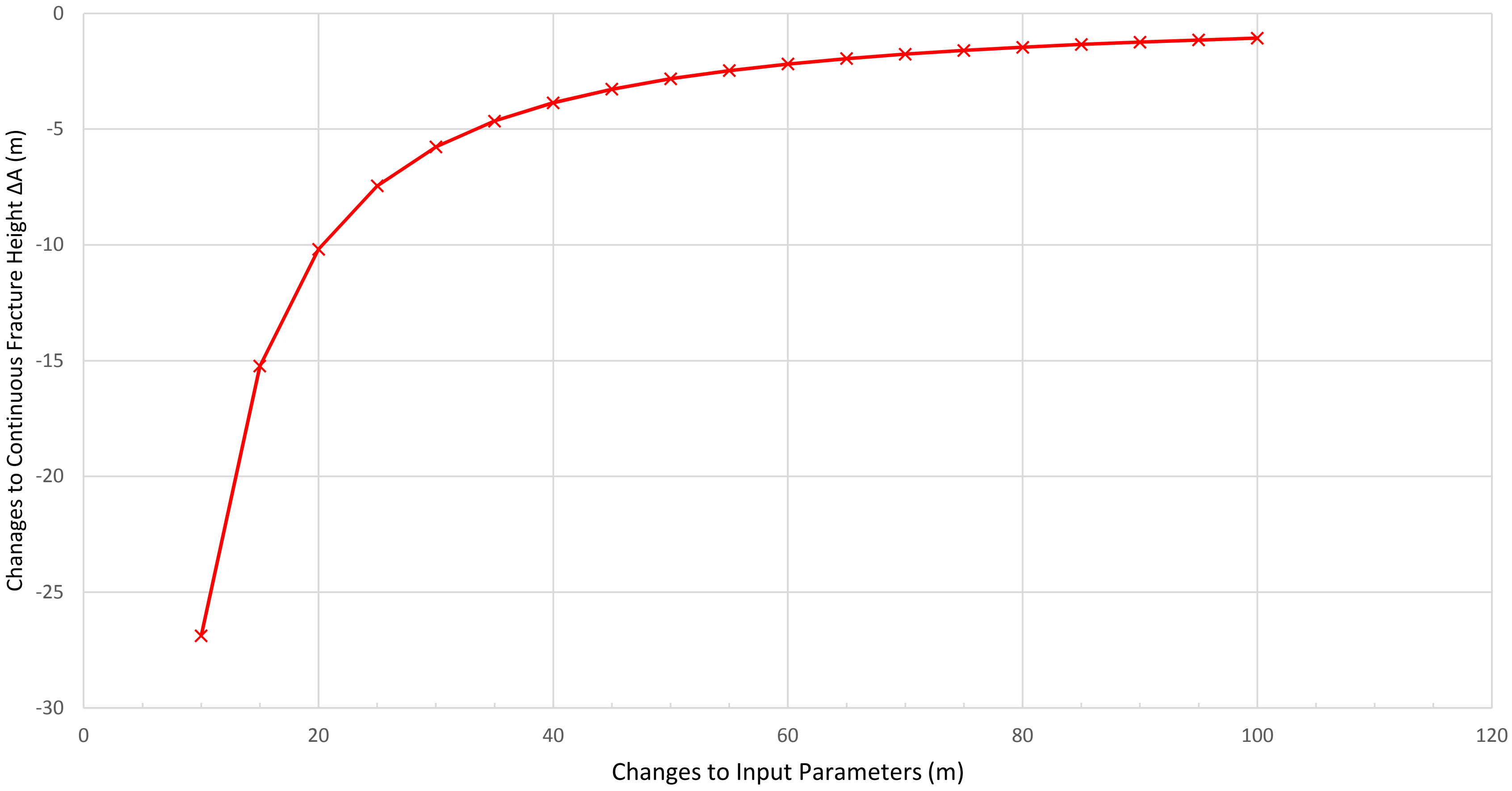
Scale: NTS

Figure No: A43f

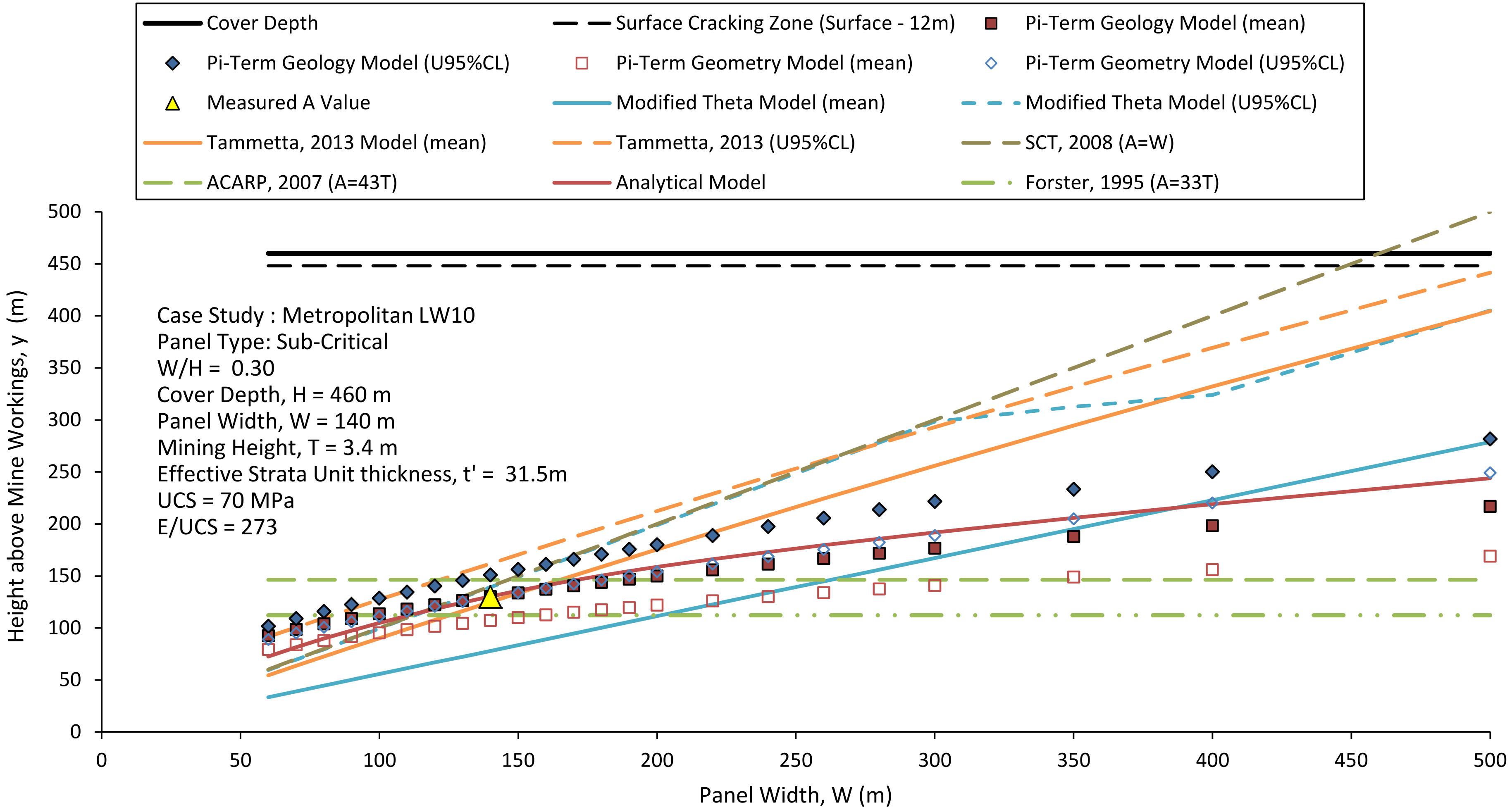


DgS

| | | | |
|---|---|---|---|
| Engineer: | S.Ditton | Client: | Modified from ACARP, 2003 |
| Drawn: | S.Ditton | | |
| Date: | 25.05.14 | Title: | Sensitivity Analysis of Geology Pi-Term Model Input Parameters on Predicted Height of Continuous Fracturing: W' and H (as per Merrick, 2014) |
| Ditton Geotechnical Services Pty Ltd | | Scale: | NTS |
| | | Figure No: | A43g |

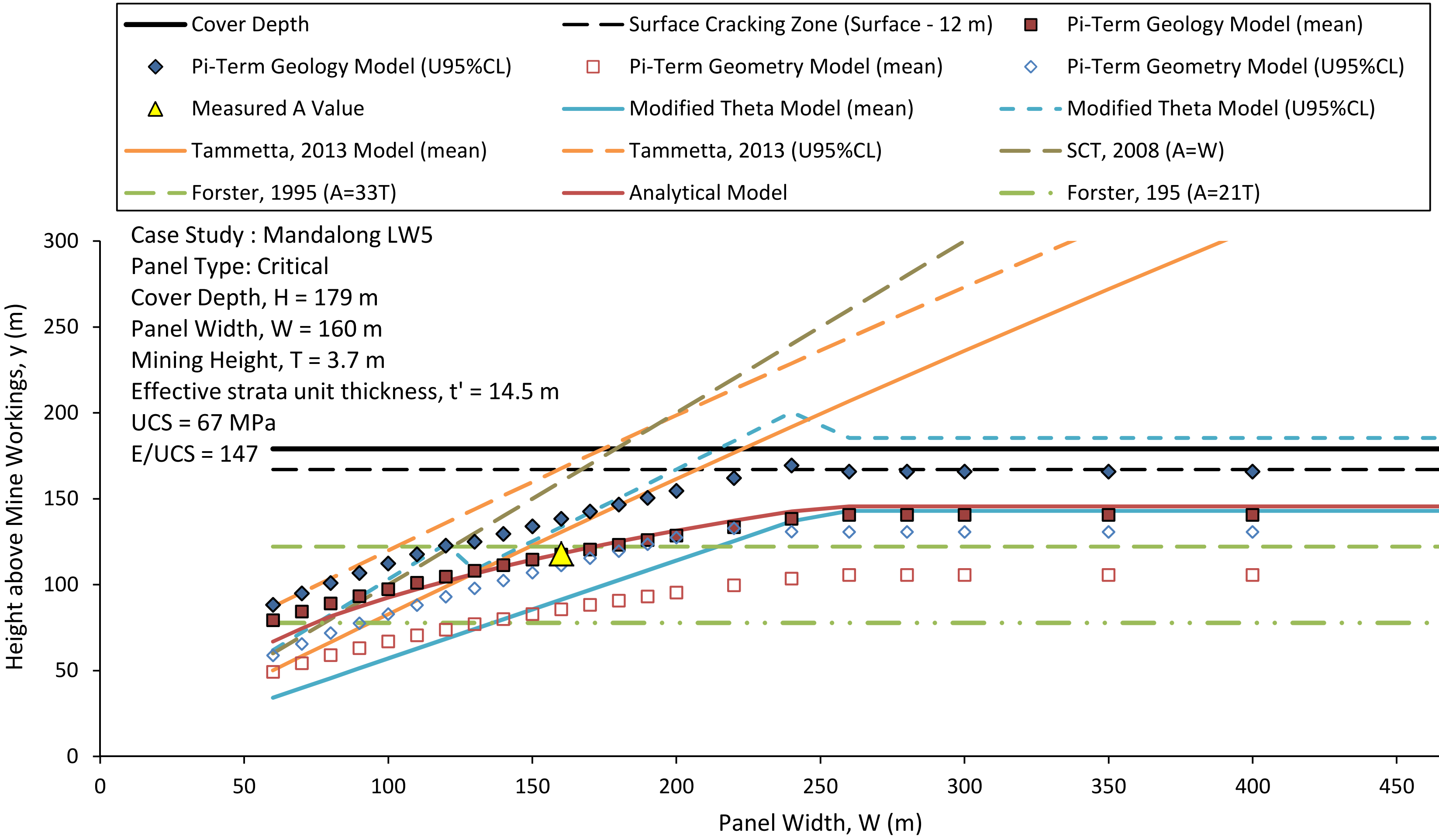


|  |  |  |  |
|---|---|---|---|
| **DgS** | Engineer: S.Ditton | Client: | Modified from ACARP, 2003 |
|  | Drawn: S.Ditton |  |  |
|  | Date: 25.05.14 | Title: | Sensitivity Analysis of Geology Pi-Term Model Input Parameters on Predicted Height of Continuous Fracturing: t' (as per Merrick, 2014) |
|  | Ditton Geotechnical Services Pty Ltd | Scale: | NTS Figure No: A43h |

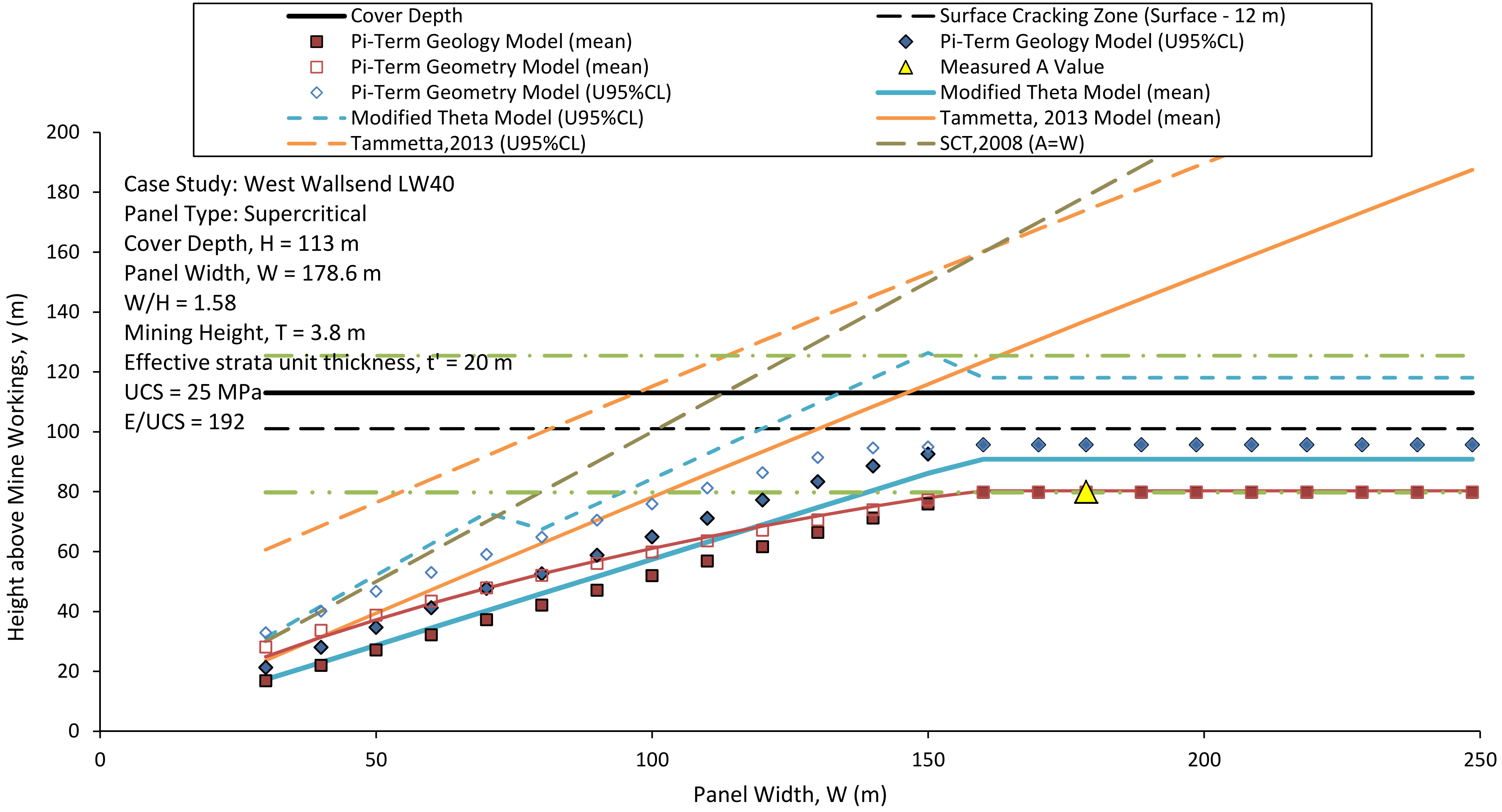


DgS

| | | | | |
|---|---|---|---|---|
| Engineer: | S.Ditton | Client: | Modified from ACARP, 2003 | |
| Drawn: | S.Ditton | | | |
| Date: | 16.03.14 | Title: | Predicted A-Zone Fracture Heights for Varying Panel Widths using Pi-Term Geometry and Geology Models and Current State of the Art Models | |
| Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: A43i |

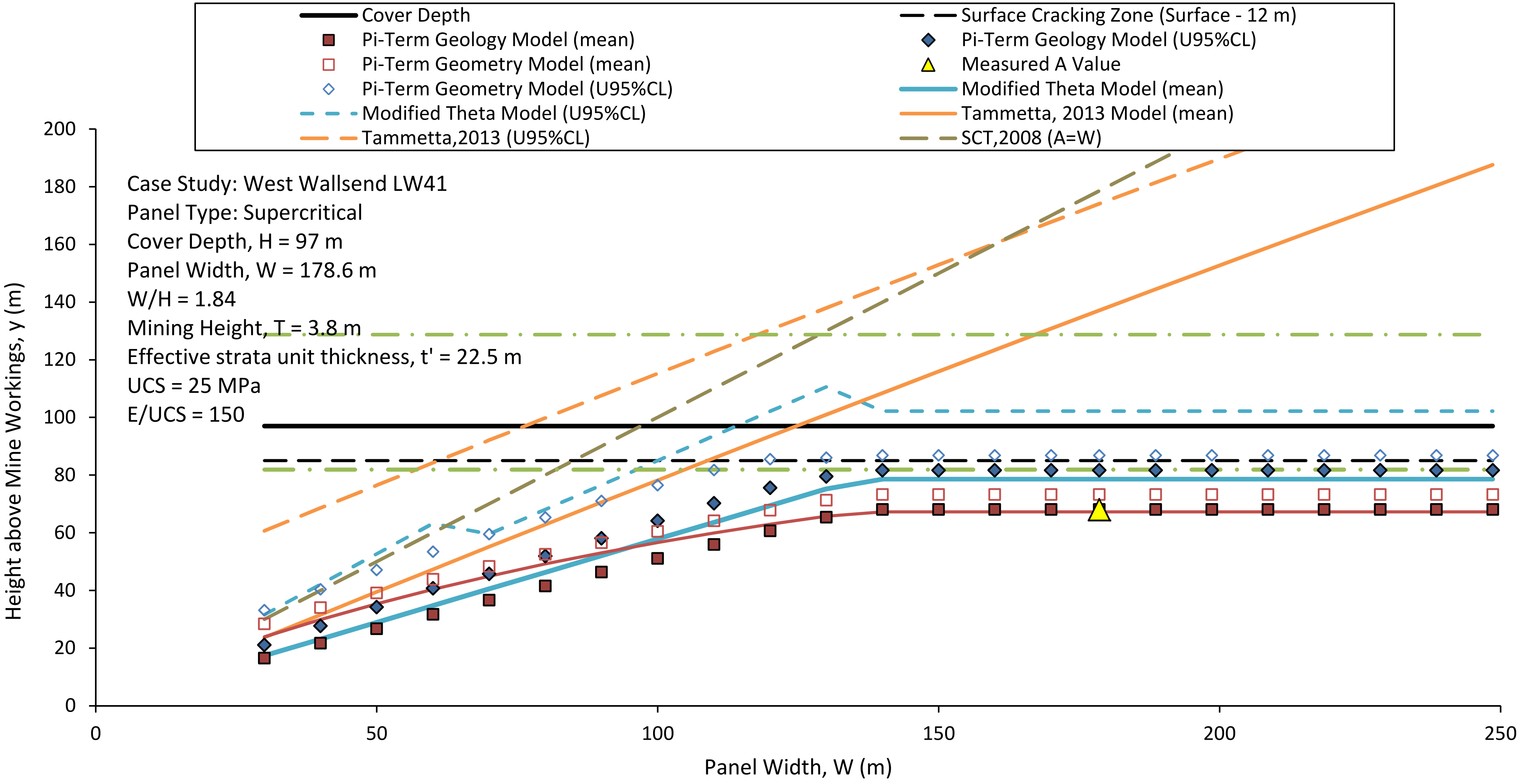


| | | | | | |
|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Modified from ACARP, 2003 | |
| | Drawn: | S.Ditton | | | |
| | Date: | 16.03.14 | Title: | Predicted A-Zone Fracture Heights for Varying Panel Widths using Pi-Term Geometry and Geology Models and Current State of the Art Models | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: A43j |

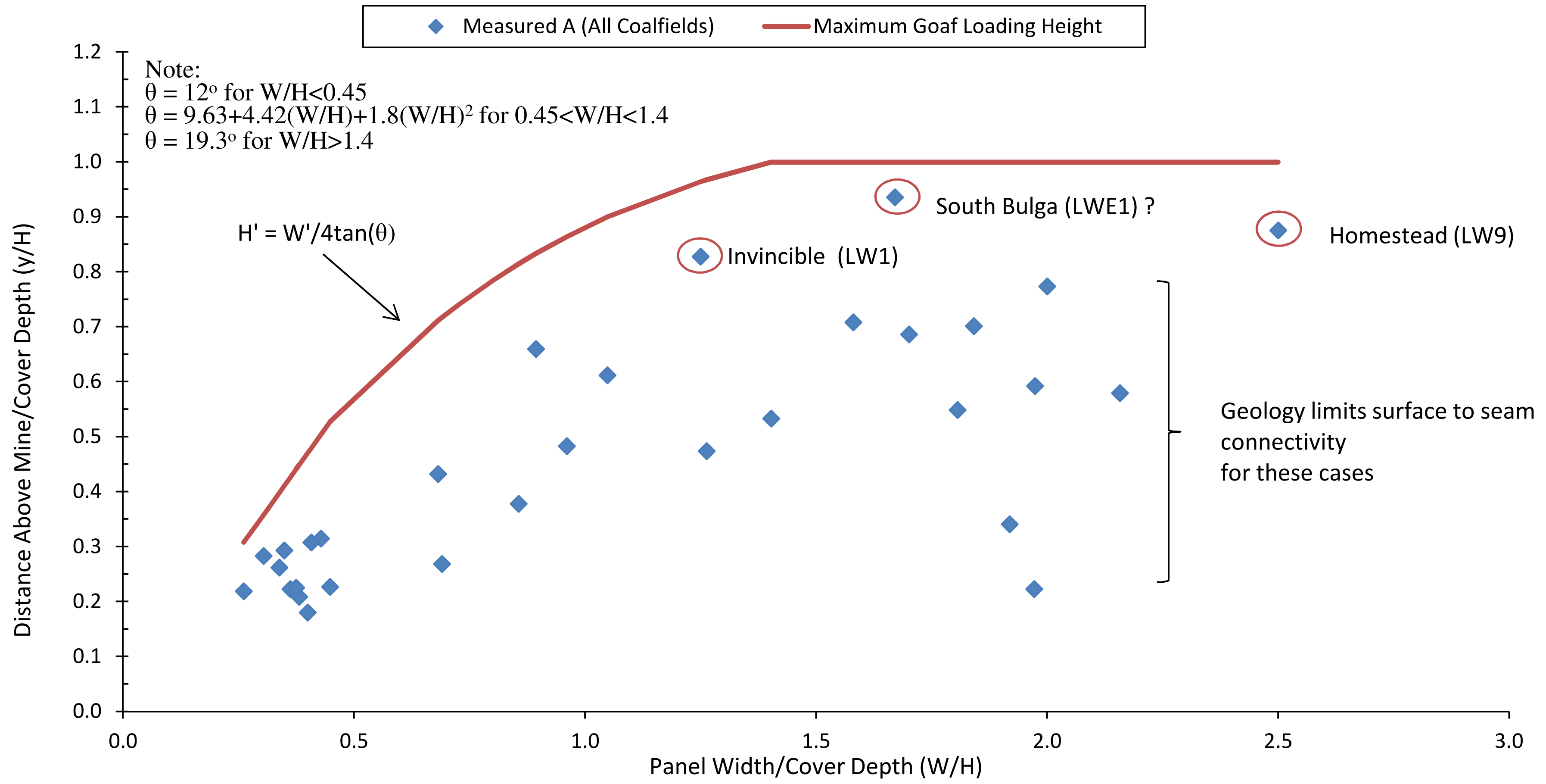


Case Study: West Wallsend LW40
Panel Type: Supercritical
Cover Depth, H = 113 m
Panel Width, W = 178.6 m
W/H = 1.58
Mining Height, T = 3.8 m
Effective strata unit thickness, t' = 20 m
UCS = 25 MPa
E/UCS = 192

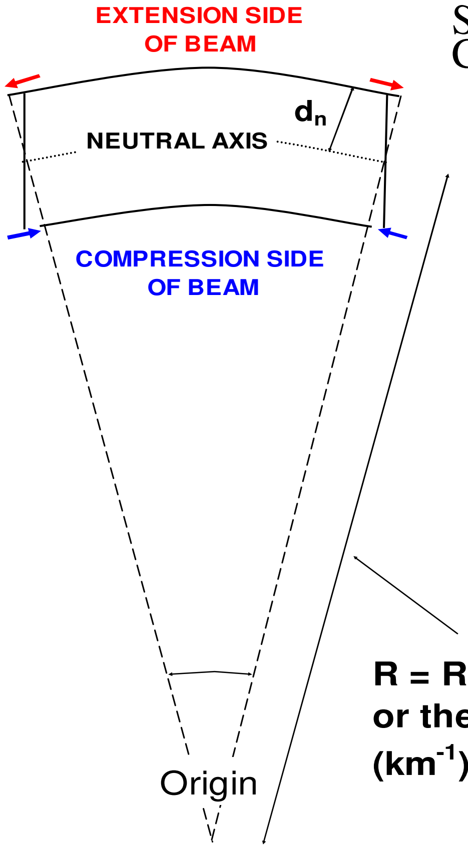
| | | | | | |
|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Modified from ACARP, 2003 | |
| | Drawn: | S.Ditton | | | |
| | Date: | 16.03.14 | Title: | Predicted A-Zone Fracture Heights for Varying Panel Widths using Pi-Term Geometry and Geology Models and Current State of the Art Models | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: A43k |



| | | | | |
|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Modified from ACARP, 2003 |
| | Drawn: | S.Ditton | | |
| | Date: | 16.03.14 | Title: | Predicted A-Zone Fracture Heights for Varying Panel Widths using Pi-Term Geometry and Geology Models and Current State of the Art Models |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS Figure No: A43I |



| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Review of Height of Fracturing Data | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 01.05.14 | Title: | Measured Heights of Continuous Fracturing in NSW and QLD Coalfields with Reported Surface to Seam Connectivity Cases and Theoretical Goaf Loading Height | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A43m |



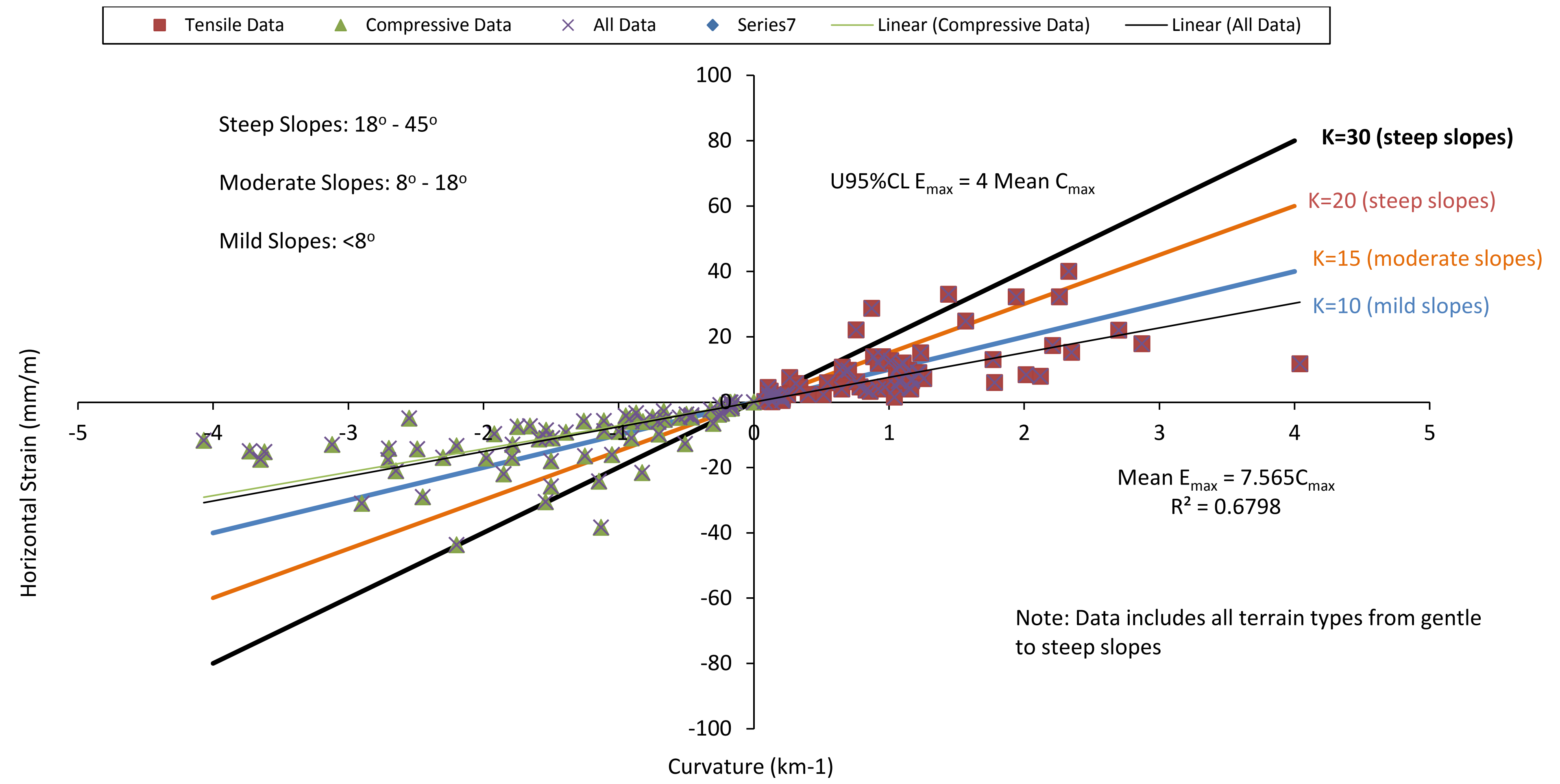
Strain E = (mm/m)
Curvature C = $km^{-1}$

$E = C \times d_n$

**= Depth of Cracking**

**R = Radius of curvature or the curvature, C = 1/R ($km^{-1}$)**

| | | | | | |
|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Extract from ACARP, 2003 | |
| | Drawn: | S.Ditton | | | |
| | Date: | 08.08.08 | Title: | Bending Beam Theory for Strain Prediction from Curvature Measurements | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: A43n |



| | | | | | | |
|---|---|---|---|---|---|---|
| DgS | Engineer: | S.Ditton | Client: | Extract from ACARP, 2003 | | |
| | Drawn: | S.Ditton | | | | |
| | Date: | 08.08.08 | Title: | Empirical Model for Maximum Panel Strain Prediction Above Longwall Panels for Smooth and Cracked Profiles in the Newcastle Coalfield | | |
| | Ditton Geotechnical Services Pty Ltd | | Scale: | NTS | Figure No: | A43o |

20th September 2014

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Wolgan Rd
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NSW 2790

For the attention of Mr. Peter Corbett,
Technical Services Manager

Dear Peter,

## Peer Review of Mine Subsidence Induced Height of Fracturing Issues for Angus Place and Springvale Collieries

Centennial Coal has requested Mine Subsidence Engineering Consultants Pty Ltd (MSEC) to undertake an initial review of and provide comments on the height of connected fracturing (HoCF) that are provided in:

- Ditton Geotechnical Services (DgS) report, titled "***Subsurface Fracture Zone Assessment above the Proposed Springvale and Angus Place Mine Extension Project Area Longwalls***", DgS Report No. SPV-003/7b, dated 9th September 2014; and
- Commonwealth Scientific and Industrial Research Organisation (CSIRO) report, titled "***Angus Place and Springvale Colliery Operations – Groundwater Assessments***", Report No. EP132799, dated May 2013.

We are pleased to provide the following generalised overview or summary on this subsidence induced HoCF issue.

The primary porosity of a rock is a measure of the size of void spaces (i.e. the empty or open) between the grains within the rock as a proportion of the total rock volume. When all these void spaces are filled with water the rock is said to be saturated. The secondary porosity exists in rocks due to the presence of fractures, joints, faults and bedding plane partings that were created after the rock was originally formed. This secondary porosity is usually more important in layered sequences of typical sedimentary coalfield strata, but, the secondary porosity cannot be measured in a laboratory since it is impossible to use a large enough sample to represent the rock in situ. Measurements of porosity within a rock mass must be made by field tests to sample a large enough volume of rock. However, the existence of primary or secondary porosity in a rock does not in itself imply the existence of permeability or the ability to transmit water.

Water may flow through a rock mass depending on the size and the length of the available flow path and the available head. Whilst porosity is related to storage capacity, permeability is related to flow. Permeability of a rock is a measure of the ease with which a fluid will pass through that rock. In homogeneous rocks, such as those normally constituting uniform-grained aquifers, permeability is commonly equal in all directions. However, in many of the horizontally bedded consolidated rocks, such as shales, sandstones and claystones of sedimentary coal measures, permeability is measured to be far greater in the horizontal directions parallel to the bedding planes than in a vertical direction. It is easier and more accurate to determine permeability by direct site measurements by means of flow experiments. Henry Darcy, in 1856, was the first to experiment with the flow of water through sand, and he found that the rate of flow through sand is proportional to the hydraulic gradient (Darcy's Law). The constant of proportionality in Darcy's Law is known as the coefficient of permeability. It includes properties of the rock and the fluid and has the dimensions of velocity (i.e. metres per day). The coefficient of permeability of a rock used in the groundwater industry, where the fluid is always water, is known as the hydraulic conductivity. Hydraulic Conductivity is defined as the rate at which water can be transmitted, in cubic metres per day, through a cross sectional area of one square metre normal to the direction of flow, under a hydraulic gradient of one. The units of hydraulic conductivity are usually metres per day or centimetres per second.

A hydraulic conductivity of say 10 metres per day does not mean that water will flow through that rock at the rate of 10 metres per day; it can do so only if the hydraulic gradient is one. If the hydraulic conductivity is 1/1000 then water will flow through the rock at the rate of 0.01 metres per day. The table below provides a range of hydraulic conductivity for typical rocks with the values for highly fractured rocks can be much higher than rocks that are not fractured.

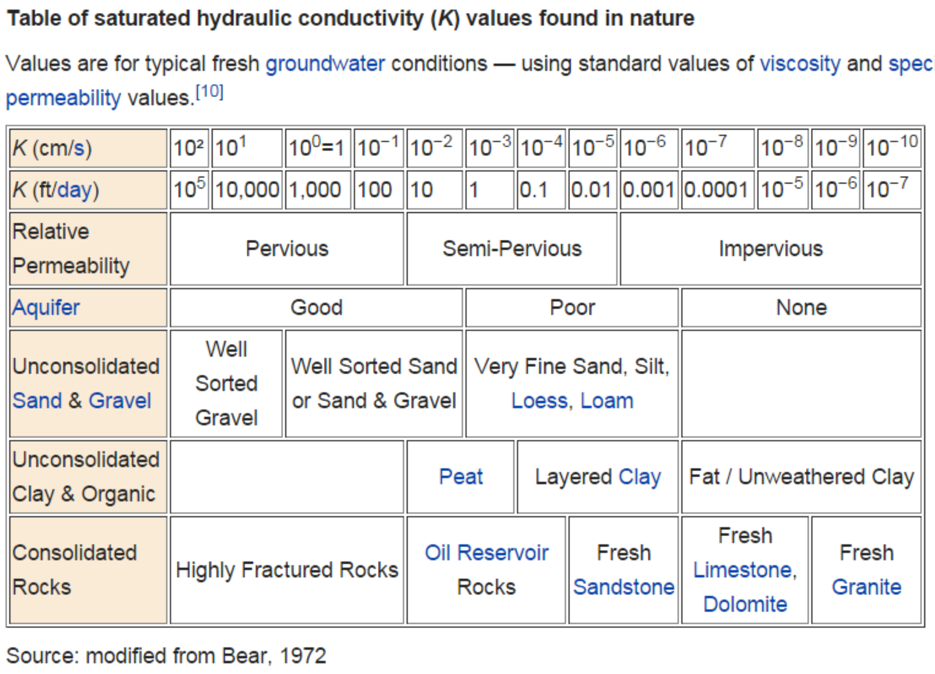


**Table of saturated hydraulic conductivity (*K*) values found in nature**

Values are for typical fresh groundwater conditions — using standard values of viscosity and speci
permeability values.[10]

| *K* (cm/s) | $10^{2}$ | $10^{1}$ | $10^{0}=1$ | $10^{-1}$ | $10^{-2}$ | $10^{-3}$ | $10^{-4}$ | $10^{-5}$ | $10^{-6}$ | $10^{-7}$ | $10^{-8}$ | $10^{-9}$ | $10^{-10}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *K* (ft/day) | $10^{5}$ | 10,000 | 1,000 | 100 | 10 | 1 | 0.1 | 0.01 | 0.001 | 0.0001 | $10^{-5}$ | $10^{-6}$ | $10^{-7}$ |
| Relative Permeability | Pervious | | | | Semi-Pervious | | | | Impervious | | | | |
| Aquifer | Good | | | | | Poor | | | | None | | | |
| Unconsolidated Sand & Gravel | Well Sorted Gravel | | Well Sorted Sand or Sand & Gravel | | | Very Fine Sand, Silt, Loess, Loam | | | | | | | |
| Unconsolidated Clay & Organic | | | | | Peat | | Layered Clay | | | Fat / Unweathered Clay | | | |
| Consolidated Rocks | Highly Fractured Rocks | | | | Oil Reservoir Rocks | | | Fresh Sandstone | | Fresh Limestone, Dolomite | | Fresh Granite | |

Source: modified from Bear, 1972

For water to move through rocks the head available has to overcome surface tension and frictional resistance. It is possible to have rocks of such low hydraulic conductivity that they require large differences in head to overcome the frictional resistance and therefore they only transmit negligible quantities of water except by molecular and surface tension forces; such rocks are termed impervious or impermeable despite the fact that they may process some hydraulic conductivity. Use of this knowledge is made in the design of engineering structures such as rock fill dams. The vertical flow of water through a layered sequence cannot be obtained by using the average vertical hydraulic conductivity of the layers; the prime controls being the layer of lowest vertical hydraulic conductivity and the head acting on it.

It is common for aquifers to be encountered at a number of levels within a layered sequence of horizontally bedded sedimentary rocks, each having a successively deeper standing water level (i.e. the level at which water from the aquifer concerned will stand in a bore exposed to that aquifer). The sequence in water levels is due to there being layers of lower permeabilities within the strata and these retard downward movement of water.

Longwall mining results in surface and sub-surface subsidence displacements and it creates new fractures and opens up or widens pre-existing bedding planes and natural joints within the overburden. The location of and the impacts from these mining induced fractures within the overburden depend on both the mining geometry and the geology and lithology of the strata as discussed below.

The opening of existing joints and bedding planes and the creation of new mining induced cracks within the overburden over a mined panel does increase the permeability of the existing strata layers. The height at which new mining induced fractures (HoF) may form above a mined panel has been measured to be up to 1 to 1.5 times the panel width, depending on the spanning capacity of the overlying strata and the bulking of the goafed strata. However the creation of these new fractures does not necessarily imply that a direct hydraulic connection will exist vertically up through the strata layers to each fracture. Significant volumes of mine inflow only occur from the height where the fractures form a connected continuous path or a conductive network towards the mined opening.

The height of the connected fracturing zone (HoCF) which is defined, for the purposes of this review, as the height of a zone above the seam that mining induced connected or continuous fractures can transmit water from the overlying strata to the mined void, or, the height of a zone above the seam from which water would flow freely into the mine. The HoCF is commonly much lower than the HoF, depending on many factors as is discussed below.

Unfortunately, there have been mining cases at shallow depths of cover where mine subsidence movements have caused extensive surface cracking and where surface water flows were captured and drained down into mine workings. There have also been mining cases where mine subsidence movements impacted on groundwater aquifers that were located at deep and shallow cover above the mine workings. These failures have been observed in all geological regions, especially where the depth of cover was shallow, or, the interburden thickness between the workings and the aquifer was shallow.

On the other hand, there have also been many cases where mining has been successfully carried out at very shallow depths of cover under surface waters, rivers, creeks as well as under various aquifers with negligible, minor or only small losses of water being recorded into the mines.

In 1972 Kapp and Williams advised that 80 years ago coal was successfully mined at shallow cover beneath the Hunter River and Newcastle Harbour. In the Stored Waters Inquiry Report, Reynolds (1977) advised that first workings coal was extensively and successfully mined under Newcastle Harbour and under the ocean off Newcastle with narrow bords and pillars at the following mines taking up to 50% of the coal by plan area with no reported inundations:

- The Winning or Sea Pit, where the depth of cover was more than 140 feet (43 metres);
- Newcastle Coal Mining Company's A and B Pits, where the depth of cover varied from 150 feet (46 metres) to 113 feet (35 metres);
- Burwood Colliery, where the depth of cover was more than 120 feet (36 metres);
- Dudley Colliery, where the depth of cover was more than 100 feet (31 metres);
- Redhead Colliery, where the depth of cover was more than 120 feet (36 metres); and
- John Darling Colliery, where the depth of cover was more than 120 feet (36 metres).

Additionally extensive areas of first workings, panel and pillar second workings, longwall panel extraction and total extraction has taken place under the lake areas south of Newcastle.

Hence, the impacts of mining and subsidence on surface water and groundwater resources have been found to be extremely variable and it is important to appreciate the circumstances for each of these mining cases in order to understand when water may be lost from the surface or aquifers and when mining can be undertaken safely without noticeable impacts on groundwater or surface flows.

The issue of hydraulic connections between the surface water bodies and the mine workings has been the subject of several government inquiries and reports over the past few decades by the NSW State government and more recently by the federal government. The first major inquiry was commenced in 1974 by Mr Justice Reynolds for the State Government of NSW because of the possibility that hydraulic connections between surface stored waters and deep mine workings beneath several major water dams in the Southern Coalfields of NSW could impact on Sydney's water supply. The Stored Waters Inquiry concluded in 1977 that under certain strict conditions mining could be permitted. At depths of cover greater than 120 meters, the extracted panel widths should not exceed one third of the cover depth and the panels should be separated by pillars that had a width of one fifth of the cover depth or fifteen times the height of extraction. Effectively these dimensions were proposed (and were determined to be appropriate) to prevent pillar failure and to maintain a constrained zone above the mined panels that was likely to include at least one of the less permeable layers from the Narrabeen Group.

After this Inquiry was completed a range of field, laboratory and computer simulation studies were undertaken and the results of these studies indicated that the Inquiry recommendations were overly conservative in most circumstances, especially, since a number of very low permeability claystone strata layers, such as the Bald Hill claystone, are now considered to function as aquitards or hydraulic barriers to surface water flowing into the mine workings that have remained relatively “dry” even though many panels had been extracted under the stored waters and known groundwater aquifers.

Based on these developments, mine owners have successfully petitioned, on a number of occasions, the Dam Safety Committee of NSW and other government regulators to approve less conservative mine layouts than those that were recommended by Justice Reynolds as long as they could prove that strata layers of low permeability existed above the predicted heights of interconnected fracturing.

Many engineers, surveyors, geologists and groundwater hydrologists have published reports and papers on the effects of mine subsidence on surface water and groundwater resources. Over the past decade the Australian Coal Industry's Research Program (ACARP) sought research proposals that addressed this issue as one of their key industry problems. Several ACARP research reports have now been published that provide advice on the likely impacts of mining on surface water and aquifers.

Recently some further extensive studies have been published on this issue by the Australian Government Department of Environment, on the advice of the Independent Expert Scientific Committee on Coal Seam Gas and Large Scale Mining Development. This Committee was established as a statutory committee in 2012 by the Australian Government under the *Environment Protection and Biodiversity Conservation Act 1999 (Cth)* in response to community concerns about coal seam gas and coal mining.

Despite the availability of many new reports on this issue, varying opinions have been given on: which subsidence parameter most influences the observed impacts; how best to determine the likely impacts of mining on water resources; and the choice of which computer programmes should be utilised in these studies. Fortunately, some basic concepts and understandings have developed, even though; some authors have not yet understood all the complex issues. Some authors, who only see limited data on a local perspective, rather than on a state wide basis, have assumed the influence of geology is not important, but, the presence of strong or massive strata and the presence of layers of low permeability can have a significant effect on the impact of mining on surface and aquifers and on water inflows into mines. Contrary to what one researcher recently published, i.e. “host geology appears to play a minor role”, MSEC believes the impacts of mining and subsidence on surface water and groundwater resources vary significantly due to changes in the local geology and lithology.

The following review of some important research papers provides some interesting background in this field.

Holla 1987 published a paper titled “***Design of mine workings under surface waters in New South Wales***” in 1987 in which he advised; “*Guidelines for mining coal from underneath large bodies of surface water should ideally aim at achieving maximum and efficient recovery of coal resource consistent with the safety of underground mine operations and overlying surface features or improvements. The guidelines prevailing at present in New South Wales (NSW) were framed during the 19705. Even though the basic engineering concepts used for developing them are sound, the guidelines themselves are conservative and over-restrictive given the circumstances and level of available local knowledge at that time.”*

*“Mining under tidal lakes, rivers, streams and the ocean in NSW is controlled in accordance with the provisions of the Coal Mines Regulation Act (NSW Government, 1982) and other regulations framed and administered by the Chief Inspector of Coal Mines. The present regulations are based on Wardell's report (Wardell, 1975) and are designed to minimise water encroachment upon surrounding lands and to contain surface and sub-surface strata movement to levels required to ensure mine safety.”*

*“Movement at rockhead under tidal waters (outside HWMSB) is controlled by the following four guidelines.*

1. *The minimum solid strata cover depth for any extraction to occur is 46 m.*
2. *The maximum horizontal tensile strain al rockhead is limited to 7.5 mm/ m.*
3. *For total extraction to occur, the minimum solid strata cover depth should be sixty times the extracted seam thickness.*
4. *Panel and pillar workings can occur with panel width restricted to O.4D and pillar width to 0.120 or eight times the extracted seam thickness, whichever is the greater.”*

*“Guideline 3 was obtained from Guideline 2 using the well known relationship that connects strain, subsidence and depth of cover, which is given below.*

*Emax = K x Smax/D where,*
*Emax = maximum tensile strain (non-dimensional)*
*Smax = maximum subsidence (m)*
*D = solid cover depth (m)*
*K = maximum tensile strain coefficient (non·dimensional)”*

*“Wardell (1975) assumed the following values in arriving at the minimum depth of solid strata cover D for mining a seam of thickness T.*

*Emax = 0.0075*
*Smax = 0.6 x T*
*K =0.75*
*D = K x Srnax/Ema> = 0.75 x 0.6 x T 10.0075 ) =60 x T”*

*“Equating 60 times the extracted seam thickness with the rock·head tensile strain of 7.5 mm/m is valid only for the assumed values of Smax: and K. If the input values for Smax and K are changed, the minimum depth of cover would assume a different value for the same rockhead strain of 7.5 mm/ m. In other words, the rockhead tensile strain is the independent and essential criterion, and 60 times the extracted seam thickness is the dependent and nonessential criterion. The guidelines for mining under the Pacific Ocean are assumed to be similar to those for mining under tidal waters.”*

Holla (1989) also published a NERRDC funded report titled “***Investigation into Sub-Surface Subsidence***” which documents research to collect information on the heights of caving above the seam and to study the variation in subsidence-surface subsidence for various panel width to depth ratios and the associated vertical strains. Holla reported that

“*During the course of this project, it was considered that the measure of the movement of strata might not adequately demonstrate the possible changes in permeability of the strata due to mining. It was therefore decided to collect additional data on fracturing and bulk permeability of strata before and after mining.”*

*“The investigation was carried out in four collieries reflecting different geological and mining environments. The collieries were Ellalong and Wyee collieries in the Newcastle Coalfield, Invincible colliery in the Western Coalfield and Tahmoor colliery in the Southern Coalfield.”*

*The zone of caving and bed separation at Ellalong was observed to be 13 times the extracted seam thickness. Longwall panel 2 at the Invincible colliery was sub-critical (the extraction width to mining depth ratio being 1.24) and the zone of caving and bed separation was confined to 9 times the extracted seam thickness. At Wyee, where multi-seam mining was undertaken, the caving extended up to the previously formed goaf, which was 26 m above the extracted seam.”*

*“These observed caving heights of 9 to 13 times are significantly larger than the caving height of two to five times the extracted seam thickness reported in the British coalfields. The difference appears to be due to the more competent seam roof strata in NSW caving with much smaller bulking factors than the weak seam roof strata generally found in the UK caving with larger bulking factors.”*

*“At the Ellalong borehole, high vertical dilations were confined to a rectangular area behind the face and extended roughly to 50 m height above the seam roof. The average tensile strain in the overburden above the caving zone was 1.28 mm/m. In the region extending 75 m below the surface, the tensile strains were less than 1 mm/m. In the case of the Invincible borehole, high strains developed throughout the overburden which ranged between 1 and 10 mm/m. At the Tahmoor borehole, the strains in the overburden to 165 m depth below the surface were generally*

*small, and the average tensile strain was 0.77 mm/m.  Strains varied between less than 0.5 mm/m compressive strain and 4.0 mm/m tensile strain."*

*"The strain contours were layered in all boreholes, which indicates a correlation between strata dilation and geology. this trend was more pronounced at the Invincible borehole, where larger strains were associated with layers of sandstone, siltstone and conglomerate. Layers of mudstone, claystone and coal subsided in blocks, thereby exhibiting smaller strains.  Vertical dilation in the overburden tended to be much more closely related to stratigraphy than to proximity to the extracted seam roof."*

*"Generalising the above observation, overburdens consisting of competent strata such as massive sandstones and conglomerates capable of accommodating large vertical strains are likely to subside less resulting in less surface subsidence.  Conversely, overburdens consisting of weak mudstones and claystones are likely to develop larger surface subsidence. "*

*"The vertical dilation of strata in the region extending from the surface to 100 m downwards was small both at Ellalong and at Tahmoor, where the mining depths were respectively 370 m and 420 m.  Based on the criterion of rock fracture at dilations in excess of 2.5 mm/m, the strata to the depth of 100 m below the surface are expected to remain elastic and free from fracturing.  The overburden in such a condition is highly unlikely to provide a continuous hydraulic connection between the surface water body and mine workings."*

Holla provided that following additional comments on the influence of geology of observed subsidence in a later 1991 paper titled "*Some Aspects of Strata Movement relating to Mining under Water Bodies in New South Wales, Australia*":

*"Successful mining layouts for mining coal under large water bodies should ensure that a substantial thickness of overburden strata remains undisturbed to prevent the flooding of mine workings. One of the criteria followed in many countries for controlling sub-surface strata disturbance is to specify a limit on the rockhead tensile strain. However, the generally specified rockhead strains are well in excess of the strain required to cause surface fracturing.  It therefore leads to the conclusion that the composition of strata between the cracked zone on the surface and the caved zone above the extracted seam plays an important role in preventing water inflows into mine workings.  Ductile beds like shales, mudstones and clay bands appear more effective than sandstone beds of the same thickness."*

*"Mudstones, shales and claystones absorb a large amount of strain energy before fracture.  Thus, these beds in the overburden can subside significantly without fracturing and therefore are preferred to sandstones and conglomerates in providing a barrier against downward movement of surface water."*

"*In a tightly constrained condition, many rocks including coal are impermeable and remain so until they are fractured and expanded.  In constrained condition, shales, mudstones, siltstones and coal are impermeable, whilst sandstones and conglomerates are considered more permeable.  "*

*"In spite of this, most rock materials with a few exceptions have relatively low permeability when compared with the high permeability caused by the joints and fissures in the rock mass.  It can be said that the water flow occurs almost entirely through the voids and fissures in the rock mass and not through the rock material.  Therefore, the permeability of the rock mass will depend on the degree of jointing and fracturing and the opening and interconnection of these fractures."*

The following comments on the heights of observed caving and cracking (HoF) were copied from a published paper by Mills and O'Grady in 1998 titled "*Impact of Longwall Width on Overburden Behaviour*":

"*Clarence Colliery mines the Katoomba seam, the uppermost seam in the sequence. The immediate overburden strata comprises a sequence of competent interbedded fine grained sandstones and siltstones with some weaker coarse grained sandstones. A major sandstone unit occurs at about 25 m above the seam with another major unit some 50-70 m above the seam. The sandstones in each unit are generally massive and free from bedding."*

*"Four surface extensometers and two subsidence lines over Longwalls 4 and 5.  The first extensometer was installed in the centre of Longwall 4 and was monitored during retreat of both panels. Three more extensometers were installed over Longwall 5 on the same cross-section, one in the centre of the panel and the other two offset 65 m toward each gateroad. Subsidence measurements were made on two cross-lines over Longwalls 4 and 5.*

*"Fig. 7 (below) shows the zones of large downward displacement inferred from the extensometer measurements for various distances past the longwall face. The edges of this zone are somewhat arbitrarily defined because the downward movements decrease exponentially. For the purposes of discussion, the 200 mm contour has been assumed to represent the edge of this zone.  "*

*"The zone of large displacement was essentially dome shaped above each extracted longwall panel. The sides of the zone were steeper than the front edge. The front edges extended back from the face over the goaf at about 35° from vertical.  The sides extended upward from the chain pillars at approximately 20° from vertical."*

*"The study showed that a zone of large downward movement (<0.5 m)—developed at a height above the mining horizon approximately equal to the panel width and the shape of the zone of large downward movement—was approximately a paraboloid, similar to the shape observed in physical model studies. The study also showed that there must be large, open voids created within the overburden strata around the sides of the zone of large downward movement and potentially also at the top of it (in the sandstone strata at this site)"*

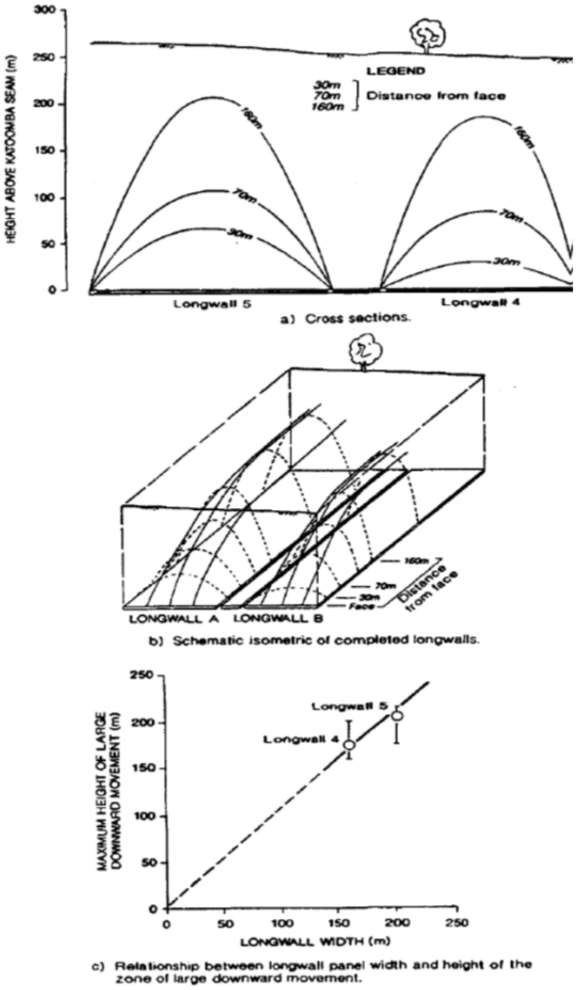


*Fig. 7 - Zones of large downward displacement above two Longwall panels of different widths at Clarence Colliery* (Mills and O'Grady 1988)

The following comments on the HoF and the HoCF have been copied from the ACARP Project C13013 that titled "***Aquifer Inflow Prediction above Longwall Panels***" and dated September 2008 that was prepared by Gale.

*"Water inflow into coal mines has been a design issue for many years. Guidelines as to the potential for water inflow have been developed in many countries based on local experience and the form of mining being undertaken."*

*"In most instances, the guidelines relate to inflows which would endanger underground personnel and operations. In more recent times, water inflow criteria for mines has been widened to include lesser inflows which may not impact on mine safety or operations, but have the potential to reduce water flow within streams and surface aquifers. For the purpose of this report the larger inflows relating to mining safety are defined as mine inflow and the lesser inflow relating to aquifer water loss as environmental inflow."*

*"Extraction of the coal causes caving of the immediate roof (5 to 20m, depending on the strata types) behind the supports to form a goaf. Above this goaf zone, the strata tend part along particular bedding planes and form "beams or plates". These subside onto the goaf as an interlocked but fractured network of bedding planes, pre-existing joints, mining induced fractures and bending related fractures within the beams."*

*"Tensile fracturing and dilation of existing jointing occurs in the upper zones of the overburden as a result of bending strains. The development of these zones is dependent on panel geometry and depth."*

*"Caving and cracked beam subsidence movements tend to occur up to a height of 1-1.7 times the panel width. Examples of this have been monitored by surface to seam extensometers (Mills and 0'Grady 1998, Holla and Armstrong 1986, Holla and Buizen 1991, Guo et al. 2005, Hatherley et al. 2003) and predicted to occur from computer models (Gale 2006). This indicates that cracking and deflection related to such caving and cracked beam subsidence could extend to the surface for panel widths greater than 0.75-1 times depth, depending on geology."*

*"Longwall mining creates additional fractures and changes the conductivity of pre-existing fractures. The height that mining related fractures may form has been established from monitoring and computational studies as being 1-1.5 times the panel width.*

*"However, the creation of these fractures alone does not necessarily imply that a direct hydraulic connection exists over this zone. In order for mine inflow to occur, the fractures created must form a connected and conductive network to allow significant volumes of inflow.*

*"The flow quantity and velocity is highly dependent on the conductivity of the in situ fracture networks and those created by mining. Therefore, inflow into a mine is related to the combined insitu and mining induced fracture networks and the extent that they form a connected system to allow migration through the overburden strata.*

*"A review of mine inflow experience from Australia and the UK conducted found that unsafe volumes of water inflow in the UK occur for longwall mines having a rockhead less than 105m to the water source and theoretical tensile strains above 10mm/m. Longwall faces tended to be dry for strains on the strata at the water source less than 4mm/m. It was found that longwall faces were typically wet with strains at 6mm/m and high inflows may occur at strains greater than 10mm/m.*

*"Water inflow experience in Australia was consistent with this experience, albeit with some variance related to geology. Overall, the data suggests that mine inflow (observed inflows) can occur for theoretical strain values above approximately 6mm/m and the severity of inflow increases as the strain increases. Strains above approximately 10mm/m are likely to be associated with significant inflow.*

*"Overall, the results indicate that the overburden above panels having theoretical tensile strains of 4mm/m has flow networks close to the in situ conductivity. This therefore provides a reasonable estimate for the onset of enhanced conductivity of the overburden.*

*"As the subsidence increases the conductivity increases to the point of a highly conductive fractured mass. Average conductivity overburden for panels having a theoretical strain of 10mm/m is typically in the 10-2 to 10-3 m/s range.*

*"Conductivity of 10-1 to 10-2 m/s was noted for strain values greater than 10mm/m. Inflow for the highly conductive cases close to and greater than 10mm/m would be largely controlled by the aquifer properties.*

*"These results are summarised in Figure S1.*

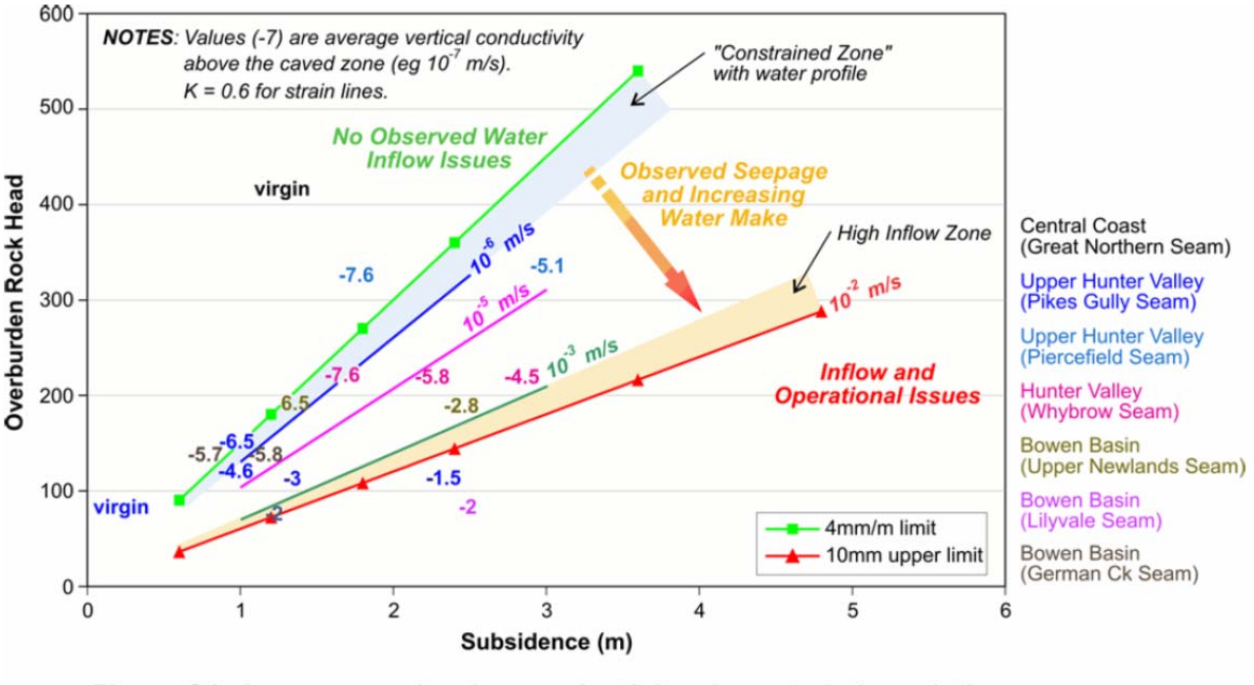


**Figure S1 Average overburden conductivity characteristics relative to subsidence and depth criteria.**

*"In order to evaluate the potential inflow it is essential to assess the surface or aquifer conditions which would provide input into the fractured network as the nature of soils and surface topography may impact on the location and rate at which surface water may connect with the mining fractures.*

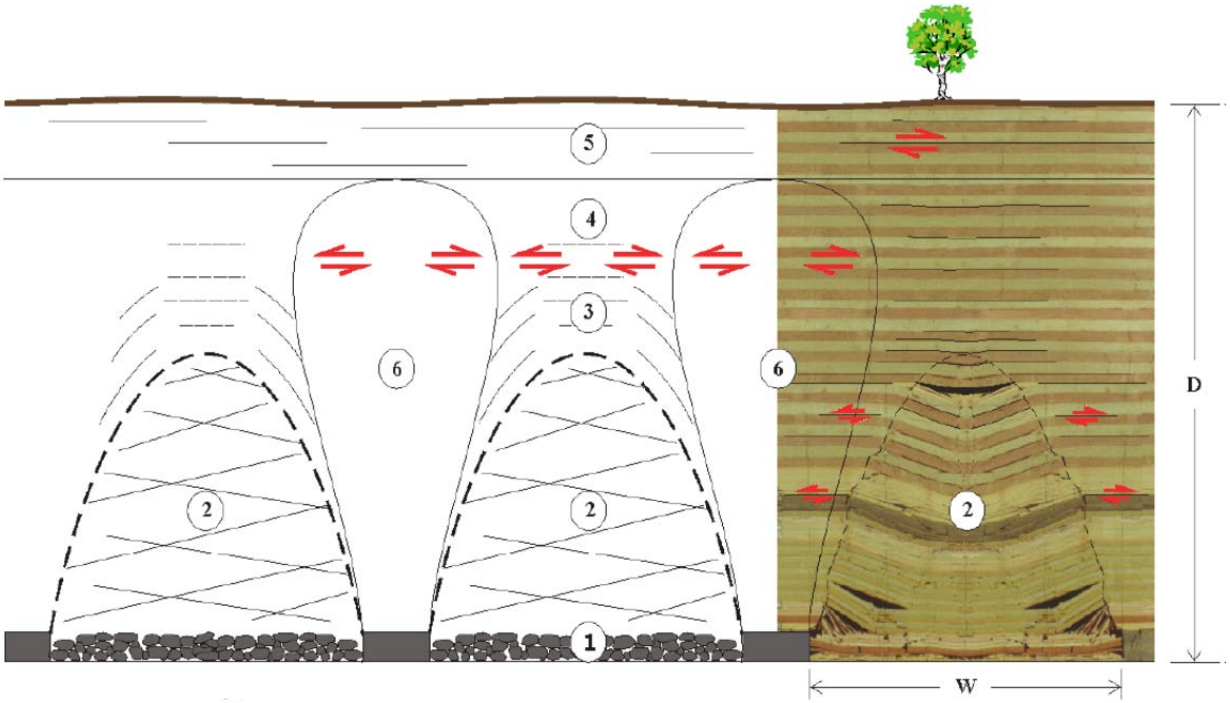
*"The panel width has been found to influence the height that mining induced fractures can extend above the coal seam. However, for mine inflow to occur, the fractures must have formed a connected network to allow observable volumes of inflow. It is considered that the frequency, networking and aperture of those fractures increases with increasing overburden strain and subsidence. Therefore, whilst panel width typically controls the height of fracturing, the network connectivity and conductivity of fractures is controlled by the magnitude of strain and subsidence. Panel width, depth and seam thickness influence strain and subsidence. Therefore there are a number of inter related factors which can influence the result. If a significant thickness of clay material occurs, this may have the effect of constraining the fracture network either due to the fact that it can strain without fracturing or it is able to heal fractures by expansion of the clay."*

Mills (2011) advised in a paper titled "***Developments in Understanding Subsidence with Improved Monitoring***":

*"Subsidence monitoring provides an excellent view of the ground movements at the surface.*

*"Extensometer monitoring presented in Mills and O'Grady (1998) indicates that these zones are arch-shaped above each panel similar to the doming type roadway failures observed in an underground roof fall once all the material has been removed."*

*"The figure below shows a schematic of the zones of ground displacement above multiple longwall panels differentiated in subsidence monitoring and characterised using camera observations, packer testing, piezometer data, and extensometer monitoring. The upper zones shown in Figure 5 are not to scale."*



LEGEND

① Zone of chaotic disturbance immediately above mining horizon (0-20m).

② Zone of large downward movement (→1.0 x panel width).

③ Zone of vertical dilation on bedding planes (1.0w - 1.6w)

④ Zone of vertical stress relaxation (1.6w - 3.0w).

⑤ Zone of no disturbance from sag subsidence (>3.0w) but shear during elastic compression subsidence of multiple panels.

⑥ Zone of compression above chain pillars.

*"Zone 5, the uppermost zone is essentially undisturbed above single panels. However, when multiple longwall panels are mined adjacent to one another at depth, there is typically significant elastic strata compression subsidence. The broad area subsidence associated with elastic strata compression results in differential shearing on bedding planes within this upper zone. "*

*"The freeing up of these bedding planes contributes to the stress relief movements controlled by topography that tend to be the dominant type of ground movement whenever mining is deep enough for Zone 5 to be present."*

*"In Zone 4, between 1.6 and 3.0 times panel width above the mining horizon, the vertical displacements are consistent in magnitude with elastic relaxation of the pre-mining vertical stresses without the need for physical opening of bedding planes."*

A number of other researchers have also investigated and commented on the likely mechanics of these mining induced strata deformations in order to assess the impact of mining on surface and aquifers. A common approach to the study of these impacts on groundwater issues, has centred on the dividing the overburden strata over a mined panel into a number of zones with different deformation characteristics. The size and nature of these overburden zones have been based on either, sub-surface borehole measurements and fracture observations, or, pore pressure and piezometer readings and permeability monitoring. However, the terminology used by different authors to describe these strata deformation zones above extracted longwalls varies considerably and caution should be taken when comparing the recommendations from differing authors. The important points to note between many of these researchers is whether they were commenting on the likely HoF or the HoCF

Singh and Kendorski (1981) in a paper titled "***Strata Disturbance Prediction for Mining Beneath Surface Water and Waste Impoundments***", proposed the following three zones that he called the fracture zone, the aquiclude zone and the zone of surface cracking.

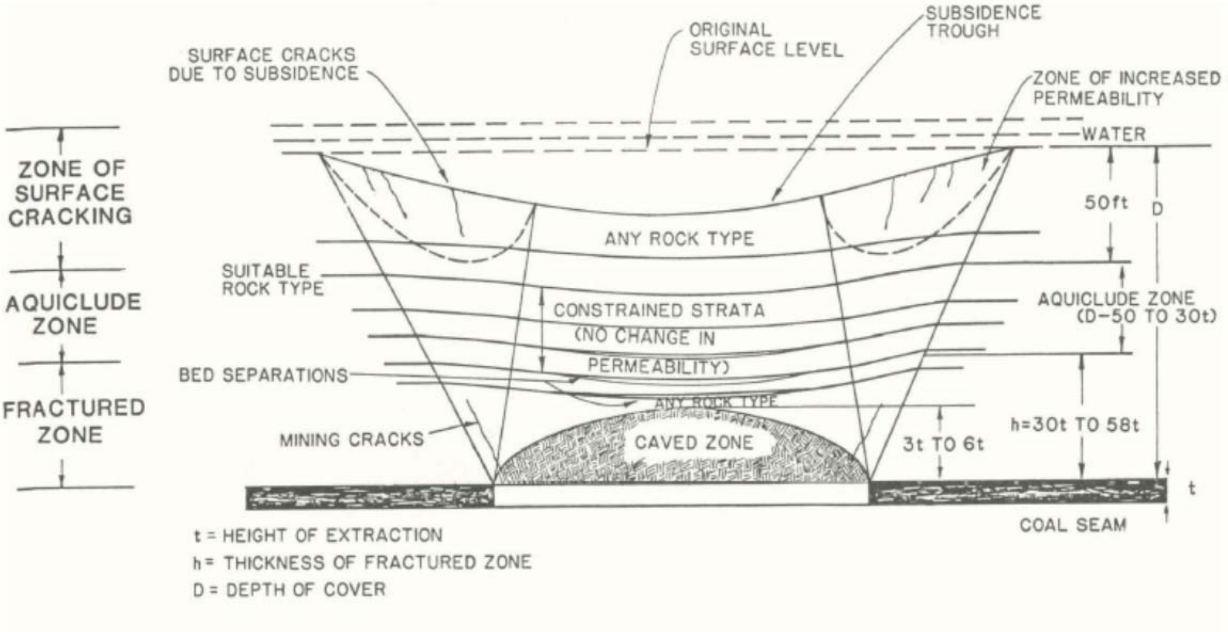
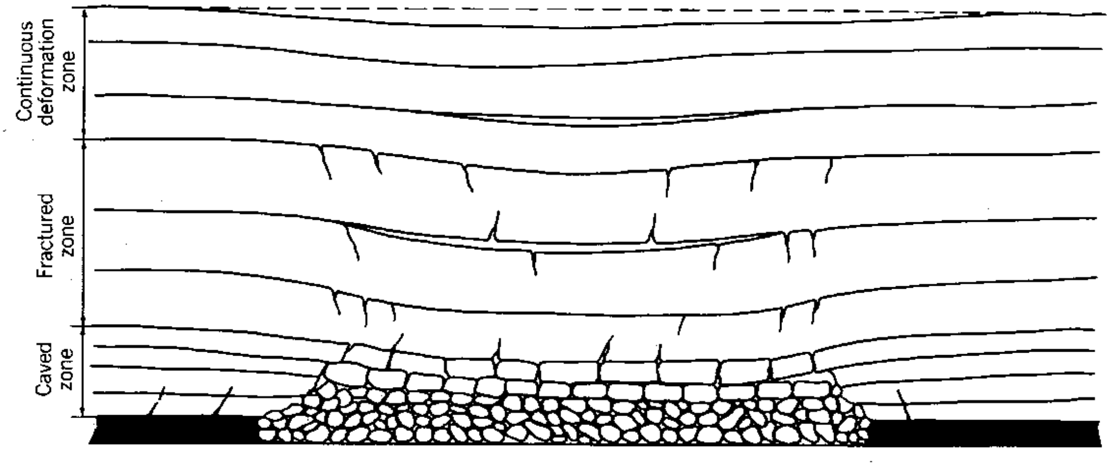


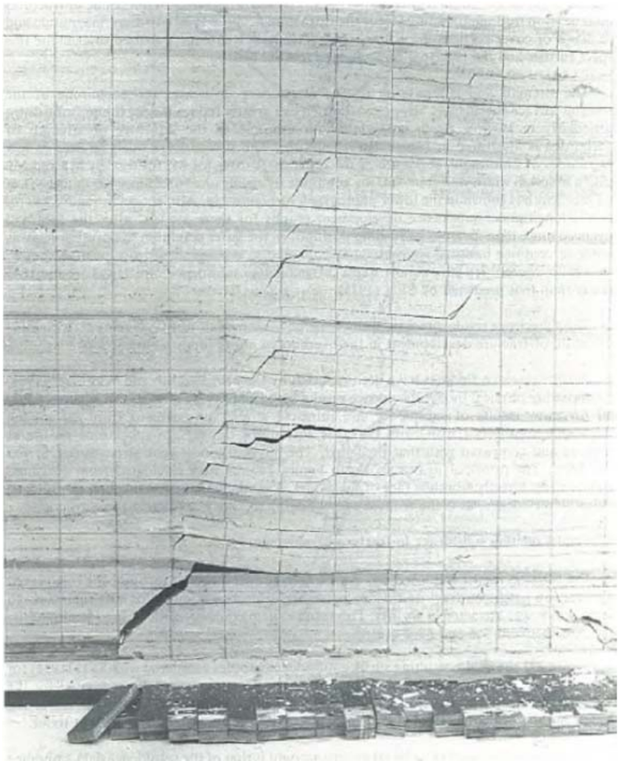
Fig. 4 - Generalized Depiction of Strata Behavior With Total Extraction Mining

Kratzsch (1983) in his text book titled "***Mining Subsidence Engineering*** ", identified four zones, but he named them the immediate roof, the main roof, the intermediate zone and the surface zone.

Peng and Chiang (1984) in his text book titled "***Coal Mine Ground Control***", recognised only three zones as reproduced below.

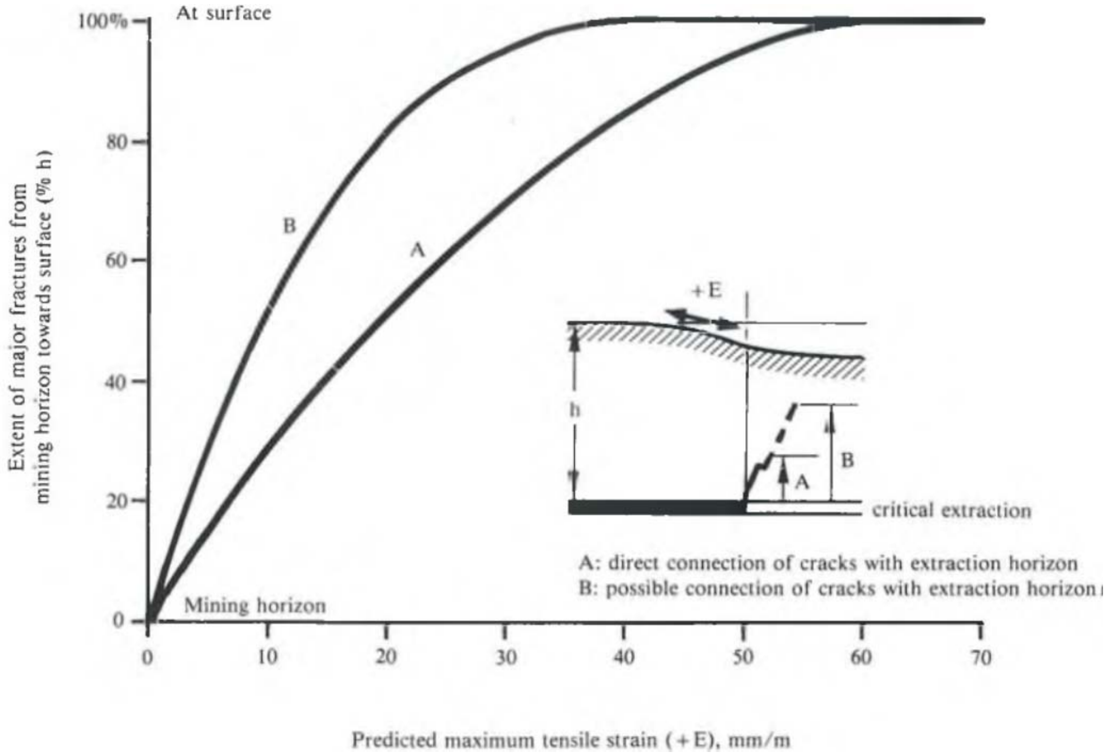


Whittaker and Reddish (1989) in their text book titled "***Subsidence - Occurrence, Prediction and Control***", used physical models built of sand/plaster/water mixes, as shown in the sketch below, that were suitably scaled in strength and size to simulate ground movement of the overburden to illustrate the development of fracture distributions and help understand the subsidence phenomena and strata mechanisms. Two fracturing types were addressed in these models, firstly the maximum height extended by those fractures which were judged to be definitely interconnected with the extraction horizon, (called zone A), and secondly the extent of any appreciable fracture even if they did not necessarily interconnect with the extraction horizon (called zone B).

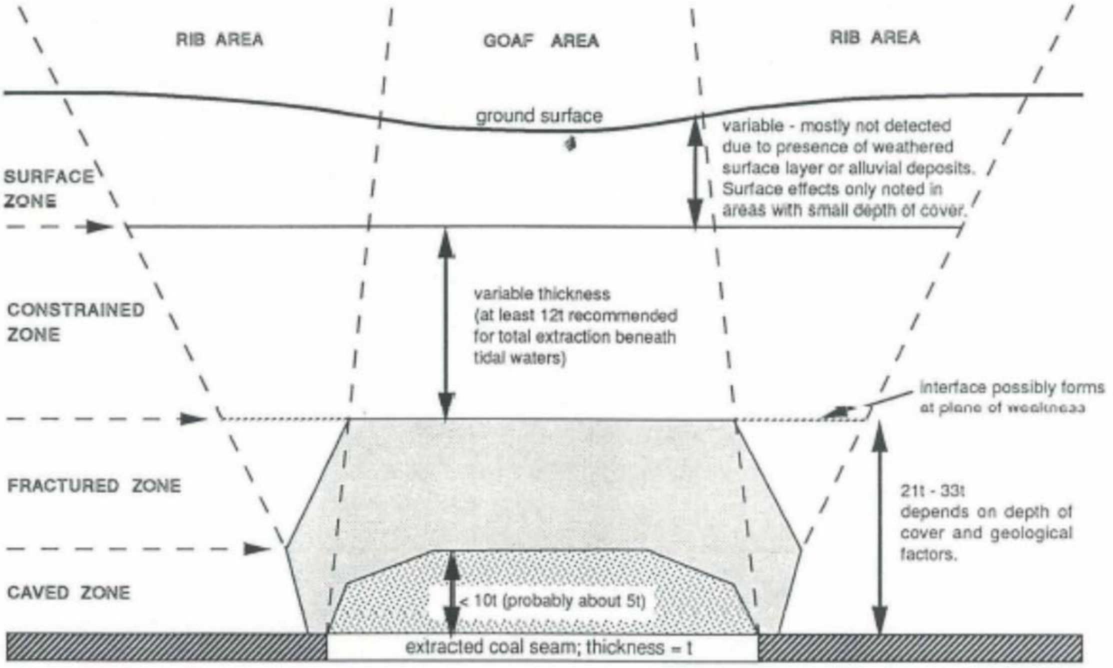


Zone A fracture development was interpreted as being indicative of where free flow from an overlying aquifer would readily occur, whilst the second could be indicative of where there might be a risk of water inflow seeping horizontally from an overlying aquifer but not necessarily flowing downwards to the mine. The second figure below shows an interpretation of these fracture development zones as a proportion of the depth of cover based on maximum tensile stresses in the overburden.

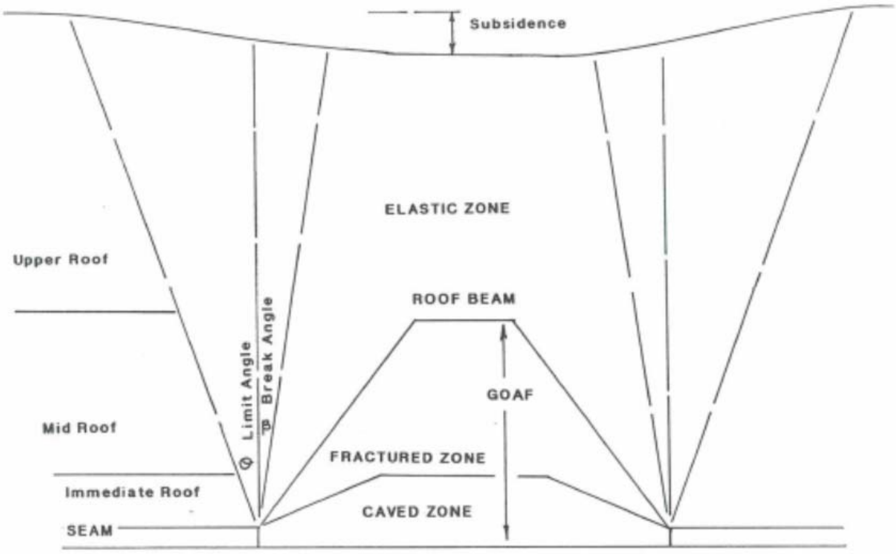
Whittaker and Reddish (1989) also recognised that local geology and depth of mining play important roles, especially in influencing the magnitude and extent of fracture development. They stated that bands of clay and aquicludes that can be located in the overburden can act as major factors in controlling water seeping from overlying horizons even though stronger fractured beds may exist above and below such pliable and impervious bands. It was also noted that the existence of pliable mudstone beds within the strata sequence would tend to inhibit the magnitude and extent of fracture development above the ribside.



Forster and Enever (1992) in their report titled "***Study of the Hydrogeological Response of Overburden Strata to Underground Mining Central Coast - New South Wales***", undertook a major groundwater investigation over supercritical extraction areas in the Central Coast of NSW and concluded that that overburden could be sub divided into four separate zones, as shown below, with some variations in the definitions of each zone. Forster and Enever noted that while the height of the caved zone over these total extraction areas were related principally to the extracted seam height, seam depth and the nature of the roof lithology, the extent of the overlying disturbed zone was dependent on the strength and deformation properties of the strata and to a lesser extent on the seam thickness, depth of cover and width of the panel.

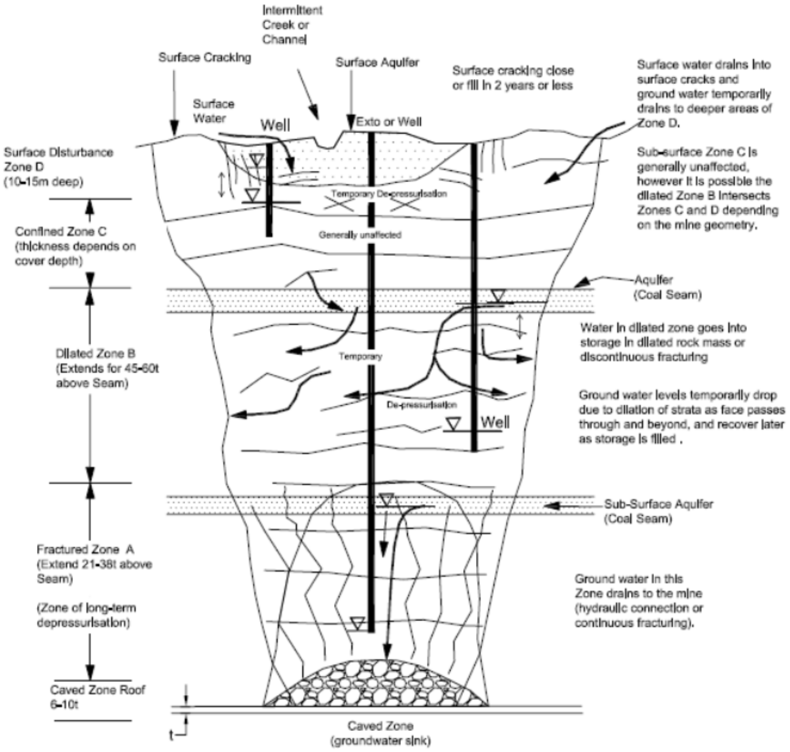


McNally et al (1996) in their paper titled "***Geological factors influencing longwall-induced subsidence***", recognised only three zones, which they referred to as the caved zone, the fractured zone and the elastic zone.

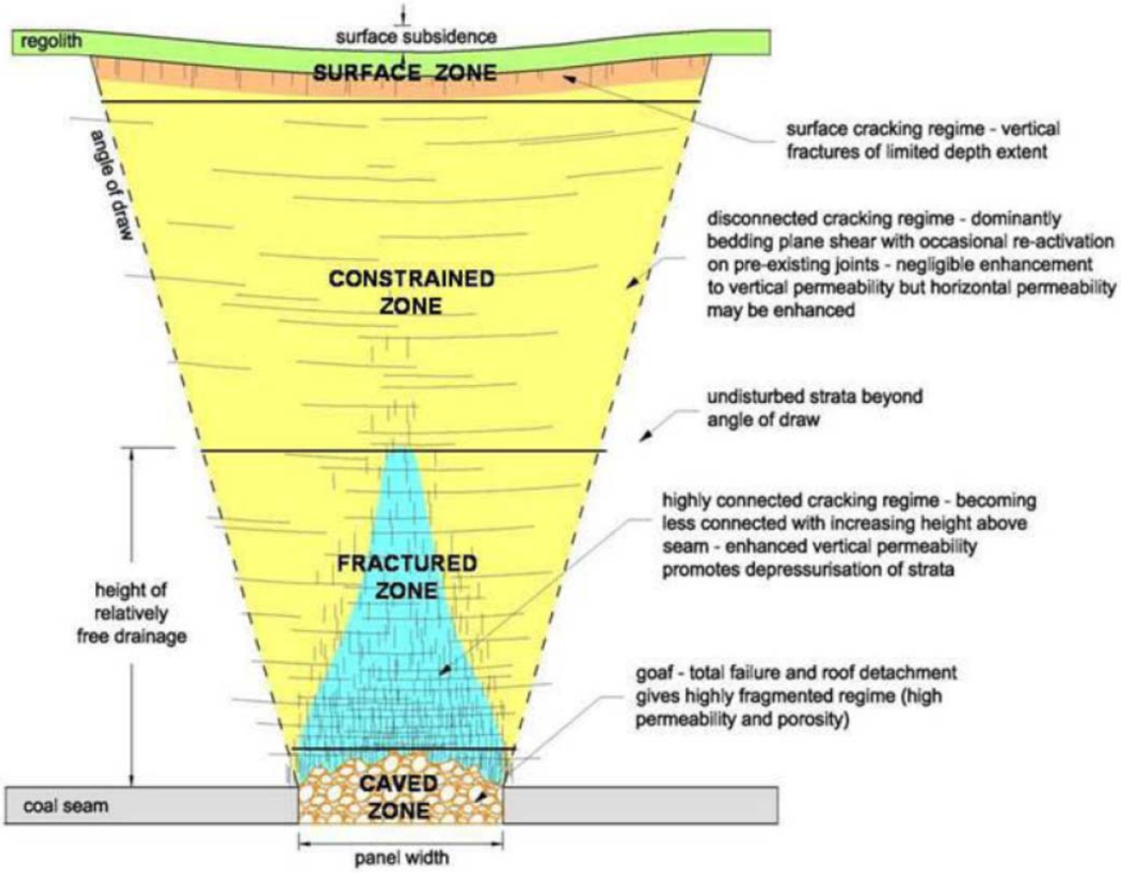


Ditton, Frith and Hill (2003) in their report titled "***Review of Industry Subsidence Data in Relation to the Influence of Overburden Lithology on Subsidence and an Initial Assessment of a Sub-Surface Fracturing Model for Groundwater Analysis***", reviewed the above Whittaker and Reddish Model plus the available borehole data in the Central Coast Region of the Newcastle Coalfield and then derived formulas for the height of continuous fracturing (HoCF), called Zone A, and the height of discontinuous fracturing zone (HoF), called Zone B as discussed by Whittaker and Reddish (1989). Ditton, Frith and Hill confirmed the definitions that the HoCF refers to the height at which a direct connection of the fractures occurs within the overburden and over the workings and represents a direct hydraulic connection for groundwater inflows. The HoF refers to the height at which the horizontal permeability increases as a result of strata de-lamination and fracturing, however, a direct connection of the fractures within this zone and the workings does not occur.

Ditton (2005) in a later report titled “***Surface and Sub-Surface Investigation and Monitoring Plan for LWs 1 to 6 at the Proposed North Wambo Mine***”, expanded on these A and B zones by providing the following description of five zones in the following sketch. It can be noted that Ditton has split the constrained zoned, as described by Forster and Enever into the Dilated Zone (B) and the Confined Zone C.



Since then there have been several major government inquiries and Planning and Assessment Commission reviews that have investigated the potential effects of mining on surface and groundwater and the potential loss of water towards mined openings. Most of these reports have included the following sketch that was initially prepared by Mackie in 2007 to explain the nature of fracturing of the overburden over a coal mine. This model has four zones.



From the above discussions, it can be noted that just as the terminology used by the various researchers differs and the means of determining the extents of each of these zones also varies. Indeed some of the difficulties in establishing the heights of the various zones of disturbance above extracted longwalls stem from: the imprecise definitions of the fractured and constrained zones; the differing zone names and clarity regarding whether the discussed fractures were continuous, connected, discontinuous or not connected; the use of different extensometer borehole testing methods; the use of differing permeability or piezometer measuring methods; and differing interpretations of monitoring data.

Some authors have suggested simple equations to estimate the heights of the collapsed and fractured zones based solely on the extracted seam height, whilst others have suggested equations based solely on the widths of extraction, and then others have suggested equations should have been based on the width-to-depth ratios of the extractions. Some authors interpret the influence of geology on the height of the connected collapsed and/or fractured zones to only relate to those geotechnical strength issues that are associated with the possible presence of massive strong strata layers. Whilst others believe that the presence of layers of low permeability, (such as shales, siltstones, mudstones, and tuffs within the overburden), was a more important influencing factor.

Hence MSEC believes that this is a complex issue and it is not possible for a simple geometrical and geotechnical equation to accurately estimate the heights of the connected collapsed and fractured zones. Perhaps these equations can estimate the HoF, but a more thorough analysis is required to determine the HoCF and this analysis should include other groundwater factors, including the presence of strata layers of low permeability within the overburden strata.

Therefore the HoCF zone above extracted longwalls are believed to be affected by at least the following factors:

- widths of extraction, (W)
- heights of extraction, (t)
- depths of cover, (H)
- presence and proximity of previous workings, if any, near the current extractions,
- presence of pre-existing natural joints within each strata layer,
- thickness, geology and geomechanical properties of each strata layer,
- angle of break of each strata layer,
- spanning capacity of each strata layer, particularly those layers immediately above the collapsed and fractured zones,
- bulking ratios of each strata layer within the collapsed zone, and the
- groundwater factors such as the presence of and the head in aquiclude or aquitard zones within the overburden and the permeability of each strata layer.

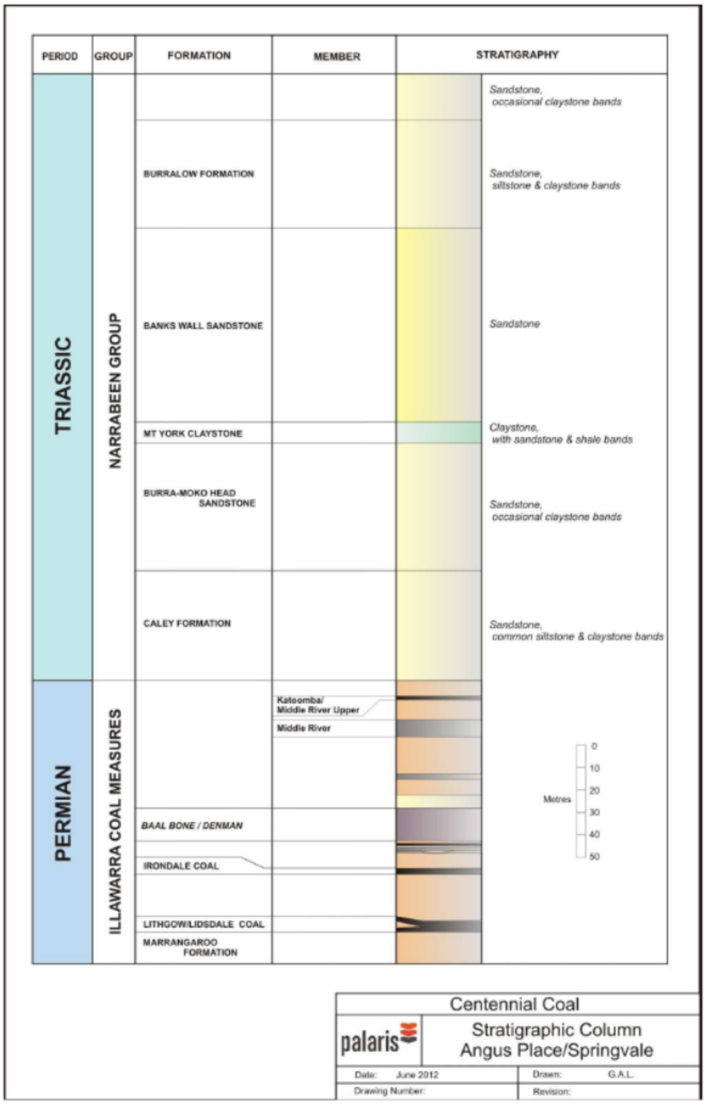
The following listed reports from two recent ACARP funded studies provide extensive discussions on mining induced groundwater flows and computer based modelling techniques that are available to assess the heights of the various defined zones over mined panels and the potential inflows into a mine;

- CSIRO, Guo, Adhikary & Gaveva, (2007), ACARP C14033, "***Hydrogeological Response to Longwall Mining***", and
- SCT, Gale, (2008), ACARP C13013 "***Aquifer Inflow Prediction above Longwall Panels***".

These reports highlight that; the location of and the impact from these mining induced fractures depends on a a complex combination of the mining geometry and the lithology and geology of the overburden strata.

The proposed longwalls at the Springvale and Angus Place Mine Extension Projects are located within the Illawarra Coal Measures. Above the coal measures lie the Narrabeen Group of the Triassic period. The surface geology of the terrain that is overlying these panels is located within the Burralow Formation of the upper Narrabeen Group which usually comprise sandstone, claystone and siltstone bands.

Within the Narrabeen Group of rocks, the Burralow Formation and the Mount York Claystone are key stratigraphic horizons in terms of their hydrogeological significance. The groundwater system underlying the Project Application Area has been extensively researched and has been found to be relatively complex with multi-layered units of variable permeability resulting in a number of discrete groundwater flow systems. A number of additional key hydrostratigraphic units have been identified from past investigations as shown in the stratigraphic sequence and geological cross section presented below that have been copied from a report by Palaris titled "***Stratigraphic Setting -Angus Place and Springvale Collieries***", Doc No CEY1535-01, dated January April 2013.



| PERIOD | GROUP | FORMATION | MEMBER | STRATIGRAPHY |
|---|---|---|---|---|
| TRIASSIC | NARRABEEN GROUP | | | Sandstone, occasional claystone bands |
| | | BURRALOW FORMATION | | Sandstone, siltstone & claystone bands |
| | | BANKS WALL SANDSTONE | | Sandstone |
| | | MT YORK CLAYSTONE | | Claystone, with sandstone & shale bands |
| | | BURRA-MOKO HEAD SANDSTONE | | Sandstone, occasional claystone bands |
| | | CALEY FORMATION | | Sandstone, common siltstone & claystone bands |
| PERMIAN | ILLAWARRA COAL MEASURES | | Katoomba/ Middle River Upper | |
| | | | Middle River | |
| | | BAAL BONE / DENMAN | | |
| | | IRONDALE COAL | | |
| | | LITHGOW/LIDSDALE COAL | | |
| | | MARRANGAROO FORMATION | | |

Centennial Coal

palaris

Stratigraphic Column
Angus Place/Springvale

Date: June 2012
Drawn: G.A.L.
Drawing Number:
Revision:

*Figure 1.1 Generalised Stratigraphic Column*

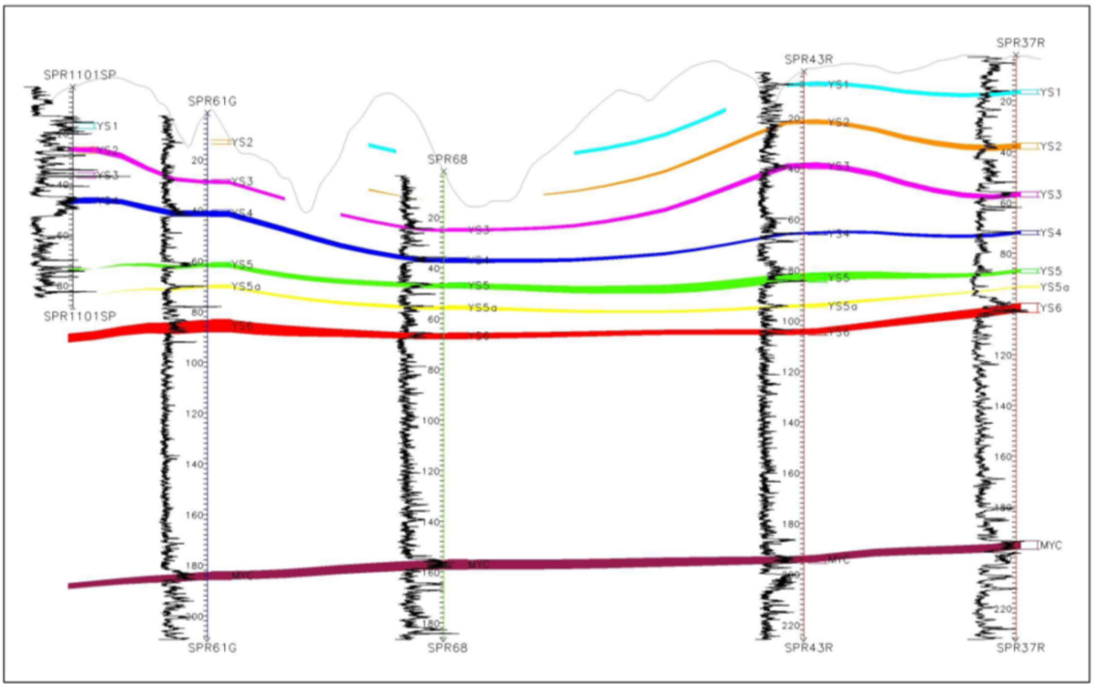
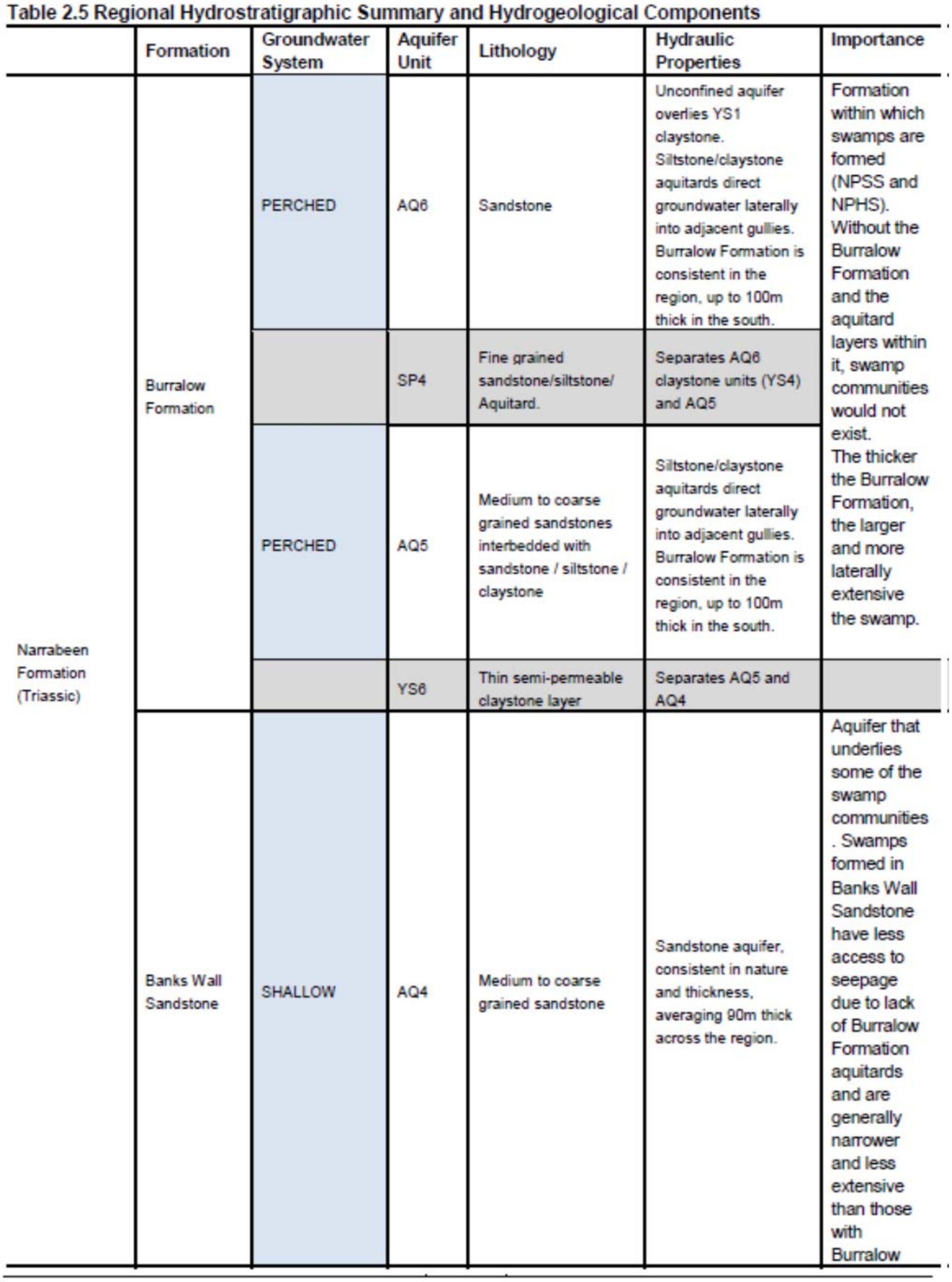


*Figure 1.3 Correlated & Modelled Units in the Narrabeen Group*

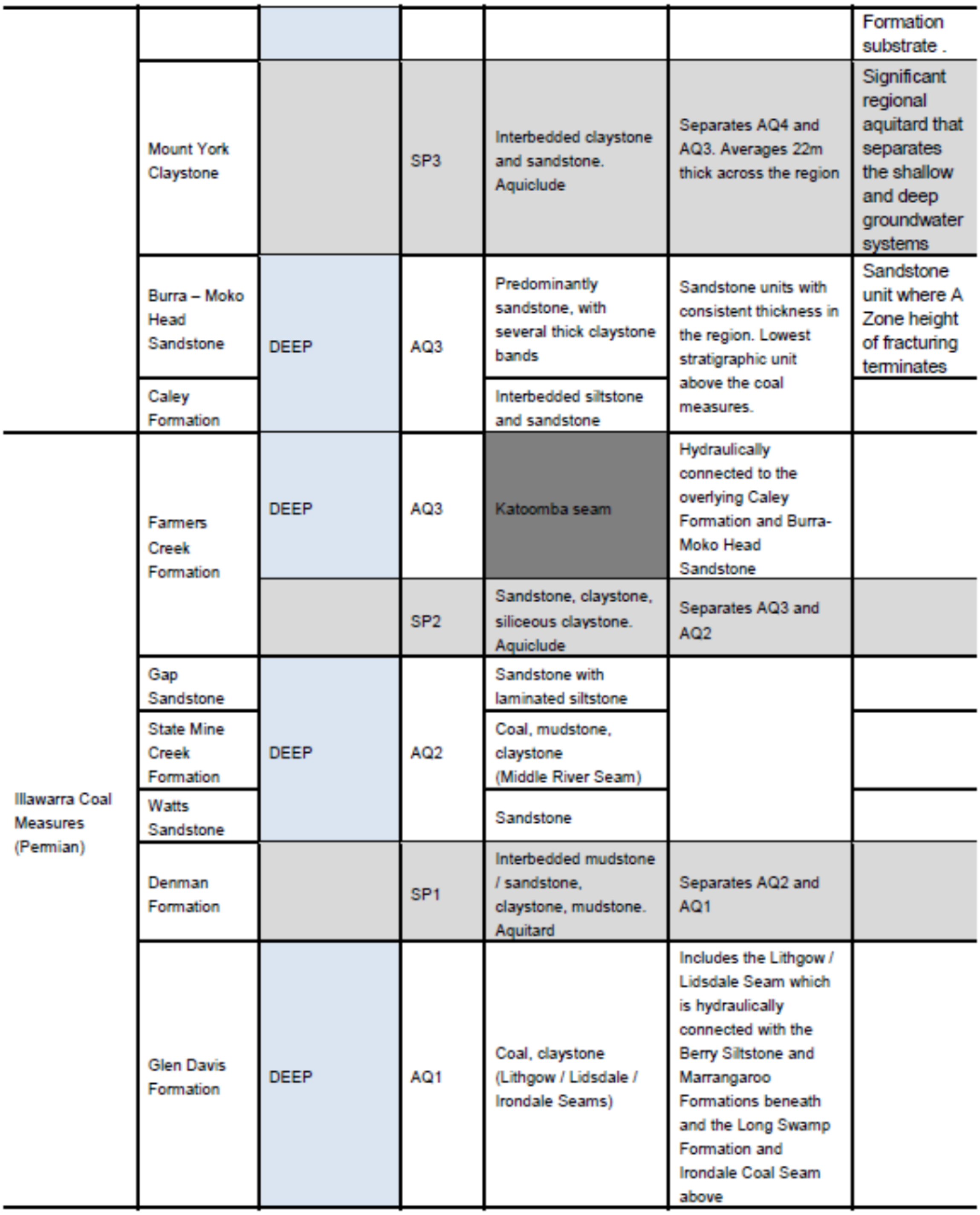
These plots show a series of horizontally layered and bedded, highly laminated and flat-lying sedimentary layered lithologies, which form a complex layered sequence of less-permeable and more-permeable horizons. Each layered sequence has differing grain size, lithification and strength properties which define their range in permeability. The generalised stratigraphy of this area as presented in following Table 2.5, which was copied from the a Golder and Associates report titled “Angus Place Mine Extension Project State Significant Development 5602 Environmental Impact Statement Volume 1: Report”, and dated April 2014.

This table presents information on corresponding aquifer designations and less permeable horizons. The hydrostratigraphic sequences were incorporated into the hydrogeological model developed for the site by the above referenced CSIRO report (2013). The stratigraphic sequence were further subdivided into three groundwater systems, separated by the Burralow Formation (SP4) and the Mount York Claystone (SP3), and in the natural environment, are largely independent of each other. These groundwater systems are denoted as perched, shallow and deep groundwater systems respectively.

**Table 2.5 Regional Hydrostratigraphic Summary and Hydrogeological Components**



| | Formation | Groundwater System | Aquifer Unit | Lithology | Hydraulic Properties | Importance |
|---|---|---|---|---|---|---|
| Narrabeen Formation (Triassic) | Burralow Formation | PERCHED | AQ6 | Sandstone | Unconfined aquifer overlies YS1 claystone. Siltstone/claystone aquitards direct groundwater laterally into adjacent gullies. Burralow Formation is consistent in the region, up to 100m thick in the south. | Formation within which swamps are formed (NPSS and NPHS). Without the Burralow Formation and the aquitard layers within it, swamp communities would not exist. The thicker the Burralow Formation, the larger and more laterally extensive the swamp. |
| | | | SP4 | Fine grained sandstone/siltstone/ Aquitard. | Separates AQ6 claystone units (YS4) and AQ5 | |
| | | PERCHED | AQ5 | Medium to coarse grained sandstones interbedded with sandstone / siltstone / claystone | Siltstone/claystone aquitards direct groundwater laterally into adjacent gullies. Burralow Formation is consistent in the region, up to 100m thick in the south. | |
| | | | YS6 | Thin semi-permeable claystone layer | Separates AQ5 and AQ4 | |
| | Banks Wall Sandstone | SHALLOW | AQ4 | Medium to coarse grained sandstone | Sandstone aquifer, consistent in nature and thickness, averaging 90m thick across the region. | Aquifer that underlies some of the swamp communities. Swamps formed in Banks Wall Sandstone have less access to seepage due to lack of Burralow Formation aquitards and are generally narrower and less extensive than those with Burralow |



| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | Formation substrate . |
| | Mount York Claystone | | SP3 | Interbedded claystone and sandstone. Aquiclude | Separates AQ4 and AQ3. Averages 22m thick across the region | Significant regional aquitard that separates the shallow and deep groundwater systems |
| | Burra – Moko Head Sandstone | DEEP | AQ3 | Predominantly sandstone, with several thick claystone bands | Sandstone units with consistent thickness in the region. Lowest stratigraphic unit above the coal measures. | Sandstone unit where A Zone height of fracturing terminates |
| | Caley Formation | | | Interbedded siltstone and sandstone | | |
| Illawarra Coal Measures (Permian) | Farmers Creek Formation | DEEP | AQ3 | Katoomba seam | Hydraulically connected to the overlying Caley Formation and Burra-Moko Head Sandstone | |
| | | | SP2 | Sandstone, claystone, siliceous claystone. Aquiclude | Separates AQ3 and AQ2 | |
| | Gap Sandstone | DEEP | AQ2 | Sandstone with laminated siltstone | | |
| | State Mine Creek Formation | | | Coal, mudstone, claystone (Middle River Seam) | | |
| | Watts Sandstone | | | Sandstone | | |
| | Denman Formation | | SP1 | Interbedded mudstone / sandstone, claystone, mudstone. Aquitard | Separates AQ2 and AQ1 | |
| | Glen Davis Formation | DEEP | AQ1 | Coal, claystone (Lithgow / Lidsdale / Irondale Seams) | Includes the Lithgow / Lidsdale Seam which is hydraulically connected with the Berry Siltstone and Marrangaroo Formations beneath and the Long Swamp Formation and Irondale Coal Seam above | |

The extent, severity and manner of the observed impacts of coal mining on surface water resources and groundwater aquifers vary between different coal mines because every situation is different. The nature and extent of mining induced ground movements around, beneath and near these surface water resources and groundwater aquifers varies considerably due to differing size of the extraction and depth of cover and differing proximities to the water bodies. Each stream, pond or lake is unique in terms of its characteristics and each characteristic (i.e. stream flow conditions, water quality, gradients, valley depths and degree of incision, sediment and nutrient load, bedrock mineralogy, ecosystems and geomorphology) influences the observed consequences and impacts.

Hence, the specific geology of each case should be closely considered as the presence or absence of either strong channels or impermeable layers in the overburden can completely change generalised impact assessment that are only based on longwall widths or seam thicknesses.

The complexity of all these factors requires groundwater impact assessments for mining applications near streams or groundwater aquifers to be undertaken on a case by case basis.

Extensive groundwater testing programs over the years by various researchers have resulted in various hydro-geological models for subsurface behaviour zones. The first such hydro-geological model that was published for NSW conditions was one prepared by Forster and Enever in 1992 that studied various supercritical longwall panels in the Central Coast area of NSW. Several studies, since then, have suggested that the vertical extents of each of the various hydrogeological zones vary depending on many factors, including; the longwall width, extraction height, depth of cover, proximity of previous workings, local geology, overburden rock strength and the permeability and conductivity of the various strata layers in the overburden. Recently Forster wrote a groundwater report for a mine in this Central Coast area providing the following advice; "*The exact level of the top of this zone* (HoCF) *will most likely depend on the position of the numerous tuff layers located in the upper part of the formation. Previous analyses of bore cores indicated that there are up to 100 separate tuff or tuffaceous claystone horizons ranging from 1 mm to more than 3 metres thick in the overburden. Any cracks which penetrate the entire thickness of coarse-grained material in the lower section of the formation should be sealed when they reach the tuff layers, due to plastic deformation or swelling of the reactive clays contained in them. This is even more likely if the cracking results in some groundwater movement. Any one of these tuff layers therefore could form a relatively impermeable horizon that would present a barrier to vertical groundwater movement in the overburden strata, provided that it is located higher than about 65 metres above the* roof of the seam."

Similar more recent studies have highlighted that mine design recommendations should not be applied blindly based on the extracted seam thickness or the longwall panel width as some authors have recently suggested without assessment of the host geology. Careful consideration must always be given to specific site geology as "host geology" does play a significant or major role in determining the HoCF.

Experience in NSW, Queensland and around the world has indicated that, if the right type and thickness of the less permeable strata layers are present above the "fractured zone" and within a "constrained zone", then extraction may take place beneath water bodies without surface water finding its way into the workings. It is now generally recognised that where there are no low permeable layers within the overburden and above the "fractured zone", then, much higher HoCF are observed than where there are many of the lower permeable strata layers. Where there are many low permeable strata layers within the overburden, then, relatively low HoCF have been observed, even where the panels were supercritically wide.

MSEC has reviewed the above referenced CSIRO and DgS Reports and found that they provide detailed information on the existing environment, the groundwater systems, the overburden and the presence of layers of low permeability for this Western Coalfields area. The selection and use of both numerical and empirical models which have been calibrated to site data over many years and used for the Angus Place and Springvale Mine Extension Projects, are believed to represent the current "industry best practice".

MSEC has reviewed these reports and, in our opinion, we consider the assessments of the HoCF for the proposed longwalls at Angus Place and Springvale Collieries that are included in these reports are reasonable for this particular geological region.

It is noted that these reports have provided geologically adjusted and calibrated predictions and assessments of the likely HoCF over the proposed longwalls at Angus Place and Springvale Collieries, which, in our opinion, appear to be appropriate for this geological region and, hence, should provide a satisfactory estimate for the impact assessments on the groundwater systems from the proposed mining for this particular geological region.

Yours sincerely

Don Kay

Don Kay

Mine Subsidence Engineering Consultants

NSW EPA

Our reference: DOC14/113652; EF13/3625 & EF13/3933.
Contact: Richard Whyte 6332 7600

Mr Mick Cairney
General Manager – Western Operations
Centennial Coal Company Ltd
Locked Bag 1002
WALLERAWANG NSW 2845

Dear Mr ~~Cairney~~ Mick

I wish to thank you for hosting the meeting on 26 June 2014 between Centennial Coal and the Environment Protection Authority (EPA) and inspection of the Springvale Delta Water Transfer Scheme (SDWTS).

The EPA appreciated the presentation from Centennial, and especially being advised about the role of Centennial's Project Team which will be addressing the matters raised in the EPA's submission to the Department of Planning and Environment (DPE) on the Springvale and Angus Place Mine Extension Projects. From the meeting I wish to confirm the following matters as key issues that EPA requires Centennial to note and address.

**Springvale and Angus Place Mine Extension Projects**

As Centennial is aware, the EPA has advised DPE that it is unable to support the Springvale and Angus Place Extension Projects in their current form given the absence of any commitment and detailed plan by Centennial in the Environmental Impact Statements (EIS) to address the handling/treatment of the mine water, in either the short or long term.

Given that the proposed Extension Projects will extend the life of each mine for 13 and 25 years respectively, and most importantly substantially increase the volumes of mine water, Centennial should have included in its EISs a commitment and detailed plan (to be implemented by a set date) delivering a strategic approach to the treatment and/or beneficial re-use of its mine water. Such a commitment and detailed plan should have evolved from the Pollution Reduction Project (PRP) negotiated by the EPA with Centennial which resulted in Centennial producing its Options Study by September 2013. As you know, from Centennial's Options Study, the EPA is now undertaking a review in order to better understand the feasibility of the six options Centennial nominated on its short list of 37 options considered.

As mentioned at the meeting, the EPA will be guided by the standards of the Australian and New Zealand Environmental Conservation Council 2000 (ANZECC 2000) in carrying out its regulatory responsibilities in order to improve the water quality, and as a result the aquatic health, of the upper Coxs River. I want to reinforce that the EPA will be requiring a discharge limit for salinity of 350 micro-Siemens per centimetre (µS/cm) Electrical Conductivity, and concentrations of other pollutants such as metals which do not result in environmental harm. Nevertheless, as mentioned at the meeting, the EPA would accept a mixture of options to handle the current discharge in ways that achieves the required environmental protection outcome. For example, a combination of beneficial re-use by a water user and a discharge to a waterway within the upper Coxs River which is capable of meeting the EPA's discharge limit for salinity and concentrations of other pollutants.

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www.epa.nsw.gov.au

Given that Centennial's discharge makes up a large proportion of the flow in the river any discharge needs to meet the required in-stream water quality. However, it remains the responsibility of Centennial to determine which option(s) best suits its proposed Extension Projects and to present a commitment and detailed plan for one definite option to the EPA and the DPE through the current planning process. If the project is approved then this option must be implemented and operational prior to any additional mine water being generated. This assumes that the treatment/re-use of existing mine water is addressed separately to the extension solution or as part of it.

Centennial's Project Team should contact Richard Whyte, Manager Central West, to further progress these issues.

**The Toxicity Characteristics of the Current Discharge**

The final report of the Direct Toxicity Assessment (DTA) performed on the two discharge samples collected by the EPA on 8 May 2014 confirms the discharge from Licensed Discharge Point 9 (LDP9) is toxic to Cladoceran *Ceriodaphnia dubia*. Regarding the Microtox tests, one discharge sample caused some reduction in luminescence in the exposed bacteria (a harmful effect), whereas the second had minimal effect.

The EPA will provide its DTA results to Centennial so that you can undertake further assessment which will lead to the treatment of the discharge to reduce the toxicity. To ensure that Centennial can address this matter straightaway, I understand that the EPA's Central West Region has already provided these results to Centennial and will provide further advice on the pollutants of most concern.

**Angus Place Operational Issue – Mine Water Management**

Centennial's advice that it will have difficulty managing the mine water at Angus Place in about six months is of serious concern to the EPA. Given all the attention to mine water management in recent years, and the succession of PRPs for Angus Place, it is the EPA's expectation that Centennial would be able to manage this water without the need for there to be any increases in the volumes of water to be discharged.

Before the EPA will consider a variation to Environment Protection Licence 467 to increase the volumetric discharge limit at licensed discharge point LDP001, the EPA requires that Centennial submit a formal licence variation application form with all supporting information/justification for the variation that is being sought. This information must include what the causes of the addition mine water are, how these are to be controlled in an attempt to avoid the need for a licence variation, if this cannot be fully achieved how the volume and concentrations of pollutants in the residual discharge will be minimised and what permanent solutions are to be implemented in the short and medium term (i.e. 6 to 12 months) to eliminate the additional discharge and the need for the variation.

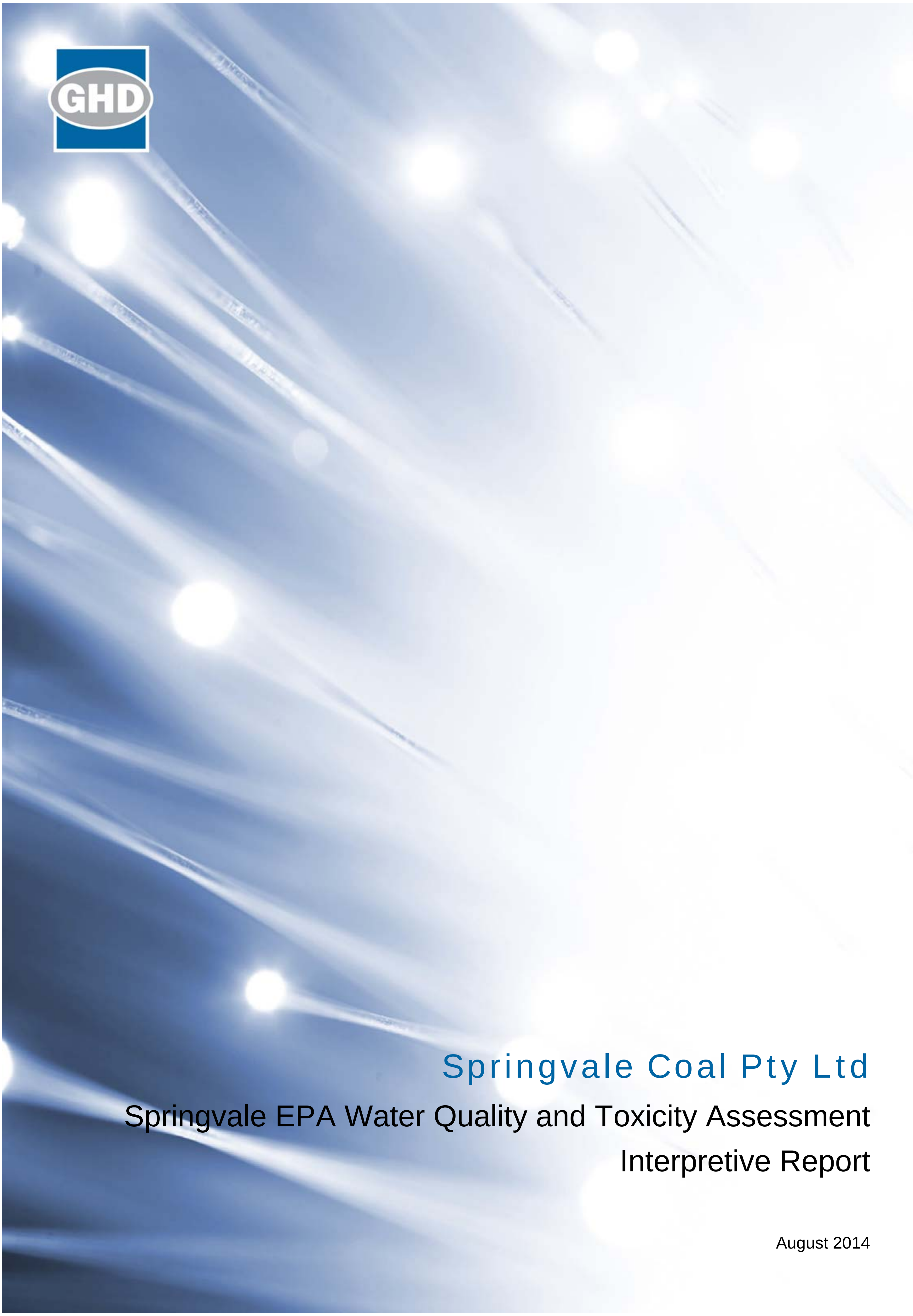
A licence variation application form can be obtained at www.epa.nsw.gov.au/licensing by selecting "Online forms" and download the form "Licence variation application – premise" form. The completed form including Section 6 Details of variation and Section 8 relevant supporting documentation needs to be signed and submitted to the Central West (Bathurst) Office of the EPA at PO Box 1388 Bathurst NSW 2795 for consideration.

Should you wish to discuss these matters further please contact Richard Whyte, Manager Central West at the EPA's Central West Region office on 6332 7600 or richard.whyte@epa.nsw.gov.au.

Yours sincerely

Gary Whytcross 2 July 2014.

**GARY WHYTCROSS**
**Director South**
**Environment Protection Authority**



## Springvale Coal Pty Ltd

# Springvale EPA Water Quality and Toxicity Assessment
# Interpretive Report

August 2014

# Table of contents

# Table index

# Figure index

# Appendices

# 1. Introduction

## 1.1 Introduction

GHD understands that the NSW EPA require Centennial Coal to identify and implement a solution to manage mine water quality from Springvale Colliery. Management options include redirection of discharge water to old underground mine workings or treatment options. In order to proceed with these requirements, Centennial Coal must better understand the chemistry and toxicity of the current discharge from the licenced discharge point LDP009 and also take into account the understanding that the water quality may vary in the future with additional mining activities (this work is currently being undertaken). This report will provide information on the potential environmental impacts of the current discharge on the receiving ecosystem and determine potential chemicals of concern.

## 1.2 Purpose of this report

The purpose of this report is to use information provided on the chemistry of LDP009 and the ecotoxicology conducted by the NSW EPA to determine impacts on the receiving environment and, if possible, to determine the need for water treatment.

## 1.3 Scope and limitations

GHD completed the following Scope of Works to provide information to Centennial Coal in relation to water quality concerns from the LDP009 discharge;

- Review and interpret the toxicology results and chemistry results provided by NSW EPA to Centennial Coal.
- Determine contaminants of concern from the NSW EPA sampling using a multivariate analysis.
- Compare the results from the NSW EPA sampling with the current and historical data from the Centennial Coal – Springvale discharge point LDP009 and Coxs River.
- Include recommendations for additional investigations required to provide an accurate indication of the environmental effects from increased concentrations of the parameters of concern and/or recommendations for treatment options.

### 1.3.1 Limitations

This report: has been prepared by GHD for Centennial Coal Company Limited and may only be used and relied on by Centennial Coal Company Limited for the purpose agreed between GHD and the Centennial Coal Company Limited as set out in Section 1.3 of this report.

GHD otherwise disclaims responsibility to any person other than Centennial Coal Company Limited arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report.  GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer Section 1.4 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Centennial Coal Company Limited and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

## 1.4 Assumptions

The following assumptions have been made on the results provided by the NSW EPA:

- Transport and storage has maintained the integrity of the samples and has not been compromised.
- That samples reached the laboratory and testing commenced within holding times.
- Trained samplers took the samples.
- That ecotoxicology samples remained at 4 degrees prior to testing.

# 2. EPA Results and Discussion

## 2.1 Sample locations

The NSW EPA collected water samples on the 8 May 2014 at the locations shown in Table 1 and Figure 1. A chain of custody form was provided by the NSW EPA for quality control (Appendix C). However a field data sheet was not provided.

Table 1 NSW EPA Sample Locations

| Sample | Easting | Northing | Location |
|---|---|---|---|
| LDP SP1 | Not provided | Not provided | Sampled at Springvale DLP009 discharge to Sawyer Swamp Creek next to SDWTS treatment ponds |
| LDP SP2 | Not provided | Not provided | Duplicate of LDP SP1 |
| Coxs River | 229625 | 6310850 | Road crossing Coxs River south east of Gardiners Gap |
| Kangaroo Creek | Not provided | Not provided | Western side of Wolgan Road at Angus Place |

LEGEND:

● LDP009 Water Quality Sampling Points

● EPA Water Quality Sampling Points

NOTES:

Locations of Water
Quality Sampling Points
Provided by Environment and Community
Coordinator Tony Nolan.

DRAWN: Zac Burley

DATE: 21-07-2014

PLAN No: SVY02405

COMPUTER PATH: N:\Z_Plans

INFORMATION SUPPLIED BY: Tony Nolan

SCALE: SCALE 1:50000

A4V
Sheet
1 of 1

SPRINGVALE MINE

TITLE:

# EPA Water Sampling Locations

**Springvale** Coal

SPRINGVALE MINE
Castlereagh HWY
Lidsdale NSW 2790
PO Box 198
Wallerawang NSW 2845
Phone: 02-63501600
Fax: 02-63551052

:\Z_Environmental\Sampling Points.dwg

## 2.2 Ecotoxicology Bioassays

The acute bioassays listed in Table 2 were conducted by the NSW EPA's Environmental Forensics Section.

Table 2 Bioassays

| Species | Endpoint | NATA Accredited |
|---|---|---|
| Marine bacteria (*Vibrio fischeri*) | 30 minute luminescence reduction – 30 minute EC50 | Yes |
| Cladoceran (*Ceriodaphnia dubia*) | 48 hour immobility – 48 hour EC50 | Yes |
| Fish larvae (*Melanotaenia duboulayi*) | 48 hour imbalance – 48 hour EC50 | No |

The marine bacteria is not an ecologically relevant species to be used to detect impacts in a freshwater ecosystem. However, this test is useful for comparative purposes such as determining changes in toxicity over time or changes on operational procedures such a water treatment.

Both the cladoceran and larval rainbowfish are representative of a NSW freshwater ecosystem. The crimson spotted rainbowfish are distributed throughout northern NSW and south–east Queensland and provide a suitable surrogate species for the Coxes River. The cladoceran are commonly found in temperate freshwater systems worldwide and this is a recognised species for assessing impacts in temperate Australian freshwater ecosystems.

## 2.3 Concentrations Tested

Usually, receiving water is used as the bioassay diluent for all dilutions and controls to mimic site specific conditions. However, in some cases the receiving water has shown toxicity which masks the toxicity of the discharge. Therefore, the NSW EPA used laboratory water as the dilution water for the larval fish and cladoceran test as shown in Table 3 to provide information on the toxicity of the discharge without potential confounding factors. It must be noted that, in many cases, depending on the chemistry of the receiving water, i.e. high DOC and pH, toxicity can be ameliorated. The marine bacteria bioassay used recommended diluent as shown in Table 3. A laboratory control was run concurrently with all tests.  All samples were serially diluted with the diluent to achieve the required test concentrations.

Table 3 Diluent types and test concentrations

| Bioassay | Diluent | Concentrations | Replicates per Concentration |
|---|---|---|---|
| Marine bacteria | Microbics diluent | Control LDP SP1:<br>0.625 %, 1.25 %, 2.5 % 5.0 %, 10 %, 20 %, 40 % and 80 %<br>Others:<br>10 %, 20 %, 40 % and 80 % | 4 control<br>2 replicates per treatment |
| Cladoceran | Filtered thiosulphate-treated Sydney mains water with 5 % mineral water and conductivity adjusted to 500 µS/cm with filtered seawater | Control:<br>25 %, 50 % and 100 % | 4 control<br>2 replicates per treatment<br>5 animals/replicate |
| Larval fish | Filtered Sydney mains water with conductivity adjusted to 500 µS/cm with filtered seawater | Control:<br>25 %, 50 % and 100 % | 4 control<br>2 replicates per treatment<br>5 animals/replicate |

## 2.4 Bioassay Results

All bioassays met the appropriate reference toxicant criteria and test validity criteria. Testing commenced within five days of sampling. It is assumed that the samples were maintained at <4°C until testing commenced.

Table 4 Bioassay results

| Test Endpoint | LDP SP1 % (95 % CL) | LDP SP2 % (95 % CL) | Coxs River % | Kangaroo Creek % |
|---|---|---|---|---|
| **Marine bacteria** | | | | |
| 30 min inhibition at 80 % | 24 | <5 | 12 | <5 |
| **Cladoceran** | | | | |
| NOEC | 50 | 50 | 100 | 100 |
| LOEC | 100 | 100 | 100 | 100 |
| EC50 | 71 (53-100) | 79 (47-100) | - | - |
| **Larval Fish** | | | | |
| NOEC | 100 | 100 | 100 | 100 |
| LOEC | 100 | 100 | 100 | 100 |

It should be noted that the results presented in Table 4 must be treated with caution as insufficient data is available for statistical analysis as only two replicates were used for each treatment.  Standard methodology (USEPA  2002) would use four replicates to improve statistical analysis. The methodology used by the NSW EPA has been compared with the US EPA methods as ANZECC (2000) does not provide information on the accepted use of screening bioassays. ANZECC recommends the use of a suite of bioassays representative of the receiving environment with a minimum of five species from four taxonomic groups for the calculation of a species sensitivity distribution (SSD) which can be used to determine safe dilution factors of the mine water for the protection of the receiving environment. This ANZECC (2000) methodology is current accepted practice for environmental protection in Australia.

### 2.4.1 Marine Bacteria

The results provided in Ecotox 4 Report No. 201400181 marine bacteria bioassay are reported as percent luminescence inhibition at 80 percent sample concentration. The table also reports the results as percent sample concentration. It is unclear what is being reported, therefore, the results are recorded in Table 4 as reported in the NSW EPA report with the assumption that the results show percent sample concentration.

The marine bacteria samples show that the duplicate samples LDP SP1 and LDP SP2 are different with no decrease in luminescence observed in the LDP SP2 sample. The LDP SP2 result is the same as that of the Kangaroo Creek sample where no toxicity was detected. The far upstream sample shows reduction in luminescence that is greater than the LDP SP2 sample indicating greater toxicity in the Coxs River sample.  As the marine bacteria are not representative of the LDP009 receiving environment and the results are inconsistent, the marine bacteria results will not be included in discussions in this report.

### 2.4.2 Cladoceran

The NSW EPA reports EC50 results for the cladoceran test, however, there is insufficient data to provide the EC50 result with any confidence as shown by the large 95 percent confidence limits. Therefore, the cladoceran EC50 results will not be discussed in this report. The LDP SP1 and duplicate LDP SP2 showed similar results for the cladoceran test.

### 2.4.3 Larval fish

The larval fish were not adversely affected by exposure to the LDP009 discharge, the Coxs River or Kangaroo Creek waters at 100 percent concentration.

### 2.4.4 Discussion

There is insufficient confidence in the ecotoxicity test results due to the low number of replicates for each treatment. Further, insufficient treatments were tested to calculate the EC50 results with confidence as reported in Test Report No. 201400181.  The USEPA (2002) standard methods state that the recommended toxicity test consists of a control and five or more concentrations of effluent. Therefore, the results from the cladoceran test do not meet the requirements for a standard toxicity test.

Toxicity tests can be used to determine the toxicity of the receiving water with a paired test. The results presented by the NSW EPA better fit this model of analysis, however, the US EPA recommends four replicates to be used to enable hypothesis testing. As only two replicates were used in this series of bioassays, the testing conducted by the NSW EPA does not meet the requirements for a standard receiving water bioassay and the results are of low confidence. Further, the NSW EPA do not report the results of each replicate and it is not possible to interpret the data to determine the variability between replicates. The variability between replicates is very important in the interpretation of bioassay data as inconsistent data will skew the results. By testing only two replicates the influence of any inconsistent data cannot be determined and, if present, will unduly influence any statistical analysis.

An example, the cladoceran LDP SP2 (Sample Number 201401004) results at 100 percent concentration where the percentage of animals immobilised after 48 hour exposure was reported at 60 percent could mean that three animals were immobile in each replicate or that one replicate had five animals immobilised  while the other only had one animal immobilised. This latter scenario may indicate that there was another issue present that may have adversely impacted on the replicate with 100 percent immobilisation, such as laboratory error or contamination within the treatment (unclean glassware).

Without the presence of the replicate data, it is not possible to have confidence in the results as they are presented by the NSW EPA in Report No 201400181.

Further, the NSW EPA do not supply downstream ecotoxicity data to determine any impacts the discharge may be having on the receiving ecosystem.

## 2.5 Chemistry

The samples taken on 8 May 2014 were tested for the analytes listed in Table 5 using a non-NATA accredited laboratory.

Table 5 Chemical analytes

| | Analytes |
|---|---|
| General | pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), dissolved organic carbon (DOC), hardness |
| Organics | TPH, BTEX, pesticides and herbicides |
| Metals Total and 0.45 µm filtered | Aluminium, antimony, arsenic, barium, beryllium,  boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, molybdenum,  mercury, nickel, selenium, silver, silicon, strontium, sulphur, thallium, tin, titanium, vanadium and zinc |
| Anions | Alkalinity (bicarbonate, carbonate, hydroxide, total), chloride, fluoride, sulfate |
| Cations | Sodium, calcium, potassium, magnesium, phosphorous |
| Nutrients | Ammonia, free reactive phosphorous, NOx, TKN, total nitrogen, total phosphorous |

## 2.6 NSW EPA Chemistry Results

Table 6 shows the chemistry results of the samples used in the bioassays sampled on the 8 May 2014. The date the chemistry was conducted is not reported. It is assumed that the testing of all analytes took place within the required holding times.

Toxic units were calculated for analytes identified as contributing to toxicity. Toxic units were calculated by dividing the concentration of the analyte by the ANZECC (2000) 95% trigger value. The larger the TU the greater contribution to toxicity.

Table 6 NSW EPA Chemistry results

| Analyte | 95% Trigger Values | LDP SP1 | LDP SP2 | Average LPD SP1 and SP2 | LDP009 TU | Coxs River | Coxs River TU | Kangaroo Creek | Kangaroo Creek TU |
|---|---|---|---|---|---|---|---|---|---|
| pH | 8.0 | 8.0 | 8.0 | 8.0 | 1 | 6.1 | <1 | 8.4 | 1.05 |
| EC µS/cm | 2,000* | 1200 | 1100 | 1150 | 0.58 | 100 | 0.05 | 820 | 0.41 |
| Hardness mg/L $CaCO_3$ | - | 21 | 21 | 21 | | 27 | | 100 | |
| TDS mg/L | 1,340** | 870 | 970 | 921 | 0.69 | 72 | 0.05 | 550 | 0.41 |
| Chloride mg/L | - | 5.1 | 5.1 | 5.1 | | 6.4 | | 8.2 | |
| Fluoride mg/L | - | 1.0 | 1.0 | 1.0 | | <0.3 | | 0.6 | |
| Sulfate mg/L | 129*** | 30 | 31 | 30.5 | 0.24 | 21 | 0.16 | 20 | 0.16 |
| Calcium mg/L | - | 3.9 | 4.0 | 3.95 | | 6.1 | | 17 | |
| Manganese µg/L | - | 8.3 | 9.7 | 9.0 | | 74 | | 9.8 | |
| Potassium mg/L | - | 13 | 13 | 13 | | 3.1 | | 32 | |
| Sodium mg/L | - | 280 | 250 | 265 | | 5.2 | | 130 | |
| Total alkalinity mg/L $CaCO_3$ | - | 580 | 580 | 580 | | 14 | | 420 | |
| Ammonia mg/L | - | 0.49 | 0.49 | 0.49 | | <0.01 | | <0.01 | |
| NOx mg/L | 2.4## | 0.32 | 0.31 | 0.315 | 0.13 | 0.02 | 0.01 | 0.26 | 0.11 |
| TKN mg/L | - | 0.7 | 0.6 | 0.65 | | 0.4 | | <0.2 | |
| TN mg/L | - | 1.0 | 0.9 | 0.95 | | 0.4 | | 0.4 | |
| TP mg/L | - | 0.019 | 0.019 | 0.019 | | <0.015 | | <0.015 | |
| ***Dissolved Metals*** | | | | | | | | | |
| Antimony µg/L | 9# | 0.7 | 0.71 | 0.705 | 0.08 | <0.5 | - | <0.5 | - |
| Arsenic µg/L | 13 | 20 | 19 | 19.5 | 1.5 | <1.0 | - | <1.0 | - |
| Barium µg/L | - | 24 | 25 | 24.5 | | 22 | | 110 | |
| Cobalt µg/L | 1.4# | 1.4 | 1.4 | 1.4 | 1 | 1.3 | 0.93 | 0.15 | 0.11 |
| Copper µg/L | 1.4 | <0.5 | 0.53 | 0.515 | 0.37 | 0.63 | 0.45 | 0.76 | 0.54 |

| Analyte | 95% Trigger Values | LDP SP1 | LDP SP2 | Average LPD SP1 and SP2 | LDP009 TU | Coxs River | Coxs River TU | Kangaroo Creek | Kangaroo Creek TU |
|---|---|---|---|---|---|---|---|---|---|
| Iron mg/L | 0.3[#] | <0.03 | <0.03 | <0.03 | <0.1 | 0.58 | 1.93 | 0.05 | 0.17 |
| Lead µg/L | 3.4 | 0.34 | 0.43 | 0.385 | 0.11 | 0.13 | 0.03 | <0.1 | |
| Lithium mg/L | - | 0.18 | 0.19 | 0.185 | | 2.4 µg/L | | 0.25 | |
| Magnesium mg/L | 2.5^ | 2.7 | 2.7 | 2.7 | 1.1 | 2.8 | 1.12 | 15 | 6 |
| Molybdenum µg/L | 34[#] | 37 | 37 | 37 | 1.1 | <0.5 | | 10 | 0.29 |
| Nickel µg/L | 11 | 3.8 | 3.9 | 3.85 | | 0.61 | | 2.2 | |
| Silicon mg/L | - | 3.6 | 3.6 | 3.6 | | 4.3 | | 3.9 | |
| Strontium µg/L | - | 17 | 18 | 17.5 | | 26 | | 93 | |
| Sulfur mg/L | - | 10 | 10 | 10 | | 6.1 | | 6.3 | |
| Vanadium µg/L | 6[#] | <0.2 | 0.25 | 0.225 | 0.04 | 0.29 | 0.05 | <0.2 | |
| Zinc µg/L | 8 | 7.2 | 11 | 9.1 | 1.1 | 3.6 | 0.45 | 5.2 | 0.65 |
| Total TU | | | | | 9.04 | | 5.23 | | 9.9 |

The following analytes were below detection limits and were not included in Table 6:

TSS, FRP, TPH, BTEX, herbicides and pesticides, aluminium, boron, titanium, beryllium, cadmium, chromium, mercury, selenium, silver, thallium and tin.

* The ANZECC (2000) EC 95% trigger value is based on EC naturally occurring in the waterways, it is not based on toxicity testing. Therefore, using the ANZECC (2000) TV (350 µS/cm) will result in an overestimation of toxicity i.e. indicating toxicity when there is none. Dr R. Krassoi (Ecotox Services Australia, Pers. Comm.) has indicated that Ceriodaphnia does not detect adverse impacts related to conductivity at concentrations less than 3,500 µS/cm. Kunz *et al.* (2013) states that conductivity at sites across North America above 2,000 µS/cm represents conditions that may adversely impact freshwater organisms based on ecotoxicology results. Therefore, a trigger value of 2,000 µS/cm has been used in this assessment to provide a more accurate and conservative determination of toxic impacts on receiving organisms.

** Similarly to the conductivity Kunz *et al.* (2013) states that a TDS concentration of 1340 mg/L represents conditions that may adversely impact freshwater organisms.

*** The sulfate trigger value has been calculated by Elphick et al. (2011) using the ANZECC (2000) SSD methodology. The trigger value for soft water has been calculated at 129 mg/L. This value has been used in this calculation.

[#] Low reliability trigger value.

^ Magnesium trigger value: van Dam *et al.* 2010.

[##] Revised ANZECC guideline based on toxicity tests

### 2.6.1 Centennial Coal Chemistry results

Centennial Coal takes weekly samples LDP009 and associated upstream and downstream locations. Table 7 shows that LDP009 water quality sampled on the 8 May 2014 compared with the water quality of that used in the ecotox tests and long term water quality data from LDP009 to determine if the sample used in the May 2014 toxicity tests was representative of the water quality discharged from LDP009.

Table 7 Centennial Coal Chemistry results

| **Analyte** | **LDP009 5/8 May 2014** | **LDP009 Long Term 18 months** | **NSW EP 8 May 2014** | **ANZECC Trigger Values** |
|---|---|---|---|---|
| pH | 7.72 | 8.10 | 8.0 | 7.5** |
| EC µS/cm | 1190 | 1025 | 1150 | 350** |
| Hardness mg/L $CaCO_3$ | 9.0 | - | 21 | - |
| Chloride mg/L | 5.0 | - | 5.1 | - |
| Fluoride mg/L | 1.3 | 0.8 | 1.0 | - |
| Sulfate mg/L | 37 | - | 30.5 | - |
| Calcium mg/L | 2.0 | - | 3.95 | - |
| Magnesium mg/L | 1.0 | - | 2.7 | - |
| Potassium mg/L | 10 | - | 13 | - |
| Sodium mg/L | 222 | - | 265 | - |
| Total alkalinity mg/L $CaCO_3$ | 627 | - | 580 | - |
| Ammonia mg/L | 0.54 | - | 0.49 | 0.013** |
| NOx mg/L | 0.31 | - | 0.315 | 0.015** |
| TKN mg/L | 0.6 | - | 0.65 | - |
| TN mg/L | 0.9 | - | 0.95 | 0.250** |
| TP mg/L | 0.01 | - | 0.019 | 0.020** |
| **Dissolved Metals** | | | | |
| Antimony µg/L | 1.0 | - | 0.705 | - |
| Arsenic µg/L | 17 | 19 | 19.5 | 13-24 |
| Barium µg/L | 24 | - | 24.5 | - |
| Copper µg/L | 2.0* | 1.0 | 0.515 | 1.4 |
| Iron mg/L | <0.05 | 0.05 | <0.03 | - |
| Lead µg/L | <1.0 | - | 0.385 | 3.4 |
| Lithium mg/L | 0.145 | - | 0.185 | - |
| Manganese µg/L | 8.0 | - | 9.0 | 1900 |
| Molybdenum µg/L | 35 | - | 37 | - |
| Nickel µg/L | 4.0 | 4.0 | 3.85 | 11 |
| Strontium µg/L | 18 | - | 17.5 | - |
| Zinc µg/L | 14 | 12 | 9.1 | 8.0 |

* *Copper concentrations for May 2014 with the exception of 8 May 2014 were <1.0 µg/L.*

** *Note that these concentrations have not been calculated from toxicity tests and are representative of background levels.*

The LDP009 sample taken by Centennial Coal on the 8 May 2014 showed similar chemistry to that of the two LDP009 samples taken by the NSW EPA (Table 7) with the exception of copper and zinc being slightly higher in the Centennial Coal sample. Results from LDP009 from the last 18 months (January 2013 to June 2014) shows that the sample taken on 8 May 2014 was representative of the long term water quality discharged from LDP009.

### 2.6.2 Discussion

The chemistry results for the NSW EPA sample taken on the 8 May 2014 show that the LDP009 chemistry was representative of the LDP009 quality since January 2013. Therefore, the toxicity tests would have provided a good indication of the potential toxic impacts to the receiving water. However, due to the poor quality of the bioassay results it is not possible to provide a confident interpretation of the chemistry related to the toxicity. The toxicity observed in the cladoceran bioassays cannot be attributed to a specific analyte in the LDP009 samples. The chemistry of the upstream samples, particularly Kangaroo Creek that showed no toxicity, were only slightly different from the LDP009 samples. Kangaroo Creek showed lower concentrations of hardness, calcium, potassium, barium, copper, lithium and strontium and higher concentrations of ammonia, lead, magnesium and molybdenum.

The toxic unit (TU) results at LDP009 (TU = 9.04) and Kangaroo Creek (TU = 9.9) show similar total toxicity units, however, no toxicity was observed in Kangaroo Creek even though magnesium was present at 6 TUs. The toxicity units show that no one chemical was present in sufficient concentrations to determine the contributors to the slight toxicity observed in the cladoceran bioassay at LDP009.

## 2.7 Multivariate Analysis

A principal component analysis (PCA) multivariate analysis was conducted on the chemistry data from the EPA samples. The results are shown in Figure 2. The PCA multivariate analysis indicates the main parameters at LDP009 that are most different to Kangaroo Creek and Cox's River:

- Nickel, molybdenum, lead, arsenic, zinc, antimony, ammonia/NOx, fluoride, EC/TDS (all higher concentrations at LDP009, although not sufficient to cause toxicity as evidenced by the toxicity results).
- At the same time, LDP009 also has the lowest calcium, magnesium and hardness. All of these analytes have the potential to ameliorate toxicity at higher concentrations.

These results indicate that no potential chemicals of concern can be identified in the LDP009 discharge.

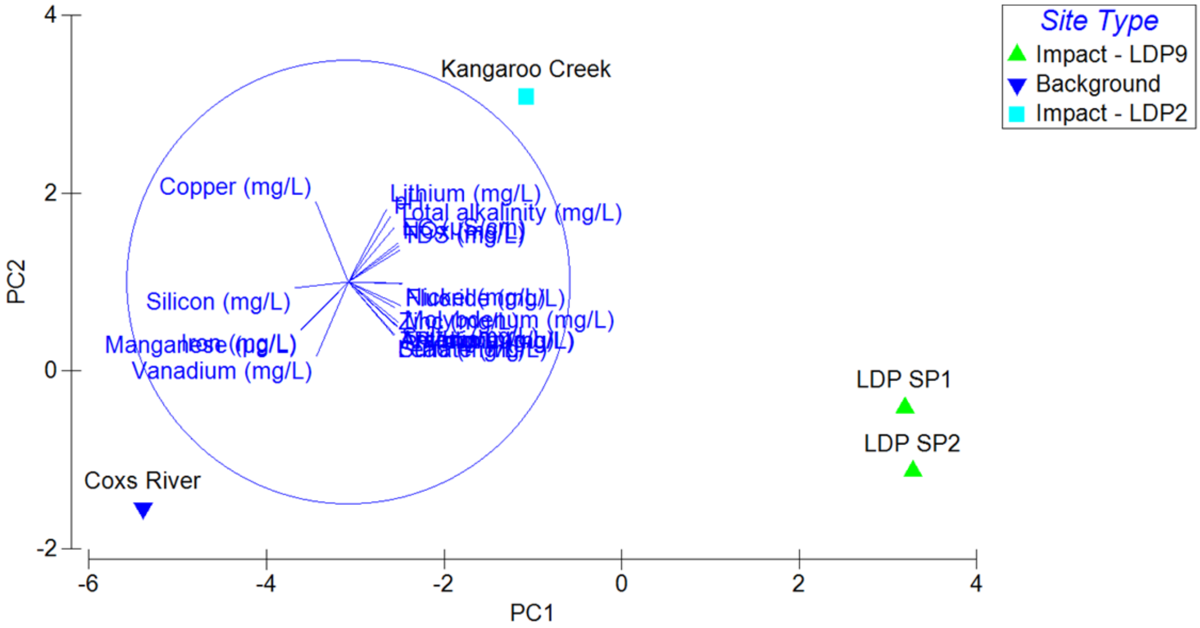


Figure 2 Multivariate Results

## 2.8 Macroinvertebrate Study Results

The 2013 Spring Aquatic Ecology Monitoring Report (MPR 2014) was reviewed to obtain an understanding of the long term heath of the receiving environment (Sawyers Swamp and Coxs River) from exposure to LDP009 discharge. The report concluded that the relative abundance of most of the macrophyte taxa throughout the study area sites were unchanged for this survey.

The MPR (2014) report did not provide interpretation of the macroinvertebrate data that could be used to determine the impacts of the LDP009 discharge. Insufficient information was provided for this sampling period for interpretation and no historical data was provided to enable long term trends to be derived.

Unfortunately the MPR (2014) report is not written in a way that can be used to provide supporting documentation that LDP009 is/is not having an adverse impact on the receiving environment. The data needs to be analysed and interpreted at the individual site level to ascertain differences between upstream and downstream sites.  Comparison between upstream and downstream sites is imperative in order to determine the impact of LDP009. The MPR (2014) report only reports site averages from each waterway which cannot be used to determine upstream and downstream impact.

# 3. Conclusions

The quality of the cladoceran ecotox bioassay results do not follow standard methodology (USEPA 2002) and the results cannot be relied upon, therefore the determination of chemicals of concern potentially causing the observed toxicity cannot be determined. The water quality results show that there are no analytes present in concentrations high enough to cause toxicity. This is supported by the calculation of toxic units for each potential chemical of concern. As the cause of this potential toxicity is unable to be identified, it is not possible to recommend treatment of the discharge water at this time. Further, as the toxicity is marginal in the 100 percent LDP009 sample, a toxicity identification evaluation (TIE) would not be possible to identify the cause of the observed toxicity.

Even though the quality of the cladoceran ecotox results is poor, there is an indication of a slight acute toxicity at the end of pipe (LDP009 discharge). Further investigations are required to determine the toxicity of the discharge at the end of the mixing zone in the Coxs River If the water quality at this point shows no chronic toxicity, then treatment of the LDP009 discharge water for environmental protection may not be required.

However, the NSW EPA has stated (Letter from Gary Whytcross (EPA) to Mick Cairney (Centennial Coal) not dated) that it will apply a discharge limit to conductivity of 350 µS/cm. This conductivity level is to enable the NSW EPA to improve the water quality in the upper Coxs River. It is important to note that currently the conductivity of the discharge has no adverse impact on aquatic ecosystems downstream of LDP009 and does not contribute to the observed toxicity in the cladoceran bioassay. Further the conductivity of the upstream Kangaroo Creek site was measured at 820 µS/cm, which will influence conductivity within the catchment, indicating that 350 µS/cm may not be an appropriate guideline. This requires additional investigation.

# 4. Recommendations

## 4.1 Assessment of Environmental Impacts

To obtain more confidence that the LDP009 discharge is not having an adverse impacts on the receiving water in Coxs River it is recommended that a freshwater ecologist  review and interpret the raw data used in the MPR reports (2010 to 2014).

## 4.2 Chronic Toxicity of LDP009

To meet the requirements of the NSW EPA as listed in the Notice of Licence Variation date 31 July 2014, Centennial Coal should conduct a full suite of chronic bioassays conducted on a sample from LDP009 to obtain EC10 concentrations to calculate a species sensitivity distribution for a dilution factor that can be incorporated into an environmental management plan.

As discussed previously, there is insufficient toxicity in the sample to allow a TIE to be conducted.

# 5. References

Elphick R.R., Davies M., Gilron G., Canaria E.C., Lo B. and Bailey H.C. 2011. An aquatic ecotoxicological evaluation of sulfate: The case for considering hardness as a modifying factor in setting water quality guidelines. Environmental Toxicology and Chemistry. 30(1):247-253.

Kunz J.L., Conley J.M., Buchwalter D.B., Norberg-King T.J., Kemble N.E., Wang N. and Ingersoll C.G. 2013. Use of reconstituted waters to evaluate effects of elevated major ions associated with mountain top coal mining on freshwater invertebrates. Environmental Toxicology and Chemistry 32(12):2826-2835.

MPR. 2014. Aquatic Ecology Monitoring Coxs and Wolgan River Catchments Spring 2013. Report prepared for Springvale Colliery Pty Ltd prepared by Marine Pollution Research Pty Ltd.

USEPA 2002. Methods for measuring the acute toxicity of effluents and receiving waters to freshwater and marine organisms. Fifth Edition. October 2002. United States Environmental Protection Agency.

Van Dam R.A., Hogan A.C., McCulloch C.D., Houston M.A., Humphrey C.L. and Harford A.J. 2010. Aquatic toxicology of magnesium sulphate and the influence of calcium in very low ionic concentration water. Environmental Toxicology and Chemistry. 29(2):410-421.

# Appendices

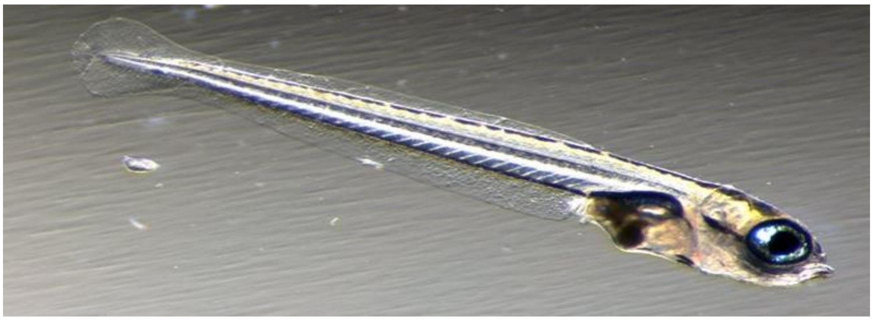
# Appendix A – Ecotoxicity Results

# Report on the Acute Toxicity of Samples from Cox River Coal Mine to Larvae of the Rainbowfish, *Melanotaenia duboulayi* (Castelnau, 1878)

Office of Environment and Heritage
Ecotoxicology Team, Environmental Forensics, Environment Protection Science
480 Weeroona Road, Lidcombe NSW 2141

Date of Issue of Report: **12 June 2014**

## Test Outline



The test was conducted to assess the potentially harmful effects of the samples to larvae of the native freshwater fish species *Melanotaenia duboulayi*. In this test the loss of balance (imbalance) is used as the endpoint as opposed to mortality, i.e. where possible, fish are removed from the test solution once they lose the ability to remain normally positioned.

Following exposure for 48 hours to various concentrations of the samples, the number of *M. duboulayi* affected was counted. This data is statistically analysed to determine sample concentrations causing a significant adverse effect to *M. duboulayi* relative to a control group

If more than 50% of exposed animals are imbalanced in any of the tested sample concentrations, a 48-hour EC50 (imbalance) value is calculated, which is the Effective Concentration of the sample which causes imbalance in 50% of exposed *M. duboulayi.*

The lower the concentration causing a significant adverse effect, or the lower the EC50 value, the greater the observed toxicity.

## Results Summary

**Samples 201401003, 201401004, 2014001005 and 201401006** had no observable acute effect on *M. duboulayi*, in that no immobilisation occurred in any in *M. duboulayi* exposed to the undiluted samples.

## Sample Information

| EF Submission Number | EF Sample Number |
|---|---|
| **201400181** | **201401003** |
| | **201401004** |
| | **201401005** |
| | **201401006** |

**Laboratory Accreditation does not extend to sample collection**

## Test Methods and Conditions

Test Commencement Date**: 12 May 2014**
Test Method Protocol No **ECOTOX 3.** The test method is based on procedures published by the USEPA (2002), Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms, 5th Edition. EPA-821-R-02-012. It differs from this guideline in that Australian fish species are used, and animals are cultured and bred in the OEH laboratory. The current animal research authority is (OEH AEC approval number 110620/02)
Deviations from Protocol**: Two replicates per sample treatment**
Test Type**:** Fish, **Acute, Static** Duration of test**: 48** hours
Test Species***: Melanotaenia duboulayi*** Age: **2 weeks**
Source: **Tank B 3**
Test Location:**Room No. F 27** Test Room No.: **F. 29**
Test Vessel Type : **100 mL beaker** Test Volume: **50 mL**
Test Temperature: **25 °C**
Test Photoperiod: **16 h L: 8 h D** Light intensity at surface of Test Vessels**: <800 Lux**
Dilution Water Source: **Filtered Sydney mains water with conductivity adjusted to 500 µS/cm with filtered seawater.**
Conductivity: **513 µS/cm** pH: **7.9**
Hardness: **75 mg/L as $CaCO_3$** Alkalinity: **38 mg/L as $CaCO_3$**

## Test Design

Concentrations tested: **25, 50 and 100%**
Test Concentrations: **Nominal**
Number of replicate test vessels per concentration and control/s**: Two for sample treatments,**
**Four for Control**
Number of animals per replicate: **5**
**Statistical Method**
Statistical Analysis Method: **Trimmed Spearman-Kärber for EC50 for reference toxicant**

## Results

### Table 1. Imbalance of *Melanotaenia duboulayi* in test solutions

| EF Sample Number | Nominal Test Concentration (% sample) | Percentage of animals imbalanced after 24 hours exposure | Percentage of animals imbalanced after 48 hours exposure |
|---|---|---|---|
| **Control** | **Diluent** | 0 | **0** |
| **201401003** | **25** | **0** | **0** |
| | **50** | **0** | **0** |
| | **100** | **0** | **0** |
| **201401004** | **25** | **0** | **0** |
| | **50** | **0** | **0** |
| | **100** | **0** | **0** |
| **201401005** | **25** | **0** | **0** |
| | **50** | **0** | **0** |
| | **100** | **0** | **0** |
| **20140101006** | **25** | **0** | **0** |
| | **50** | **0** | **0** |
| | **100** | **0** | **0** |

**A test validity criterion of Control group survival (greater than 90%) was met.**

## Table 2. Physico-chemical Variables in Test Solutions

| **Test Conc.** | **Temperature ($^0$C)** | | **pH** | | **Conductivity (µS/cm)** | | **Dissolved Oxygen (% saturation)** | |
|---|---|---|---|---|---|---|---|---|
| | **0 hr** | **48 hr** | **0 hr** | **48 hr** | **0 hr** | **48 hr** | **0 hr** | **48 hr** |
| **Control** | | | | | | | | |
| **Diluent** | 24.0 | 24.7 | 7.9 | 7.8 | 513 | 525 | 97 | 95 |
| **Sample 201401003** | | | | | | | | |
| **25** | 25.7 | 24.7 | 7.8 | 8.8 | 707 | 808 | 103 | 98 |
| **50** | 25.2 | 24.8 | 8.2 | 8.9 | 821 | 844 | 107 | 97 |
| **100** | 25.1 | 24.8 | 8.5 | 9.1 | 1166 | 1190 | 116 | 98 |
| **Sample 201401004** | | | | | | | | |
| **25** | 25.9 | 24.7 | 8.3 | 8.5 | 650 | 662 | 108 | 100 |
| **50** | 25.1 | 24.8 | 8.3 | 8.8 | 823 | 835 | 117 | 99 |
| **100** | 25.3 | 24.8 | 8.5 | 9.1 | 1156 | 1276 | 106 | 98 |
| **Sample 201401005** | | | | | | | | |
| **25** | 25.2 | 24.7 | 8.0 | 7.9 | 420 | 442 | 100 | 95 |
| **50** | 25.7 | 24.8 | 8.0 | 8.0 | 305 | 317 | 100 | 96 |
| **100** | 26.0 | 24.8 | 7.9 | 8.0 | 118 | 137 | 105 | 99 |
| **Sample 201401006** | | | | | | | | |
| **25** | 25.7 | 24.7 | 7.7 | 8.4 | 577 | 573 | 101 | 96 |
| **50** | 25.8 | 24.8 | 8.0 | 8.6 | 674 | 673 | 98 | 94 |
| **100** | 25.7 | 24.7 | 8.0 | 8.9 | 823 | 819 | 102 | 98 |

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This report is issued with the approval of

**M Julli**

**Team Leader Ecotoxicology**

**12 June 2014**

Accredited for compliance with ISO/IEC 17025

Accreditation No. 3040

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# Report on the Acute Toxicity of Samples from Cox River Coal Mine to the Cladoceran, *Ceriodaphnia dubia* Richard 1894

Office of Environment and Heritage
Ecotoxicology Team, Environmental Forensics, Environment Protection Science
480 Weeroona Road, Lidcombe NSW 2141

Date of Issue of Report: **12 June 2014**

## Test Outline

The test was conducted to assess the potentially harmful effects of the samples to juveniles of the freshwater crustacean zooplankton species *Ceriodaphnia dubia*.

Following exposure for 48 hours to various concentrations of the samples, the number of *C. dubia* immobilised was counted. In this test immobilisation is considered similar to lethality.

Immobilisation data is statistically analysed to determine sample concentrations causing a significant adverse effect to *C. dubia* relative to a control group of animals.

If more than 50% of exposed animals are immobilised in any of the tested sample concentrations, a 48-hour EC50 (immobilisation) value is calculated, which is the Effective Concentration of the sample which causes immobilisation in 50% of exposed *C. dubia*.

The lower the concentration causing a significant adverse effect, or the lower the EC50 value, the greater the observed toxicity.

## Results Summary

**Sample 201401003** caused significant immobilisation in exposed *C. dubia* at a concentration of **100**%. The sample would need to be diluted approximately 2 times to avoid these acute toxic effects on *C. dubia* (based on the tested concentrations). The 48-hour EC50 (immobilisation) concentration was calculated to be **71**% sample.

**Sample 201401004** caused significant immobilisation in exposed *C. dubia* at a concentration of **100**%. The sample would need to be diluted approximately 2 times to avoid these acute toxic effects on *C. dubia* (based on the tested concentrations). The 48-hour EC50 (immobilisation) concentration was calculated to be **79**% sample.

**Samples 201401005 and 201401006** had no observable acute effect on *C. dubia*, in that no immobilisation occurred in any *C. dubia* exposed to the undiluted samples.

## Sample Information

| **EF Submission Number** | **EF Sample Number** |
|---|---|
| **201400181** | **201401003** |
| | **201401004** |
| | **201401005** |
| | **201401006** |

**Laboratory Accreditation does not extend to sample collection**

## Test Methods and Conditions

Test Commencement Date**: 13 May 2014**

Test Method Protocol No.: Test Method Protocol No.: **ECOTOX 1.** The test method is based on procedures published by the USEPA (2002), Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms, 5th Edition. EPA-821-R-02-012. It differs from this guideline in that an Australian cladoceran species is used.

Deviations from Protocol**: Two replicates per treatment**

Test Type**:** Cladoceran, **Acute, Static** Duration of test**: 48** Hours

Test Species***: Ceriodaphnia dubia*** Age:**<24 hours** Source: **In-house Culture**

Location: **Room No F.27** Constant Temperature Room No.: **F29**

Test Vessel Type : **100 mL beaker** Test Volume: **50 mL**

Test Temperature: **25 °C**

Test Photoperiod: **16 h L: 8 h D** Light intensity at surface of Test Vessels**: <800 Lux**

Dilution Water Source: **Filtered thiosulphate-treated Sydney mains water with 5% mineral water and conductivity adjusted to 500µS/cm with filtered seawater**

Conductivity: **509 µS/cm** pH: **8.1**

Hardness: **87 mg/L as $CaCO_3$** Alkalinity: **48 mg/L as $CaCO_3$**

## Test Design

Concentrations tested**: 25, 50 and 100%**

Test Concentrations: **Nominal**

Number of replicate test vessels per concentration and control**: 2 per treatment, 4 per control**

Number of animals per replicate: **5**

**Statistical Methods**

Data Transformation for Lowest Observed Effect Concentration (LOEC): **Angular Uncorrected**

Statistical Analysis Method: **Probit or Spearman-Karber for EC50**
**Fisher Exact/Bonferroni-Hommel Test for LOEC**

# Results

## Table 1. Immobilisation of *Ceriodaphnia dubia* in test solutions

| EF Sample Number | Nominal Test Concentration (% sample) | Percentage of animals immobilised after 24 hours exposure | Percentage of animals immobilised after 48 hours exposure | Percent Minimum Significant Difference # (PMSD) |
|---|---|---|---|---|
| **Control** | | **0** | **0** | |
| **201401003** | **25** | **0** | **0** | **NC** |
| | **50** | **0** | **20** | |
| | **100** | **0** | **80*** | |
| **201401004** | **25** | **0** | **20** | **NC** |
| | **50** | **0** | **30** | |
| | **100** | **0** | **60*** | |
| **201401005** | **25** | **0** | **0** | **NC** |
| | **50** | **0** | **0** | |
| | **100** | **0** | **0** | |
| **201401006** | **25** | **0** | **0** | **NC** |
| | **50** | **0** | **0** | |
| | **100** | **0** | **0** | |

*Significantly different from the control ($p \leq 0.05$). 48-h data only analysed.
NC = Not calculable due to statistical test required for analysis
# PMSD is an estimation of the smallest percentage increase in immobilisation (relative to the control), that could be determined as statistically significant for this test.

**A test validity criterion of Control group survival (greater than 90%) was met.**

**Sample 201401003**
The Lowest Observed effect concentration (LOEC) of sample 201401003 was 100 % solution.
The No Observed Effect Concentration (NOEC) was 50 % solution.
48-Hour EC50 (Immobilisation) for sample 201401003 was 71 % (95% CL= 53-100%).

**Sample 201401004**
The Lowest Observed effect concentration (LOEC) of sample 201401004 was 100 % solution.
The No Observed Effect Concentration (NOEC) was 50 % solution.
48-Hour EC50 (Immobilisation) for sample 201401004 was 79 % (95% CL 47-100 %).

## Table 2. Physico-chemical Variables in Test Solutions

Laboratory Accreditation does not extend to measurements of pH, conductivity or dissolved oxygen.

| Test Conc. | Temperature ($^0$C) | | pH | | Conductivity (µS/cm) | | Dissolved Oxygen (% saturation) | |
|---|---|---|---|---|---|---|---|---|
| | 0 hr | 48 hr | 0 hr | 48 hr | 0 hr | 48 hr | 0 hr | 48 hr |
| **Control** | | | | | | | | |
| **Diluent** | 24.6 | 24.6 | 8.1 | 8.2 | 509 | 547 | 96 | 90 |
| **Sample 201401003** | | | | | | | | |
| **25** | 24.3 | 24.7 | 8.2 | 8.6 | 658 | 656 | 88 | 87 |
| **50** | 24.4 | 24.8 | 8.4 | 8.9 | 823 | 814 | 93 | 89 |
| **100** | 24.7 | 24.6 | 8.5 | 9.1 | 1137 | 1155 | 97 | 89 |
| **Sample 201401004** | | | | | | | | |
| **25** | 24.4 | 24.7 | 8.4 | 8.7 | 665 | 681 | 88 | 87 |
| **50** | 24.4 | 24.7 | 8.4 | 8.9 | 834 | 825 | 85 | 87 |
| **100** | 24.7 | 24.6 | 8.5 | 9.1 | 1145 | 1155 | 98 | 86 |
| **Sample 201401005** | | | | | | | | |
| **25** | 24.6 | 24.7 | 8.1 | 8.1 | 408 | 430 | 91 | 87 |
| **50** | 25.0 | 24.7 | 8.1 | 8.1 | 322 | 381 | 90 | 86 |
| **100** | 25.0 | 24.6 | 8.1 | 8.0 | 119 | 142 | 98 | 86 |
| **Sample 201401006** | | | | | | | | |
| **25** | 24.7 | 24.7 | 8.1 | 8.2 | 580 | 590 | 82 | 88 |
| **50** | 24.7 | 24.7 | 8.4 | 8.7 | 667 | 669 | 91 | 88 |
| **100** | 24.8 | 24.6 | 8.6 | 8.9 | 830 | 825 | 94 | 88 |

## Reference toxicant test No. 318

A reference toxicity test using Cr (VI) run in parallel with the above test resulted in 48-h EC50 (immobilisation) value of **220** µg/L (190 µg/L lower and 260 µg/L upper 95% CL). This value is within the 95% confidence limits of previous reference toxicity test results conducted at this laboratory, and indicates that the test animals used in the current tests were of typical sensitivity. The current percentage coefficient of variation of the reference toxicity data is **3.1**%

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**M Julli**

**Team Leader Ecotoxicology**

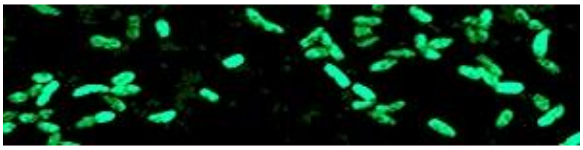
**12 June 2014**

# Report on the acute toxicity of samples from Cox River Coal Mine to *Vibrio fischeri* (Microtox®)

Office of Environment and Heritage
Ecotoxicology Team, Environmental Forensics, Environment Protection Science
480 Weeroona Road, Lidcombe NSW 2141

Date of Issue of Report: **12 June 2014**

## Test Outline



The Microtox® test was conducted to assess the potential harmful effects of the samples to the photoluminescent marine bacterium (*Vibrio fischeri*). Freshwater samples are salinity adjusted prior to testing.

Following exposure of up to 30 minutes to various concentrations of the sample/s, the light emitted by the bacteria is measured. Significant reduction in light output is considered to indicate an adverse effect on the bacteria.

If light output is reduced by more than 50% in any of the tested samples concentrations, an EC50 (luminescence inhibition) value is calculated which is the Effective Concentration of the sample which causes a 50% reduction in luminescence. The time period quoted with the EC50 indicates the exposure period of the bacteria to the sample.

The lower the EC50 value, the greater the observed toxicity, and the greater the amount of dilution required to eliminate the observed toxicity.

## Results Summary

**Sample 201401103** caused some reduction in luminescence in the exposed bacteria at the highest tested concentration, but this effect was limited to a **24**% reduction in light output at **80**% sample concentration after 30-minute exposure.

**Sample 201401004** had minimal effect on bacterial luminescence, that is, it did not cause a detectable adverse response in exposed bacteria

**Sample 201401005** caused some reduction in luminescence in the exposed bacteria at the highest tested concentration, but this effect was limited to a **15**% reduction in light output at **80**% sample concentration after 5-minute exposure.

**Sample 201401006** had minimal effect on bacterial luminescence, that is, it did not cause a detectable adverse response in exposed bacteria

## Sample Information

| EF Submission Number | EF Sample Number |
|---|---|
| 201400181 | 201401003 |
| | 201401004 |
| | 201401005 |
| | 201401006 |

Laboratory Accreditation does not extend to sample collection

## Test Methods and Conditions

Test Commencement Date: **12 May 2014**

Test Method Protocol No.: **ECOTOX4 -** The test procedure is based on the recommended tests described in the Microbics manual (1995) 'Microtox® Acute Toxicity Basic Test Procedures'. The test conducted here has been modified in the aspects of: increased upper limit of sample concentration, maximized volume of test solutions used, and additional dilution of reconstituted bacteria to increase the accuracy & precision of bacterial transfer. These modifications result in greater accuracy and precision of the calculated EC50 values.

| | | | |
|---|---|---|---|
| Test Type: | **Microtox® Acute, Basic** | | |
| Readings taken: | **5, 15, 30 Minutes** | | |
| Test Species: | ***Vibrio fischeri*** | Test Vessel Type : | **4 mL test tubes** |
| Test Volume: | 1.0 **mL** | Test Temperature: | **15.0°C** |
| Dilution Water: | Microbics diluent | Salinity: | **20‰** |

## Sample Treatment

Salinity adjustment: **Samples were adjusted to salinity of the diluent using solid NaCl.**
Filtration: **Not filtered**
Colour correction required: **No**

## Test Design

Concentrations tested: **Sample 201401003 – 0.625, 1.25, 2.5, 5.0, 10, 20, 40 and 80%;**
**Samples 201401004, 201401005 and 201401006 – 10, 20, 40 and 80%**
Test Concentrations: **Nominal**
Number of replicate test vessels per concentration and control/s: **2 for samples; 4 for controls**
Volume of stock organism per test solution: **0.2 mL (containing approx. $1x10^6$ cells)**

## Results

Laboratory Accreditation does not extend to measurements of pH, conductivity or dissolved oxygen.

| **EF Sample No.** | **pH** | **Conductivity µS/cm#** | **Dissolved oxygen (mg/L)** | **% luminescence inhibition *at highest Test Concentration of 80%*** | | |
|---|---|---|---|---|---|---|
| | | | | **5-min** | **15-min** | **30-min** |
| | | | | **% sample concentration** | | |
| **201401003** | **8.3** | **1055** | **7.74** | ***12*** | ***16*** | ***24*** |
| **201401004** | **8.3** | **1112** | **7.75** | ***<5*** | ***<5*** | ***<5*** |
| **201401005** | **7.2** | **102** | **7.75** | ***15*** | ***13*** | ***12*** |
| **201401006** | **8.2** | **773** | **7.75** | ***<5*** | ***<5*** | ***<5*** |

# conductivity of sample prior to salinity adjustment

**Reference Toxicant Test No. 239**

A reference toxicant (Phenol) test conducted with the same batch of organisms used for the tests gave 5min-EC50 value of 21 mg/L (20 mg/L lower and 23 mg/L upper 95% CL). This value is within the 95% confidence limits of previous reference toxicity test results conducted at this laboratory, indicating that the organisms used in the current test were of typical sensitivity. The percent coefficient of variation (% CV) for the previous twenty reference toxicant tests was 5.6%.

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**M Julli**

**Team Leader Ecotoxicology**

**12 June 2014**

# Appendix B – Chemistry Results

Environmental Forensics

# Report of Analysis

## Report 201400181

**25 June 2014**

Sample source: **Cox River Coal Mine**

Submitted by: **Martin Krogh**
Office of Environment and Heritage
PO Box A290
South Sydney NSW 1232

Date received: **8-May-2014**

# Office of Environment and Heritage

## Environmental Forensics

## Report of Analysis

**Report number:** **201400181**

**Report date:** 25-Jun-2014

**Date received:** 08-May-2014 16:00

**Sample source:** **Cox River Coal Mine**

### Sample details

| Lab number | Client reference | Sample type | Date sampled | Sample description |
|---|---|---|---|---|
| 201401003 | LDP SP1 | LIQUID | 08-May-2014 11:02 | |
| 201401004 | LDP SP2 | LIQUID | 08-May-2014 11:07 | |
| 201401005 | Coxs River | LIQUID | 08-May-2014 13:25 | |
| 201401006 | Kangaroo Ck | LIQUID | 08-May-2014 13:15 | |

**Report comments:** Please see the attached Ecotox reports report no: 201400181 (Ecotox 1, Ecotox 3, Ecotox 4) dated 12 June 2014.

# Organics by GC-MS

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **13/05/2014** | **13/05/2014** | **13/05/2014** | **13/05/2014** |
| **Method used** | **OMSTPH** | **OMSTPH** | **OMSTPH** | **OMSTPH** |
| C10 - C14 | <0.5 mg/L | <0.5 mg/L | <0.5 mg/L | <0.5 mg/L |
| C15 - C28 | <1.5 mg/L | <1.5 mg/L | <1.5 mg/L | <1.5 mg/L |
| C29 - C36 | <20 mg/L | <20 mg/L | <20 mg/L | <20 mg/L |

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **19/05/2014** | **19/05/2014** | **19/05/2014** | **19/05/2014** |
| **Method used** | **OMSVOC** | **OMSVOC** | **OMSVOC** | **OMSVOC** |
| (p+m) Xylene | <0.04 mg/L | <0.04 mg/L | <0.04 mg/L | <0.04 mg/L |
| Benzene | <0.03 mg/L | <0.03 mg/L | <0.03 mg/L | <0.03 mg/L |
| C6 - C9 | <1 mg/L | <1 mg/L | <1 mg/L | <1 mg/L |
| Ethylbenzene | <0.03 mg/L | <0.03 mg/L | <0.03 mg/L | <0.03 mg/L |
| o-Xylene | <0.03 mg/L | <0.03 mg/L | <0.03 mg/L | <0.03 mg/L |
| Toluene | <0.03 mg/L | <0.03 mg/L | <0.03 mg/L | <0.03 mg/L |

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **13/05/2014** | **13/05/2014** | **13/05/2014** | **13/05/2014** |
| **Method used** | **OMSWASTE** | **OMSWASTE** | **OMSWASTE** | **OMSWASTE** |
| 1,2,4,5-Tetrachlorobenzene | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| 1,2,4-Trichlorobenzene | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| 1,2-Dichlorobenzene | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L |
| 1,4-Dichlorobenzene | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L |
| 2,3,4,6-Tetrachlorophenol | <0.01 mg/L | <0.01 mg/L | <0.01 mg/L | <0.01 mg/L |
| 2,4,5-Trichlorophenol | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| 2,4,6-Trichlorophenol | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| 2,4-Dichlorophenol | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| 2,4-Dimethylphenol | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| 2,4-Dinitrophenol | <0.2 mg/L | <0.2 mg/L | <0.2 mg/L | <0.2 mg/L |
| 2,4-Dinitrotoluene | <0.01 mg/L | <0.01 mg/L | <0.01 mg/L | <0.01 mg/L |
| 2,6-Dichlorophenol | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| 2-Chlorophenol | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L |
| 2-Methyl-4,6-dinitrophenol | <0.03 mg/L | <0.03 mg/L | <0.03 mg/L | <0.03 mg/L |
| 2-Methylphenol | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| 2-Nitrophenol | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| 3+4-Methylphenol | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| 4-Chloro-3-methylphenol | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| 4-Nitrophenol | <0.03 mg/L | <0.03 mg/L | <0.03 mg/L | <0.03 mg/L |
| Acenaphthene | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L |
| Acenaphthylene | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L |
| Aldrin | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| alpha-BHC | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| alpha-Chlordane | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Anthracene | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L |
| Aroclor 1016 (screen) | <0.004 mg/L | <0.004 mg/L | <0.004 mg/L | <0.004 mg/L |
| Aroclor 1221 (Screen) | <0.004 mg/L | <0.004 mg/L | <0.004 mg/L | <0.004 mg/L |
| Aroclor 1232 (screen) | <0.004 mg/L | <0.004 mg/L | <0.004 mg/L | <0.004 mg/L |

| | **201401003**<br>**LDP SP1**<br>**LIQUID**<br>**13/05/2014**<br>**OMSWASTE** | **201401004**<br>**LDP SP2**<br>**LIQUID**<br>**13/05/2014**<br>**OMSWASTE** | **201401005**<br>**Coxs River**<br>**LIQUID**<br>**13/05/2014**<br>**OMSWASTE** | **201401006**<br>**Kangaroo Ck**<br>**LIQUID**<br>**13/05/2014**<br>**OMSWASTE** |
|---|---|---|---|---|
| Aroclor 1242 (screen) | <0.004 mg/L | <0.004 mg/L | <0.004 mg/L | <0.004 mg/L |
| Aroclor 1248 (screen) | <0.004 mg/L | <0.004 mg/L | <0.004 mg/L | <0.004 mg/L |
| Aroclor 1254 (screen) | <0.004 mg/L | <0.004 mg/L | <0.004 mg/L | <0.004 mg/L |
| Aroclor 1260 (screen) | <0.004 mg/L | <0.004 mg/L | <0.004 mg/L | <0.004 mg/L |
| Benzo (a) anthracene | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L |
| Benzo (a) pyrene | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L |
| Benzo (b) fluoranthene | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L |
| Benzo (ghi) perylene | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L |
| Benzo (k) fluoranthene | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L |
| beta-BHC | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Bis-2-ethyl hexyl adipate | <0.12 mg/L | <0.12 mg/L | <0.12 mg/L | <0.12 mg/L |
| Bis-2-ethyl hexyl phthalate | <0.060 mg/L | <0.060 mg/L | <0.060 mg/L | <0.060 mg/L |
| Chlorpyrifos | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Chrysene | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L |
| delta-BHC | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Dibenzo (ah) anthracene | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L |
| Dibutyl phthalate | <0.020 mg/L | <0.020 mg/L | <0.020 mg/L | <0.020 mg/L |
| Dieldrin | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L |
| Endosulfan I | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Endosulfan II | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Endosulfan sulfate | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Endrin | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Endrin aldehyde | <0.035 mg/L | <0.035 mg/L | <0.035 mg/L | <0.035 mg/L |
| Endrin ketone | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Fluoranthene | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Fluorene | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L |
| gamma-BHC | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| gamma-Chlordane | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L |
| Heptachlor | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Heptachlor epoxide | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Hexachlorobenzene | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L |
| Indeno (123cd) pyrene | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L |
| Isodrin | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Methoxychlor | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L |
| Naphthalene | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L |
| Nitrobenzene | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Pentachlorobenzene | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Pentachloronitrobenzene | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Pentachlorophenol | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L | <0.005 mg/L |
| Perylene | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L |
| Phenanthrene | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L | <0.002 mg/L |
| Phenol | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L |
| pp'-DDD | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L |
| pp'-DDE | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L |
| pp'-DDT | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L |
| Pyrene | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L | <0.001 mg/L |

# Metals by ICP-AES

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **30/05/2014** | **30/05/2014** | **30/05/2014** | **30/05/2014** |
| **Method used** | **ICPAES** | **ICPAES** | **ICPAES** | **ICPAES** |
| Aluminium (acid extractable) | **0.05 mg/L** | <0.04 mg/L | **0.07 mg/L** | <0.04 mg/L |
| Barium (acid extractable) | | | | **0.13 mg/L** |
| Boron (acid extractable) | <0.1 mg/L | <0.1 mg/L | <0.1 mg/L | <0.1 mg/L |
| Calcium (acid extractable) | **4.5 mg/L** | **4.4 mg/L** | **6.7 mg/L** | **21 mg/L** |
| Iron (acid extractable) | **0.12 mg/L** | **0.1 mg/L** | **0.82 mg/L** | **0.16 mg/L** |
| Lithium (acid extractable) | **0.22 mg/L** | **0.2 mg/L** | | **0.26 mg/L** |
| Magnesium (acid extractable) | **3.3 mg/L** | **3.1 mg/L** | **3.2 mg/L** | **19 mg/L** |
| Phosphorus (acid extractable) | <0.04 mg/L | <0.04 mg/L | <0.04 mg/L | <0.04 mg/L |
| Potassium (acid extractable) | **16 mg/L** | **14 mg/L** | **3.4 mg/L** | **34 mg/L** |
| Silicon (acid extractable) | **4.4 mg/L** | **4.1 mg/L** | **4.7 mg/L** | **4.4 mg/L** |
| Sodium (acid extractable) | **300 mg/L** | **300 mg/L** | **5.4 mg/L** | **150 mg/L** |
| Strontium (acid extractable) | | | | **0.1 mg/L** |
| Sulfur (acid extractable) | **14 mg/L** | **13 mg/L** | **6.8 mg/L** | **7.4 mg/L** |
| Titanium (acid extractable) | <0.01 mg/L | <0.01 mg/L | <0.01 mg/L | <0.01 mg/L |

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **30/05/2014** | **30/05/2014** | **30/05/2014** | **30/05/2014** |
| **Method used** | **ICPAES** | **ICPAES** | **ICPAES** | **ICPAES** |
| Aluminium (Lab. filtered) | <0.04 mg/L | <0.04 mg/L | <0.04 mg/L | <0.04 mg/L |
| Barium (Lab. filtered) | | | | **0.11 mg/L** |
| Boron (Lab. filtered) | <0.1 mg/L | <0.1 mg/L | <0.1 mg/L | <0.1 mg/L |
| Calcium (Lab. filtered) | **3.9 mg/L** | **4.0 mg/L** | **6.1 mg/L** | **17 mg/L** |
| Iron (Lab. filtered) | <0.03 mg/L | <0.03 mg/L | **0.58 mg/L** | **0.05 mg/L** |
| Lithium (Lab. filtered) | **0.18 mg/L** | **0.19 mg/L** | | **0.25 mg/L** |
| Magnesium (Lab. filtered) | **2.7 mg/L** | **2.7 mg/L** | **2.8 mg/L** | **15 mg/L** |
| Phosphorus (Lab. filtered) | <0.04 mg/L | <0.04 mg/L | <0.04 mg/L | <0.04 mg/L |
| Potassium (Lab. filtered) | **13 mg/L** | **13 mg/L** | **3.1 mg/L** | **32 mg/L** |
| Silicon (Lab. filtered) | **3.6 mg/L** | **3.6 mg/L** | **4.3 mg/L** | **3.9 mg/L** |
| Sodium (Lab. filtered) | **280 mg/L** | **250 mg/L** | **5.2 mg/L** | **130 mg/L** |
| Sulfur (Lab. filtered) | **10 mg/L** | **10 mg/L** | **6.1 mg/L** | **6.3 mg/L** |
| Titanium (Lab. filtered) | <0.01 mg/L | <0.01 mg/L | <0.01 mg/L | <0.01 mg/L |

# Metals by ICP-MS

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **21/05/2014** | **21/05/2014** | **21/05/2014** | **21/05/2014** |
| **Method used** | **ICPMS** | **ICPMS** | **ICPMS** | **ICPMS** |
| Antimony (acid extractable) | **0.77 µg/L** | **0.78 µg/L** | <0.5 µg/L | <0.5 µg/L |
| Arsenic (acid extractable) | **21 µg/L** | **24 µg/L** | <1.0 µg/L | <1.0 µg/L |
| Barium (acid extractable) | **26 µg/L** | **27 µg/L** | **23 µg/L** | |
| Beryllium (acid extractable) | <0.05 µg/L | <0.05 µg/L | <0.05 µg/L | <0.05 µg/L |
| Cadmium (acid extractable) | <0.1 µg/L | <0.1 µg/L | <0.1 µg/L | <0.1 µg/L |
| Chromium (acid extractable) | <1.0 µg/L | <1.0 µg/L | <1.0 µg/L | <1.0 µg/L |
| Cobalt (acid extractable) | **1.7 µg/L** | **1.6 µg/L** | **1.3 µg/L** | **0.17 µg/L** |
| Copper (acid extractable) | <0.5 µg/L | **0.51 µg/L** | **0.59 µg/L** | <0.5 µg/L |
| Lead (acid extractable) | **0.56 µg/L** | **0.55 µg/L** | **0.1 µg/L** | <0.1 µg/L |
| Lithium (acid extractable) | | | **2.5 µg/L** | |
| Manganese (acid extractable) | **10 µg/L** | **9.6 µg/L** | **76 µg/L** | **12 µg/L** |
| Molybdenum (acid extractable) | **36 µg/L** | **36 µg/L** | <0.5 µg/L | **10 µg/L** |
| Nickel (acid extractable) | **4.1 µg/L** | **4.3 µg/L** | **0.61 µg/L** | **1.9 µg/L** |
| Selenium (acid extractable) | <2.0 µg/L | <2.0 µg/L | <2.0 µg/L | <2.0 µg/L |
| Silver (acid extractable) | <0.1 µg/L | <0.1 µg/L | <0.1 µg/L | <0.1 µg/L |
| Strontium (acid extractable) | **17 µg/L** | **17 µg/L** | **25 µg/L** | **94 µg/L** |
| Thallium (acid extractable) | <0.1 µg/L | <0.1 µg/L | <0.1 µg/L | <0.1 µg/L |
| Tin (acid extractable) | <0.2 µg/L | <0.2 µg/L | <0.2 µg/L | <0.2 µg/L |
| Vanadium (acid extractable) | **0.34 µg/L** | <0.2 µg/L | **0.57 µg/L** | **0.68 µg/L** |
| Zinc (acid extractable) | **10 µg/L** | **11 µg/L** | **4.2 µg/L** | **29 µg/L** |

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **21/05/2014** | **21/05/2014** | **21/05/2014** | **21/05/2014** |
| **Method used** | **ICPMS** | **ICPMS** | **ICPMS** | **ICPMS** |
| Antimony (lab. filtered) | **0.7 µg/L** | **0.71 µg/L** | <0.5 µg/L | <0.5 µg/L |
| Arsenic (lab. filtered) | **20 µg/L** | **19 µg/L** | <1.0 µg/L | <1.0 µg/L |
| Barium (lab. filtered) | **24 µg/L** | **25 µg/L** | **22 µg/L** | |
| Beryllium (lab. filtered) | <0.05 µg/L | <0.05 µg/L | <0.05 µg/L | <0.05 µg/L |
| Cadmium (lab. filtered) | <0.1 µg/L | <0.1 µg/L | <0.1 µg/L | <0.1 µg/L |
| Chromium (lab. filtered) | <1.0 µg/L | <1.0 µg/L | <1.0 µg/L | <1.0 µg/L |
| Cobalt (lab. filtered) | **1.4 µg/L** | **1.4 µg/L** | **1.3 µg/L** | **0.15 µg/L** |
| Copper (lab. filtered) | <0.5 µg/L | **0.53 µg/L** | **0.63 µg/L** | **0.76 µg/L** |
| Lead (lab. filtered) | **0.34 µg/L** | **0.43 µg/L** | **0.13 µg/L** | <0.1 µg/L |
| Lithium (lab. filtered) | | | **2.4 µg/L** | |
| Manganese (lab. filtered) | **8.3 µg/L** | **9.7 µg/L** | **74 µg/L** | **9.8 µg/L** |
| Molybdenum (lab. filtered) | **37 µg/L** | **37 µg/L** | <0.5 µg/L | **10 µg/L** |
| Nickel (lab. filtered) | **3.8 µg/L** | **3.9 µg/L** | **0.61 µg/L** | **2.2 µg/L** |
| Selenium (lab. filtered) | <2.0 µg/L | <2.0 µg/L | <2.0 µg/L | <2.0 µg/L |
| Silver (lab. filtered) | <0.1 µg/L | <0.1 µg/L | <0.1 µg/L | <0.1 µg/L |
| Strontium (lab. filtered) | **17 µg/L** | **18 µg/L** | **26 µg/L** | **93 µg/L** |
| Thallium (lab. filtered) | <0.1 µg/L | <0.1 µg/L | <0.1 µg/L | <0.1 µg/L |
| Tin (lab. filtered) | <0.2 µg/L | <0.2 µg/L | <0.2 µg/L | <0.2 µg/L |
| Vanadium (lab. filtered) | <0.2 µg/L | **0.25 µg/L** | **0.29 µg/L** | <0.2 µg/L |
| Zinc (lab. filtered) | **7.2 µg/L** | **11 µg/L** | **3.6 µg/L** | **5.2 µg/L** |

## Metals by FIMS

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **19/05/2014** | **19/05/2014** | **19/05/2014** | **19/05/2014** |
| **Method used** | **ICVAASW** | **ICVAASW** | **ICVAASW** | **ICVAASW** |
| Mercury (dissolved) | <0.05 µg/L | <0.05 µg/L | <0.05 µg/L | <0.05 µg/L |

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **19/05/2014** | **19/05/2014** | **19/05/2014** | **19/05/2014** |
| **Method used** | **ICVAASW** | **ICVAASW** | **ICVAASW** | **ICVAASW** |
| Mercury | <0.05 µg/L | <0.05 µg/L | <0.05 µg/L | <0.05 µg/L |

# Inorganics

| Laboratory number | 201401003 | 201401004 | 201401005 | 201401006 |
|---|---|---|---|---|
| Client sample ID | LDP SP1 | LDP SP2 | Coxs River | Kangaroo Ck |
| Sample type | LIQUID | LIQUID | LIQUID | LIQUID |
| Date started | 30/05/2014 | 30/05/2014 | 30/05/2014 | 30/05/2014 |
| Method used | CALCULATION | CALCULATION | CALCULATION | CALCULATION |
| Hardness | 21 mg/L CaCO3 | 21 mg/L CaCO3 | 27 mg/L CaCO3 | 100 mg/L CaCO3 |

| Laboratory number | 201401003 | 201401004 | 201401005 | 201401006 |
|---|---|---|---|---|
| Client sample ID | LDP SP1 | LDP SP2 | Coxs River | Kangaroo Ck |
| Sample type | LIQUID | LIQUID | LIQUID | LIQUID |
| Date started | 13/05/2014 | 13/05/2014 | 13/05/2014 | 13/05/2014 |
| Method used | IGR_TDS | IGR_TDS | IGR_TDS | IGR_TDS |
| Total Dissolved Solids | 870 mg/L | 970 mg/L | 72 mg/L | 550 mg/L |

| Laboratory number | 201401003 | 201401004 | 201401005 | 201401006 |
|---|---|---|---|---|
| Client sample ID | LDP SP1 | LDP SP2 | Coxs River | Kangaroo Ck |
| Sample type | LIQUID | LIQUID | LIQUID | LIQUID |
| Date started | 13/05/2014 | 13/05/2014 | 13/05/2014 | 13/05/2014 |
| Method used | IGRTSS | IGRTSS | IGRTSS | IGRTSS |
| Total Suspended Solids | <15 mg/L | <15 mg/L | <15 mg/L | <15 mg/L |

| Laboratory number | 201401003 | 201401004 | 201401005 | 201401006 |
|---|---|---|---|---|
| Client sample ID | LDP SP1 | LDP SP2 | Coxs River | Kangaroo Ck |
| Sample type | LIQUID | LIQUID | LIQUID | LIQUID |
| Date started | 13/05/2014 | 13/05/2014 | 13/05/2014 | 13/05/2014 |
| Method used | IICAO1 | IICAO1 | IICAO1 | IICAO1 |
| Chloride | 5.1 mg/L | 5.1 mg/L | 6.4 mg/L | 8.2 mg/L |
| Fluoride | 1.0 mg/L | 1.0 mg/L | <0.3 mg/L | 0.6 mg/L |
| Sulfate | 30 mg/L | 31 mg/L | 21 mg/L | 20 mg/L |

| Laboratory number | 201401003 | 201401004 | 201401005 | 201401006 |
|---|---|---|---|---|
| Client sample ID | LDP SP1 | LDP SP2 | Coxs River | Kangaroo Ck |
| Sample type | LIQUID | LIQUID | LIQUID | LIQUID |
| Date started | 9/05/2014 | 9/05/2014 | 9/05/2014 | 9/05/2014 |
| Method used | IISECON | IISECON | IISECON | IISECON |
| Conductivity | 1200 µS/cm | 1100 µS/cm | 100 µS/cm | 820 µS/cm |

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **8/05/2014** | **8/05/2014** | **8/05/2014** | **8/05/2014** |
| **Method used** | **IISEPH** | **IISEPH** | **IISEPH** | **IISEPH** |
| pH | **8.0 pH units** | **8.0 pH units** | **6.1 pH units** | **8.4 pH units** |

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **13/05/2014** | **13/05/2014** | **13/05/2014** | **13/05/2014** |
| **Method used** | **ITIALKA** | **ITIALKA** | **ITIALKA** | **ITIALKA** |
| Bicarbonate Alkalinity | **580 mg/L CaCO3** | **580 mg/L CaCO3** | **14 mg/L CaCO3** | **410 mg/L CaCO3** |
| Carbonate Alkalinity | <6 mg/L CaCO3 | <6 mg/L CaCO3 | <6 mg/L CaCO3 | **10 mg/L CaCO3** |
| Hydroxide Alkalinity | <6 mg/L CaCO3 | <6 mg/L CaCO3 | <6 mg/L CaCO3 | <6 mg/L CaCO3 |
| Total Alkalinity | **580 mg/L CaCO3** | **580 mg/L CaCO3** | **14 mg/L CaCO3** | **420 mg/L CaCO3** |

# Nutrients by FIA

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **21/05/2014** | **21/05/2014** | **21/05/2014** | **21/05/2014** |
| **Method used** | **IFIAFRE** | **IFIAFRE** | **IFIAFRE** | **IFIAFRE** |
| Ammonia - N | **0.49 mg/L** | **0.49 mg/L** | <0.01 mg/L | <0.01 mg/L |
| Free Reactive Phosphorus | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L | <0.003 mg/L |
| NOx - N | **0.32 mg/L** | **0.31 mg/L** | **0.02 mg/L** | **0.26 mg/L** |

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **13/05/2014** | **13/05/2014** | **13/05/2014** | **13/05/2014** |
| **Method used** | **IFIAKNP** | **IFIAKNP** | **IFIAKNP** | **IFIAKNP** |
| TKN | **0.7 mg/L** | **0.6 mg/L** | **0.4 mg/L** | <0.2 mg/L |
| Total Nitrogen | **1.0 mg/L** | **0.9 mg/L** | **0.4 mg/L** | **0.4 mg/L** |
| Total Phosphorus | **0.019 mg/L** | **0.019 mg/L** | <0.015 mg/L | <0.015 mg/L |

# Toxicity by TOX

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **13/05/2014** | **13/05/2014** | **13/05/2014** | **13/05/2014** |
| **Method used** | **Ecotox 1** | **Ecotox 1** | **Ecotox 1** | **Ecotox 1** |
| Toxicity 1 | **RC** | **RC** | **RC** | **RC** |

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **12/06/2014** | **12/06/2014** | **12/06/2014** | **12/06/2014** |
| **Method used** | **Ecotox 3** | **Ecotox 3** | **Ecotox 3** | **Ecotox 3** |
| Toxicity 3 | **RC** | **RC** | **RC** | **RC** |

| **Laboratory number** | **201401003** | **201401004** | **201401005** | **201401006** |
|---|---|---|---|---|
| **Client sample ID** | **LDP SP1** | **LDP SP2** | **Coxs River** | **Kangaroo Ck** |
| **Sample type** | **LIQUID** | **LIQUID** | **LIQUID** | **LIQUID** |
| **Date started** | **12/05/2014** | **12/05/2014** | **12/05/2014** | **12/05/2014** |
| **Method used** | **Ecotox 4** | **Ecotox 4** | **Ecotox 4** | **Ecotox 4** |
| Toxicity 4 | **RC** | **RC** | **RC** | **RC** |

**Released by:**

Stephen Fuller - Senior Scientist

Anil Gautam - Senior Scientist

Moreno Julli - Team leader Ecotoxicolgy

**Codes:** **NR** = Not Required **IS** = Insufficient Sample **E** = Estimated Result
**SN** = Sample Note **RN** = Result Note **RC** = Report Comment

**Date:** 25/06/2014

This document has been digitally signed by the name that appears on this report. Digital signing has been carried out using private key encryption code.

This Report shall not be reproduced except in full.
Samples analysed as received and non-legal samples will be discarded one month from report date.
Soil samples are reported on a dry weight basis, except when analysed in accordance with the NSW EPA Waste Guidelines.

# Appendix C – Chain of Custody Form

KE 9/5/14

# NSW ENVIRONMENT PROTECTION AUTHORITY/OFFICE of ENVIRONMENT and HERITAGE SAMPLE SUBMISSION/PROJECT FORM

Page 1 of ~~7~~ 3

ite reference or ddress of event: Cox River coal mine

Report to: Martin Krogh

Submitted by: M. KROGH

Section: OEH waters.

Legal / Legal (Pest) / [✓ Non Legal]

Waste:

Contaminated sites:

Chemicals/pesticides: ✓

Submission/Project Number: 20140051

(Copy number to Chain of Custody Form)

Delivered by: M. KROGH

Date required: 5/5/14

Received by: K. Edge

Study:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Grey Areas - LAB USE ONLY | Client Sample ID / Point | LDP SP1 | LDP SP2 | COXS RIVER | Kangaroo Ck | | | | |
| | Sample Type* | water | water | water | water | | | | |
| | Date Sampled | 8/5/14 | 8/5/14 | 8/5/14 | 8/5/14 | 5 | | | |
| | Time Sampled | 11:02 | 11:07 | 1:25 | 1:15 | | | | |
| For identification and comparative testing laboratory staff must nominate all screening tests and sample preparation steps | Laboratory No | 201401003 | 201401004 | 201401005 | 201401006 | | | | |
| Specific Tests or test groups requested | Test Method | Please tick the tests required below and if applicable note the sub-sample Id and any preservatives used. | | | | | | | |
| pH | 11SEPH | ✓ | ✓ | ✓ | ✓ | | | | |
| TSS | 1QRTSS | ✓ | ✓ | ✓ | ✓ | | | | |
| TDS | 1QRTDS | ✓ | ✓ | ✓ | ✓ | | | | |
| 11SECON - conductivity | 11SECON | ✓ | ✓ | ✓ | ✓ | | | | |
| Hardness | ICPAESHARD | ✓ | ✓ | ✓ | ✓ | | | | |
| Total + Free nutrients | IFIA FRE_C<br>IFIA KNP_C | ✓<br>✓ | ✓<br>✓ | ✓<br>✓ | ✓<br>✓ | | | | |
| Total Metals + Dissolved | ICPMSW_D<br>ICPMSW_T | ✓<br>✓ | ✓<br>✓ | ✓<br>✓ | ✓<br>✓ | | | | |
| Mercury + Dissolved | ICVAASW_ | ✓ | ✓ | ✓ | ✓ | | | | |
| IC Cl + SO4 | IICA01 | ✓ | ✓ | ✓ | ✓ | | | | |
| Alkalinity<br>Fluride | ITIALK<br>X_INORGANIC | ✓<br>✓ | ✓<br>✓ | ✓<br>✓ | ✓<br>✓ | | | | |
| | LIMS line number | | | | | | | | |

Bird deaths: Number: Species:

Comments To support EIS assessment of coal mine
Cox's river - upstream.

Labels Checked: VS

Checked by VS

NOTES: * Choose from LIMS options

Non-legal samples will be discarded 1 month from report date

Issued: 07/02/2014

Authorised: HLS

LSSF001v7

KE9/5/1

# ENVIRONMENT PROTECTION AUTHORITY/OFFICE OF ENVIRONMENT AND HERITAGE
# CHAIN OF CUSTODY

**SUBMISSION/PROJECT No.** 201400181 Page 2 of ~~2~~ 3

**Shipping container**

Type of container
☐ White Plastic Box
☑ Esky
☐ Other ..........

Type of seal
☐ EPA
☑ Other ..no..
☐ Signed or Initialled

**Sample bottles**

Type of bottle
☑ EPA
☐ Other ..........
☐ Sealed

Type of seal
☐ EPA
☐ Other ..........
☐ Signed

Condition on arrival: Cooled.......... Frozen.......... Ambient.......... Alkali.......... Acid.......... Other..........

☑ If seal is intact place a tick in the appropriate box ☒ If seal is missing or broken place a cross in the appropriate box

Details if seals not intact or missing:

**Sample Collector** M. KROGH **Mobile contact:** 0427 867 330

| Shipping container | Sample bottle/s | Representative's name (Print & sign) | Organisation/Employer | Collected Date | Time 11:00 | Contact phone no. |
|---|---|---|---|---|---|---|
| ☑ | ☐ | Print MARTIN KROGH<br>Sign | OEH | 8/5/14 | | 9995 5619 |

**Submitter/Sender/Handler/Analyst**

| Shipping container | Sample bottle/s | Representative's name (Print & sign) | Organisation/Employer | Received Date | Time | Contact phone no. |
|---|---|---|---|---|---|---|
| ☑ | ☐ | Print MARTIN KROGH<br>Sign | OEH | 8/5/14 | 11:00 | 99955619 |
| ☐ | ☐ | Print Katelyn Edge<br>Sign | OEH | 8/5/14 | 16:00 | x5094 |
| ☐ | ☐ | Print<br>Sign | | | | |
| ☐ | ☐ | Print<br>Sign | | | | |
| ☐ | ☐ | Print<br>Sign | | | | |

# NSW ENVIRONMENT PROTECTION AUTHORITY/OFFICE of ENVIRONMENT and HERITAGE SAMPLE SUBMISSION/PROJECT FORM

Page 3 of 3

Site reference or address of event:

Legal / Legal (Pest) / Non Legal

Waste: Contaminated sites:

Chemicals/pesticides:

Report to:

Submission/Project Number: 20140018I (Copy number to Chain of Custody Form)

Submitted by:

Delivered by:

Received by:

Section:

Date required:

Study:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Grey Areas - LAB USE ONLY** | Client Sample ID / Point | LDP SP1 | LDP SP2 | COXS RIVER | Kangaroo Ck. | | | | |
| | Sample Type* | LIQUID | LIQUID | LIQUID | LIQUID | | | | |
| | Date Sampled | | | | | | | | |
| | Time Sampled | | | | | | | | |
| **For identification and comparative testing laboratory staff must nominate all screening tests and sample preparation steps** | Laboratory No | 201401003 | 201401004 | 201401005 | 201401006 | | | | |
| Specific Tests or test groups requested | Test Method | **Please tick the tests required below and if applicable note the sub-sample Id and any preservatives used.** | | | | | | | |
| TPH. | OMSTPH | ✓ | ✓ | ✓ | ✓ | | | | |
| BTEX | OMSVOC | ✓ | ✓ | ✓ | ✓ | | | | |
| PAHS | OMSWASTE | ✓ | ✓ | ✓ | ✓ | | | | |
| C. dubia | ECOTOX1 | ✓ | ✓ | ✓ | ✓ | | | | |
| Fish | ECOTOX3 | ✓ | ✓ | ✓ | ✓ | | | | |
| Microtox | ECOTOX4 | ✓ | ✓ | ✓ | ✓ | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | LIMS line number | | | | | | | | |

Bird deaths: Number: Species:

Comments

NOTES: * Choose from LIMS options

Non-legal samples will be discarded 1 month from report date

Issued: 07/02/2014

Labels Checked:

Checked by

Authorised: HLS

LSSF001v7

KE 9/5/14

# ENVIRONMENT PROTECTION AUTHORITY/OFFICE OF ENVIRONMENT AND HERITAGE
# CHAIN OF CUSTODY

**SUBMISSION/PROJECT No.** Page of

| Shipping container | | Sample bottles | |
|---|---|---|---|
| Type of container | Type of seal | Type of bottle | Type of seal |
| ☐ White Plastic Box | ☐ EPA | ☐ EPA | ☐ EPA |
| ☐ Esky | ☐ Other ................ | ☐ Other ........................... | ☐ Other .................. |
| ☐ Other ............................ | ☐ Signed or Initialled | ☐ Sealed | ☐ Signed |

Condition: on arrival: Cooled............ Frozen.............. Ambient.............. Alkali.............. Acid........... Other...........

☑ If seal is intact place a tick in the appropriate box ☒ If seal is missing or broken place a cross in the appropriate box

Details if seals not intact or missing: ____________________

## Sample Collector Mobile contact:

| Shipping container | Sample bottle/s | Representative's name *(Print & sign)* | Organisation/Employer | Collected Date | Collected Time | Contact phone no. |
|---|---|---|---|---|---|---|
| ☐ | ☐ | *Print* ______<br>*Sign* ______ | | | | |

## Submitter/Sender/Handler/Analyst

| Shipping container | Sample bottle/s | Representative's name *(Print & sign)* | Organisation/Employer | Received Date | Received Time | Contact phone no. |
|---|---|---|---|---|---|---|
| ☐ | ☐ | *Print* ______<br>*Sign* ______ | | | | |
| ☐ | ☐ | *Print* ______<br>*Sign* ______ | | | | |
| ☐ | ☐ | *Print* ______<br>*Sign* ______ | | | | |
| ☐ | ☐ | *Print* ______<br>*Sign* ______ | | | | |
| ☐ | ☐ | *Print* ______<br>*Sign* ______ | | | | |

GHD

72 McNamara St, Orange, NSW 2800
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T: (02) 6393 6400   F: (02) 6393 6401   E: oagmail@ghd.com

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Document Status

| Rev No. | Author | Reviewer | | Approved for Issue | | |
|---|---|---|---|---|---|---|
| | | Name | Signature | Name | Signature | Date |
| 0 | J.Woodworth | G.Metcalfe | | G.Metcalfe | | 07/08/14 |
| | | | | | | |

www.ghd.com

# Centennial Coal Company Limited

## Coxs River
## Ecotoxicology Assessment

September 2014

# Executive summary

GHD Pty Ltd was commissioned by Centennial Coal Company Limited to conduct an ecotoxicological study to determine toxicity and chemical constituents of mine water discharge from LDP001 at Angus Place Colliery (AP LDP001) and LDP009 at Springvale Mine (SV LDP009) as well as several locations within the upper Coxs River catchment to assess the impact of mine water discharge on the surrounding receiving environment. This ecotoxicology assessment will be used to support the response to submissions for the Environmental Impact Statements for both the mine extension projects.

Direct toxicity assessment was undertaken for the mine water discharge samples from AP LDP001 and SV LDP009. Toxicity testing at all other locations was conducted using screening tests with the freshwater cladoceran, which has been found to be the most sensitive test species in previous toxicity testing conducted by Centennial in the region. Toxicity testing of sampled water was performed using the ANZECC and ARMCANZ (2000) protocol with species endemic to, or representative of, the receiving environment. Water quality analysis was also undertaken for the samples from each location.

The results of this study show that the discharge at SV LDP009 is having an acute impact on cladoceran species at the Sawyers Swamp Creek site downstream of discharges; however this acute toxicity is ameliorated as the discharge enters the Coxs River. Impacts on cladoceran reproduction show a decreasing trend in the Coxs River with distance downstream of the SV LDP009 discharge point until no toxic impacts are detected in the upper portion of Lake Wallace.

The results of the toxicity testing were used to determine the concentration of SV LDP009 discharge of 2.7% to provide protection to 95% of the species in the downstream ecosystem. An estimate of the runoff contributing to the Coxs River was obtained from the water balance model developed by RPS (2014a). The estimated catchment runoff to the Coxs River at each location was compared to the predicted maximum daily discharge volume from AP LDP001 and SV LDP009 to determine the expected dilution of discharge within the river. The target dilution of SV LDP009 discharge was not found to be met under median rainfall conditions.

Aquatic ecology monitoring results provide supporting evidence that the discharges from AP LDP001 and SV LDP009 are not adversely impacting the aquatic health of the Coxs River. The sites downstream of discharges from AP LDP001 were found to have more pollution sensitive taxa present in the macroinvertebrate assemblages than the upstream Coxs River site.

The water quality results for SV LDP009 do not indicate any parameters that are present in concentrations that could cause the significant toxicity observed in the ecotoxicology results. Furthermore, the chemistry of discharge from AP LDP001, which did not show any toxicity to the cladoceran species, was found to be very similar to that of SV LDP009. Further investigations are required to determine the source of the toxicity at SV LDP009.

# Table of contents

# Table index

# Figure index

# Appendices

# Glossary

| | |
|---|---|
| Acute toxicity | The ability of a substance to cause severe biological harm or death from a single exposure. |
| Alkalinity | A measure of the ability of an aqueous solution to neutralise acids. Alkalinity of natural waters is due primarily to the presence of hydroxides, bicarbonates and carbonates. It is expressed in units of calcium carbonate (CaCO3). |
| Analyte | A substance or chemical constituent that is undergoing analysis. |
| Anion | A negatively charged ion. |
| Bioassay | An experimental test used to evaluate the relative potency of a chemical by measuring its effect on a living organism relative to a control. |
| Bioavailability | The fraction of the total of a chemical in the surrounding environment that is available to be taken up by an organism. The environment may include water, sediment, soil, suspended particles and food. |
| Catchment | The land area draining through the main stream and tributary streams to a particular location. |
| Cation | A positively charged ion. |
| Chronic toxicity | The ability of a substance to cause severe biological harm or death from prolonged exposure. |
| Community | An assemblage of organisms occupying a specified location and time, usually interacting with one another. |
| Control | The part of an experimental procedure which is like the treated part in every respect except it is not subjected to the test conditions. The control is used as a standard of comparison, to check that the outcome of the experiment is a reflection of the test conditions and not of some unknown factor. |
| Direct toxicity assessment | The use of toxicity tests to determine the acute and/or chronic toxicity of mixtures of compounds in ambient waters. |
| Discharge | The quantity of water per unit time, for example cubic metres per second or megalitres per day. |
| Ecotoxicology | Scientific study of the effects of toxic substances on living organisms. |
| Effect concentration | The concentration of a substance in water where a certain percent of test organisms exhibit a certain response or effect after a specified exposure period. For example, EC10 is the concentration where 10 percent of the test organisms exhibit a response. |

| | |
|---|---|
| Electrical conductivity | A measure of the concentration of dissolved salts or ions in water. |
| Guidelines | Numerical concentration or narrative statement that provides appropriate guidance for a designated water use or impact. |
| Hardness | The concentration of multivalent cations present in water. Generally, hardness is a measure of the concentration of calcium and magnesium ions in water and is expressed in units of calcium carbonate (CaCO3) equivalent. Hardness may influence the toxicity and bioavailability of substances in water. |
| Ion | An electrically charged atom. |
| Index | Composite value that can give a quick ranking to an ecosystem feature (e.g. a water body), derived via a formula that combines measurements of important ecosystem characteristics; typically used to rank ‘health’ or naturalness. |
| Licensed discharge point | A location where the premises discharge water in accordance with conditions stipulated with the site’s Environment Protection Licence. |
| Longwall mining | Underground coal mining where a block of coal is mined using a longwall shearer, supported by roadway development that is created using a continuous miner unit. |
| Macroinvertebrate | An animal species that does not develop a vertebral column and is large enough to be seen without the use of a microscope. These animals generally include insects, crustaceans, molluscs, arachnids and annelids. |
| Median | The middle value, such that there is an equal number of higher and lower values. Also referred to as the 50th percentile. |
| Meteorology | The science concerned with the processes and phenomena of the atmosphere, especially as a means of forecasting the weather. |
| No observed effects concentration (NOEC) | The highest tested concentration of a substance in water at which no effect is observable in test organisms in a given population (compared to the control sample). |
| Percentile | The value of a variable below which a certain per cent of observations fall. For example, the 80th percentile is the value below which 80 per cent of values are found. |
| pH | The value taken to represent the acidity or alkalinity of an aqueous solution. It is defined as the negative logarithm of the hydrogen ion concentration of the solution. |
| Physicochemical | Refers to the physical (e.g. temperature, electrical conductivity) and chemical (e.g. concentrations of nitrate, mercury) characteristics of water. |
| Riparian | Pertaining to, or situated on, the bank of a river or other water body. |

| | |
|---|---|
| Runoff | Amount of rainfall that ends up as streamflow. |
| Total dissolved solids | A measure of the inorganic and organic substances dissolved in water. |
| Total Kjeldahl nitrogen | The sum of the concentrations of organic nitrogen, ammonia (NH4) and ammonium (NH4+) in water. |
| Total nitrogen | A measure of organic and inorganic nitrogen forms in water. The sum of concentrations of total Kjeldahl nitrogen, nitrite and nitrate. |
| Total phosphorus | A measure of the organic and inorganic phosphorus in particulate and soluble forms. |
| Total suspended solids | A measure of the filterable matter suspended in water. |
| Toxicity | The inherent potential or capacity of a substance to cause adverse effects in a living organism. |
| Trigger value | The concentration or load of physicochemical characteristic of an aquatic ecosystem, below which there exists a low risk that adverse ecological effects will occur. they indicate a risk of impact if exceeded and should ‘trigger’ action to conduct further investigations or to implement management or remedial processes. |
| Turbidity | A measure of the clarity of water. Turbidity in excess of 5 NTU is just noticeable to the average person. |

# Abbreviations

| | |
|---|---|
| AUSRIVAS | Australian Rivers Assessment System |
| AWBM | Australian Water Balance Model |
| BOM | Bureau of Meteorology |
| DO | Dissolved oxygen |
| DOC | Dissolved organic carbon |
| DTA | Direct toxicity assessment |
| EC | Effect concentration |
| EPA | Environment Protection Authority |
| EPL | Environment Protection Licence |
| ESA | Ecotox Services Australasia |
| GHD | GHD Pty Ltd |
| km | Kilometre |
| km2 | Square kilometre |
| L | Litre |
| LDP | Licensed discharge point |
| m | Metre |
| mg/L | Milligram per litre |
| ML/day | Megalitre per day |
| mV | Millivolt |
| NATA | National Association of Testing Authorities |
| NOEC | No observable effect concentration |
| NOW | NSW Office of Water |
| NTU | Nephelometric turbidity unit |
| SSTV | Site-specific trigger value |
| TDS | Total dissolved solids |
| TSS | Total suspended solids |
| °C | Degrees Celsius |
| µS/cm | Microsiemens per centimetre |

# 1. Introduction

## 1.1 Background

Angus Place Colliery is an underground coal mine located approximately 5 km north of Lidsdale and approximately 15 km north-west of Lithgow. Springvale Mine is also an underground coal mine located approximately 6 km south of Angus Place Colliery. A locality figure is provided in Figure 1-1. Both mines are currently seeking approval to extend mining operations using longwall mining methods as part of the Angus Place Mine Extension Project and Springvale Mine Extension Project respectively.

Groundwater inflows into the underground workings at both Angus Place Colliery and Springvale Mine are transferred to a subterranean pipeline network prior to discharge at licensed discharge point (LDP) LDP009 at Springvale Mine. Mine water from Springvale Mine is taken as a priority, with the remaining capacity supplied by mine water from Angus Place Colliery.

GHD Pty Ltd (GHD) was commissioned by Centennial Coal Company Limited (Centennial) to conduct an ecotoxicological study to determine toxicity and chemical constituents of mine water discharge from LDP001 at Angus Place Colliery (AP LDP001) and LDP009 at Springvale Mine (SV LDP009) as well as several locations within the upper Coxs River catchment to assess the impact of mine water discharge on the surrounding receiving environment. This ecotoxicology assessment will be used to support the response to submissions for the Environmental Impact Statements for both the mine extension projects.

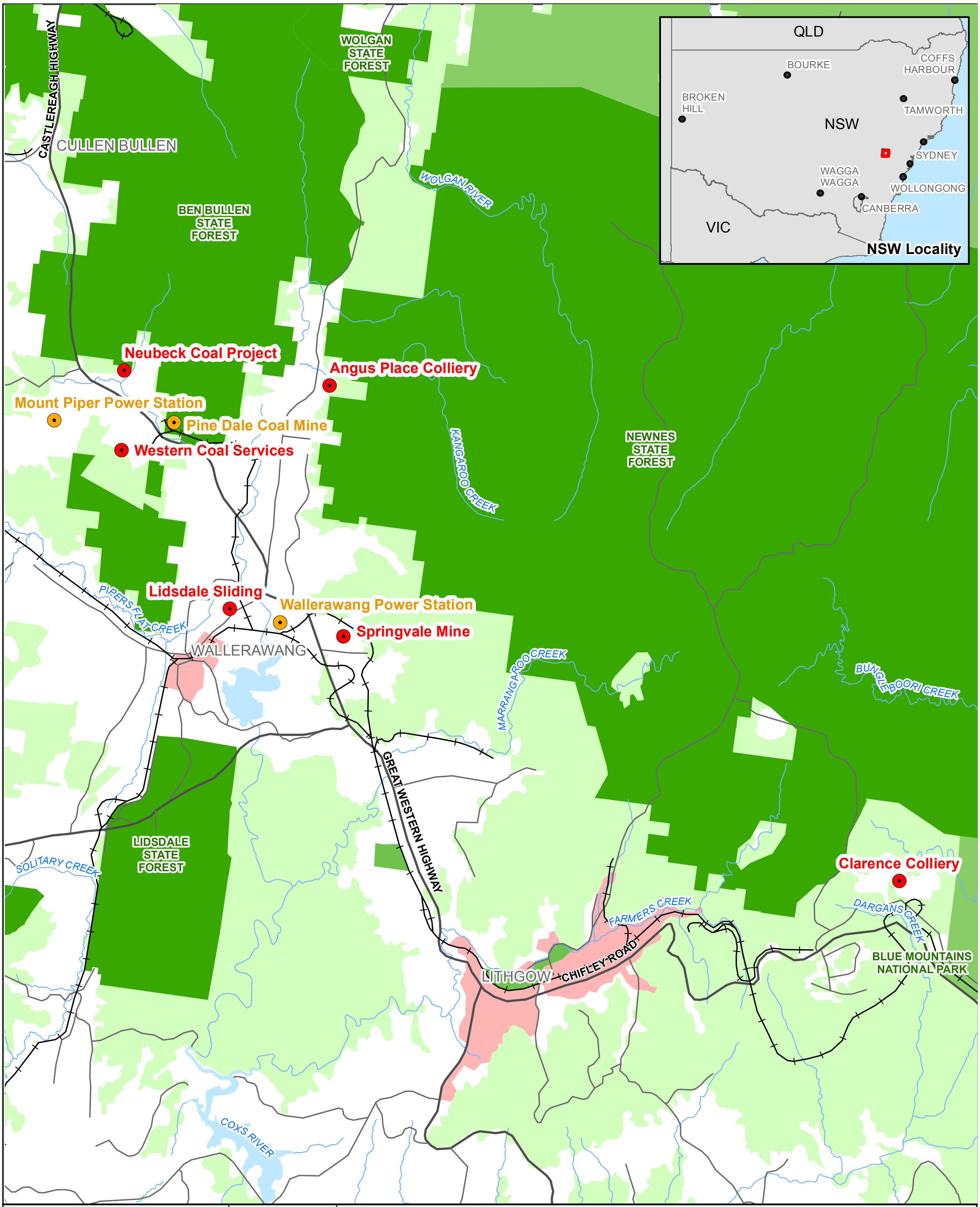
The NSW Environment Protection Authority (EPA) conducted water quality and toxicity testing on discharge from SV LDP009 and the receiving environment on 8 May 2014. GHD was engaged by Centennial to review and interpret the results of the testing provided by the NSW EPA and to determine the impacts on the receiving environment. The outcomes of this assessment are provided in *Springvale EPA Water Quality and Toxicity Assessment: Interpretive Report* (GHD, 2014). The objectives of the work detailed in this report as well as the above mentioned report are to develop a weight of evidence approach to the outcomes of the two mine extension projects.

## 1.2 Coxs River Catchment

### 1.2.1 Topography and Land Use

The Western Coalfield lies on the western slopes of the north-south oriented sandstone ridgeline of the Great Dividing Range, to the west of the Wollemi National Park and the Blue Mountains National Park. The area consists primarily of undulating hills and mountain tops, with some low-lying areas.

The region is surrounded by state recognised forests and reserves, including the Turon State Forest and Winburndale Nature Reserve in the west and the Wolgan State Forest, Ben Bullen State Forest and Newnes State Forest to the east. Low-lying areas have been cleared of vegetation for agricultural, commercial and industrial purposes, including coal mining, forestry and power generation. Nearby residential areas include Lithgow and Wallerawang to the south and Portland and Cullen Bullen to the west.



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0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

GHD

LEGEND

- ● Non Centennial Site
- ● Centennial Site
- ┼ Existing Rail
- ━ Dual Carriageway
- ━ Principal Road
- ━ Secondary Road
- ─ Minor Road
- ─ Waterway
- ▨ Waterbody
- 🟥 Built Up Area
- 🟩 Nature Conservation
- 🟩 State Forest
- 🟩 Forest Or Shrub

| | |
|---|---|
| LOCATION | - |
| SEAM | NA |
| DRAWN | S.M. |
| CHECKED | |
| APPROVED | S.Gray |
| SCALE | Refer to scalebar |

Coxs River
Ecotoxicology Assesssment

Locality Plan

Centennial Coal

DATE 29/09/2014

Figure 1-1

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Western\Angus Place\2217471\2217471_001_Locality_A.mxd

© Commonwealth of Australia (Geoscience Australia): 250K Topographic Data Series 3 2006; LPI: DTDB 2012

### 1.2.1 Hydrology

The Coxs River is a perennial river that drains a catchment area of approximately 1,700 km$^2$ as shown in Figure 1-2 and is part of the greater Hawkesbury/Nepean catchment. The river rises within the Ben Bullen State Forest east of Cullen Bullen and flows generally in a south-east direction into Lake Burragorang (impounded by Warragamba Dam), which is the primary reservoir for drinking water supply to Sydney. The flow in Coxs River is regulated by three reservoirs, Lake Wallace, Thompsons Reservoir and Lake Lyell, which are used to supply power generation activities.

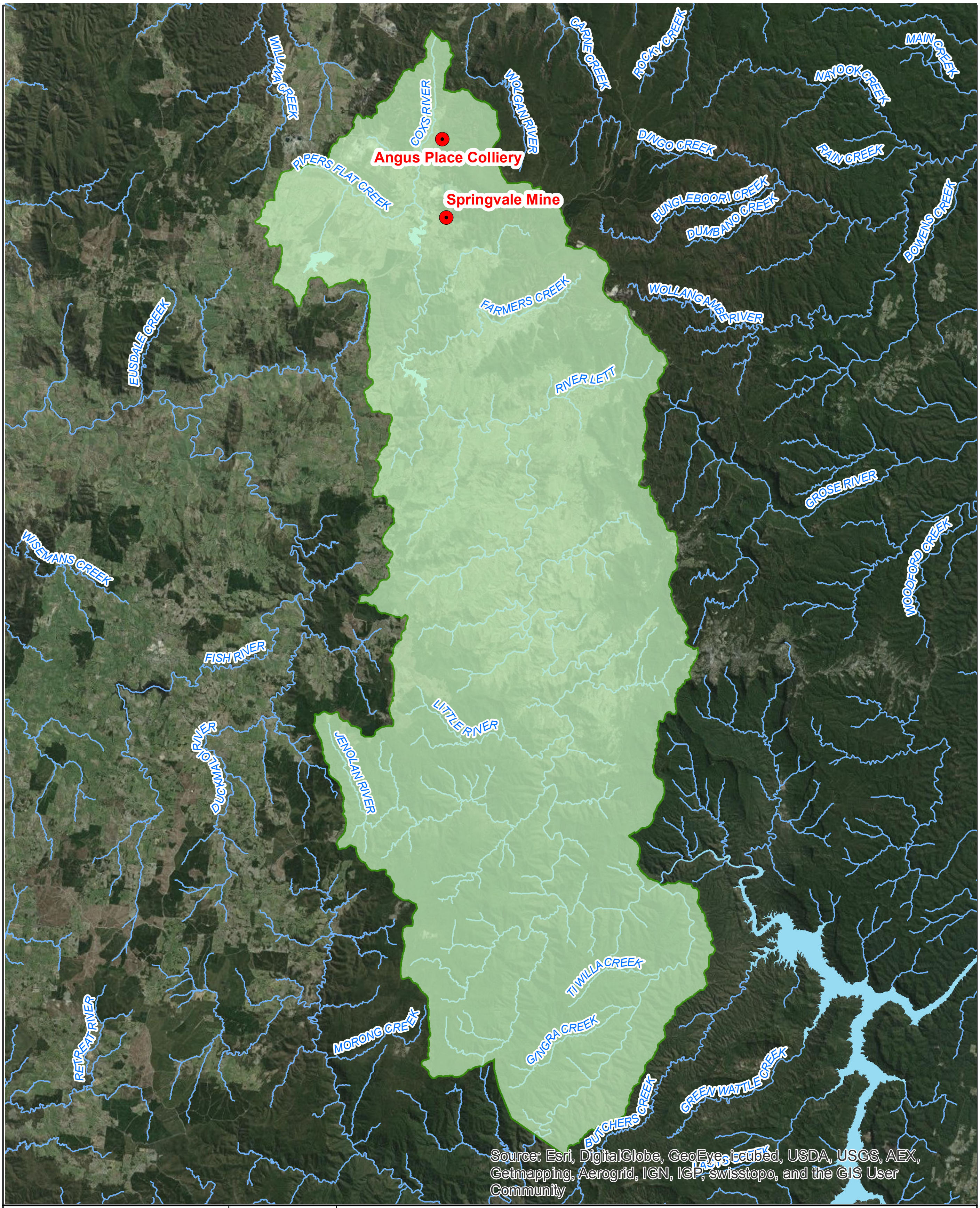
Flows within the Coxs River are monitored at several locations by NSW Office of Water (NOW) gauges. The locations of the four gauges assessed are presented in Figure 1-3 and details are provided in Table 1-1.

A partial series analysis was undertaken on the data available from the NOW gauges on the Coxs River. As the quality of data as provided by the NOW was found to vary, data with a large uncertainty was not included in the analysis. The proportion of the data record used in the analysis is included in Table 1-1 for each flow gauge.

Table 1-1 NSW Office of Water Flow Gauge Details

| | Coxs River at Wallerawang Power Station | Coxs River at Bathurst Road | Coxs River at Upstream Lake Lyell | Coxs River at Lithgow | Coxs River at Island Hill |
|---|---|---|---|---|---|
| Station number | 212054 | 212008 | 212058 | 212011 | 212045 |
| Record | January 1992 to September 2014 | January 1951 to September 2014 | December 2000 to September 2014 | May 1960 to September 2014 | August 1981 to September 2014 |
| Latitude | -33.3971 | -33.4277 | -33.4757 | -33.5343 | -33.7573 |
| Longitude | 150.0839 | 150.0825 | 150.0762 | 150.0951 | 150.1970 |
| Elevation | 875 m | 858 m | 857 m | 744 m | 264 |
| Catchment area | 178 km$^2$ | 199 km$^2$ | 250 km$^2$ | 404 km$^2$ | 970 km$^2$ |
| Proportion of record used | 97% | 97% | 95% | 97% | 99% |

Hydrographs and daily percentiles for each flow gauge assessed are presented in Appendix A with selected flow statistics provided in Table 1-2. The median flow within the Coxs River increases from 13.3 ML/day at Wallerawang Power Station downstream to 50 ML/day in the lower Coxs River catchment at Island Hill. The flow statistics presented in Table 1-2 indicate that the average values for the gauges on the Coxs River at Bathurst Road, Lithgow and Island Hill have been skewed by flood events in 1986 and 1990, which were not recorded by the gauges at Wallerawang Power Station or upstream of Lake Lyell.



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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0 1.25 2.5 5 7.5 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

GHD

LEGEND

● Centennial Site
— Waterway
🟦 Waterbody
🟩 Coxs River Catchment

| | |
|---|---|
| LOCATION | - |
| SEAM | NA |
| DRAWN | S.M. |
| CHECKED | |
| APPROVED | S.Gray |
| SCALE | Refer to scalebar |

Coxs River
Ecotoxicology Assesssment

Watercourses

Centennial Coal

DATE 29/09/2014

Figure 1-2

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Western\Angus Place\2217471\2217471_005_Watercourses_A.mxd

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0 0.5 1 2 3 4

Kilometres

N

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

GHD

LEGEND

| | |
|---|---|
| ● Non Centennial Site | — Waterway |
| ● Centennial Site | ▨ Waterbody |
| ● NOW Gauge | |

| | |
|---|---|
| LOCATION | - |
| SEAM | NA |
| DRAWN | S.M. |
| CHECKED | |
| APPROVED | S.Gray |
| SCALE | Refer to scalebar |

Coxs River
Ecotoxicology Assesssment

NSW Office of Water
Flow Gauge Locations

Centennial Coal

DATE 29/09/2014

Figure 1-3

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Western\Angus Place\2217471\2217471_004_NOWGauges_A.mxd

© Commonwealth of Australia (Geoscience Australia): 250K Topographic Data Series 3 2006; LPI: DTDB 2012

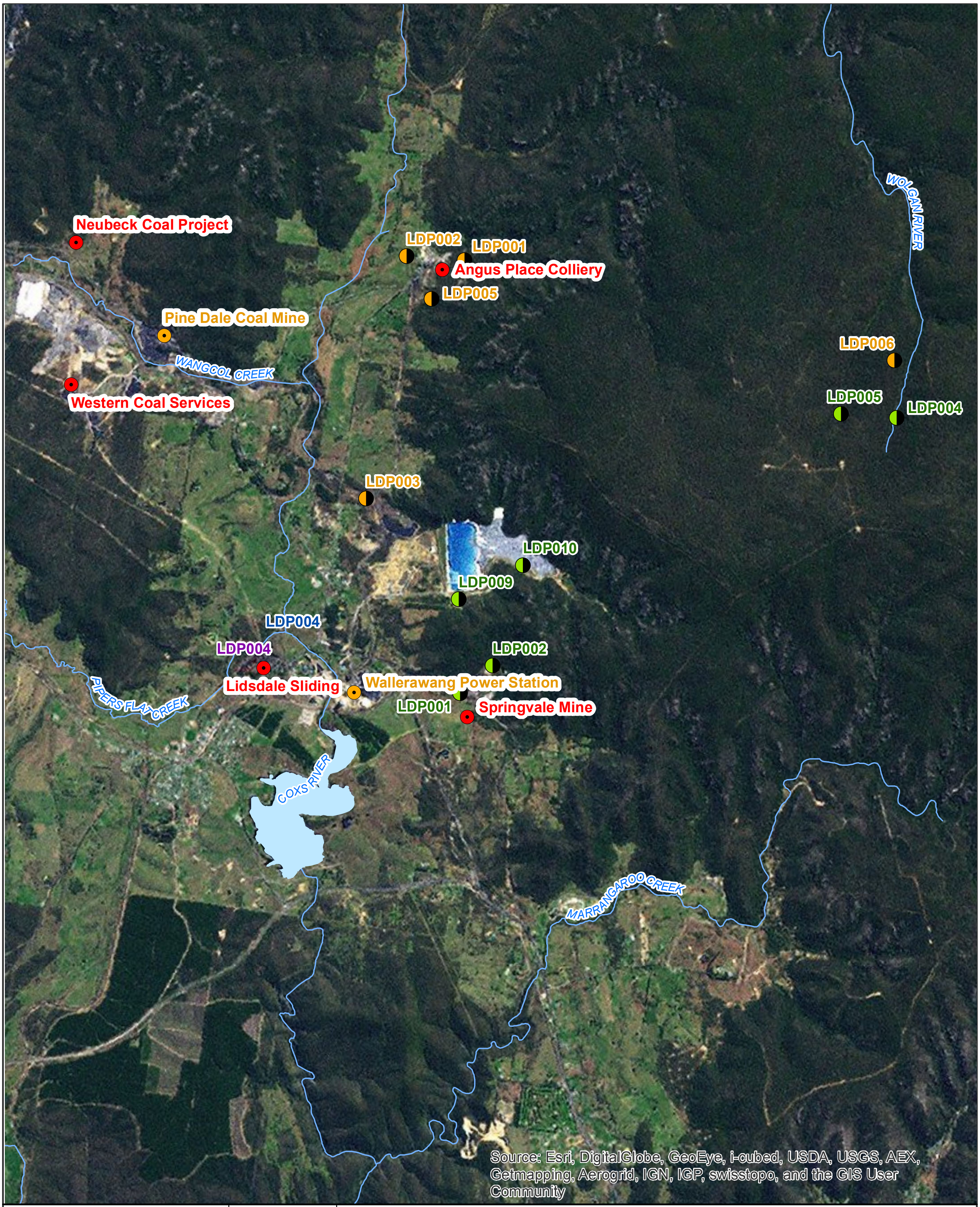
Table 1-2 Coxs River Flow Gauge Statistics

| Statistic | Coxs River at Wallerawang Power Station (ML/day) | Coxs River at Bathurst Road (ML/day) | Coxs River at Upstream Lake Lyell (ML/day) | Coxs River at Lithgow (ML/day) | Coxs River at Island Hill (ML/day) |
|---|---|---|---|---|---|
| Average | 25.5 | 61.6 | 29.4 | 119.7 | 216.2 |
| Minimum | 0.3 | 0.0 | 4.9 | 0.0 | 0.0 |
| 10th percentile | 4.5 | 3.4 | 12.2 | 3.3 | 6.0 |
| 50th percentile | 13.3 | 13.9 | 20.3 | 30.6 | 50.0 |
| 90th percentile | 44.7 | 94.4 | 54.1 | 217.8 | 425.7 |
| Maximum | 4,315 | 33,729 | 267 | 29,319 | 77,439 |

### 1.2.2 Site Overviews

The following coal mining and power generation operations that have been considered in this ecotoxicology assessment, as presented in Figure 1-4:

- Angus Place Colliery – Underground coal mine currently seeking approval to extend mining operations. Mine water is primarily transferred to a pipeline and discharged via SV LDP009.
- Clarence Colliery – Underground coal mine operated by Centennial located in the Wollangambe River catchment, adjacent to the Coxs River catchment. Water transferred from Clarence Colliery to Lithgow City Council to supplement the town water supply may contribute to Farmers Creek, which is a tributary of Coxs River.
- Lidsdale Siding – Coal storage and rail loading facility operated by Centennial that receives coal from Western Coal Services for transport by rail to Port Kembla or Port of Newcastle for export.
- Mount Piper Power Station – Coal-fired power station owned by Energy Australia.
- Neubeck Coal Project – Proposed open cut coal mine currently seeking approval.
- Pine Dale Coal Mine – Open cut coal mine owned by Energy Australia that is currently under care and maintenance while seeking approval to continue mining operations.
- Springvale Mine – Underground coal mine currently seeking approval to extend mining operations. Mine water is transferred to a pipeline and discharged via SV LDP009.
- Wallerawang Power Station – Coal-fired power station owned by Energy Australia that is currently under care and maintenance.
- Western Coal Services – Coal processing facility operated by Centennial that provides coal storage, handling and processing functions. Coal is transported by overland conveyor to Mount Piper Power Station or Lidsdale Siding.



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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0 0.2 0.4 0.8 1.2 1.6

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

GHD

LEGEND

| | |
|---|---|
| ● Non Centennial Site | ◐ Angus Place LDP |
| ● Centennial Site | — Waterway |
| ◐ Springvale LDP | |

| | |
|---|---|
| LOCATION | - |
| SEAM | NA |
| DRAWN | S.M. |
| CHECKED | |
| APPROVED | S.Gray |
| SCALE | Refer to scalebar |

Coxs River
Ecotoxicology Assesssment

Site Locations

Centennial
Coal

DATE 29/09/2014

Figure 1-4

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Western\Angus Place\2217471\2217471_007_SiteLocationandLDPs_A.mxd

© Commonwealth of Australia (Geoscience Australia): 250K Topographic Data Series 3 2006; LPI: DTDB 2012

## 1.3 Discharge Locations

Environment Protection Licences (EPLs) are issued by the NSW EPA under the *Protection of the Environment Operations Act 1997*. Licence conditions relate to pollution prevention and monitoring and can control the air, noise, water and waste impacts of an activity. Each site operates under an EPL which specifies conditions under which water is to be discharged via LDPs. Table 1-3 summarises the licence conditions for Centennial's operations. Pine Dale Coal Mine and Wallerawang Power Station are both currently under care and maintenance and are understood to have ceased discharging to the Coxs River catchment.

### Table 1-3 Licensed Discharge Points

| Environment Protection Licence | Discharge point | Discharge limit | Description |
|---|---|---|---|
| **Angus Place Colliery** | | | |
| 467 | LDP001 | 2 ML/day | Discharge of mine water and runoff to Kangaroo Creek through wetlands. |
| | LDP002 | No limit | Discharge of surface water from facilities area into the Coxs River through settling ponds. |
| | LDP003 | No limit | Discharge of surface water from the old Kerosene Vale Colliery site into the Coxs River through a settling pond. |
| **Clarence Colliery** | | | |
| 726 | LDP001 | No limit | Discharge from ventilation fan into Wollangambe River. |
| | LDP002 | 25 ML/day | Discharge of treated mine water into Wollangambe River. |
| | LDP003 | No limit | Overflow from leachate dam into another dam that is part of the water management system. |
| | LDP004 | No limit | Overflow from leachate dam into adjacent bushland and Wollangambe River. |
| **Lidsdale Siding** | | | |
| 5129 | LDP004 | No limit | Discharge of surface water from facilities area into Pipers Flat Creek through settling ponds. |
| **Springvale Mine** | | | |
| 3607 | LDP001 | 10 ML/day | Discharge of mine water, surface water from facilities area and runoff into Springvale Creek through settling ponds. |
| | LDP009 | 30 ML/day | Discharge of mine water from Angus Place Colliery and Springvale Mine into Sawyers Swamp Creek. |

| Environment Protection Licence | Discharge point | Discharge limit | Description |
|---|---|---|---|
| **Western Coal Services** | | | |
| 3607 | LDP006 | No limit | Discharge of surface water from facilities area into Wangcol Creek through settling ponds. |

## 1.4 Water Management Strategies

The following three strategies are proposed for the management of mine water as part of the mine extension projects for Angus Place Colliery and Springvale Mine (RPS, 2014a):

- Water strategy WS1 – All mine water from Angus Place Colliery (up to 30.8 ML/day) is discharged via AP LDP001 and all mine water from Springvale Mine (up to 18.8 ML/day) is discharged via SV LDP009.
- Water strategy WS2a – Up to 30 ML/day of mine water from Angus Place Colliery and Springvale Mine is discharged via SV LDP009, consisting of all mine water from Springvale Mine and the remaining volume from Angus Place Colliery. Excess mine water from Angus Place Colliery is discharged via AP LDP001.
- Water strategy WS2b – 2 ML/day of mine water from Angus Place Colliery is discharged via AP LDP001 with the remaining mine water from Angus Place Colliery and Springvale Mine discharged via SV LDP009 (up to 43.4 ML/day).

It should be noted that WS2a is the current water strategy employed by Centennial at the time of water sampling.

## 1.5 Scope of Work

This report details the ecotoxicology assessment and provides the results for water quality testing at 12 locations within the Coxs River catchment, including mine water discharge from LDPs at Angus Place Colliery and Springvale Mine. The scope of work included the following:

- Provide details of sample collection at 12 sites in the Coxs River catchment and toxicity and water quality testing conducted.
- Interpret toxicity and water quality testing results for the 12 samples of water collected.
- Compare results with current and historical monitoring conducted by Centennial and with site-specific trigger values and EPL limits specified for licensed discharge points.
- Compare results with modelled catchment runoff within the Coxs River catchment, estimated from water balance modelling provided by RPS (2014a), to determine the dilution of mine water discharge downstream of AP LDP001 and SV LDP009.

# 2. Methodology

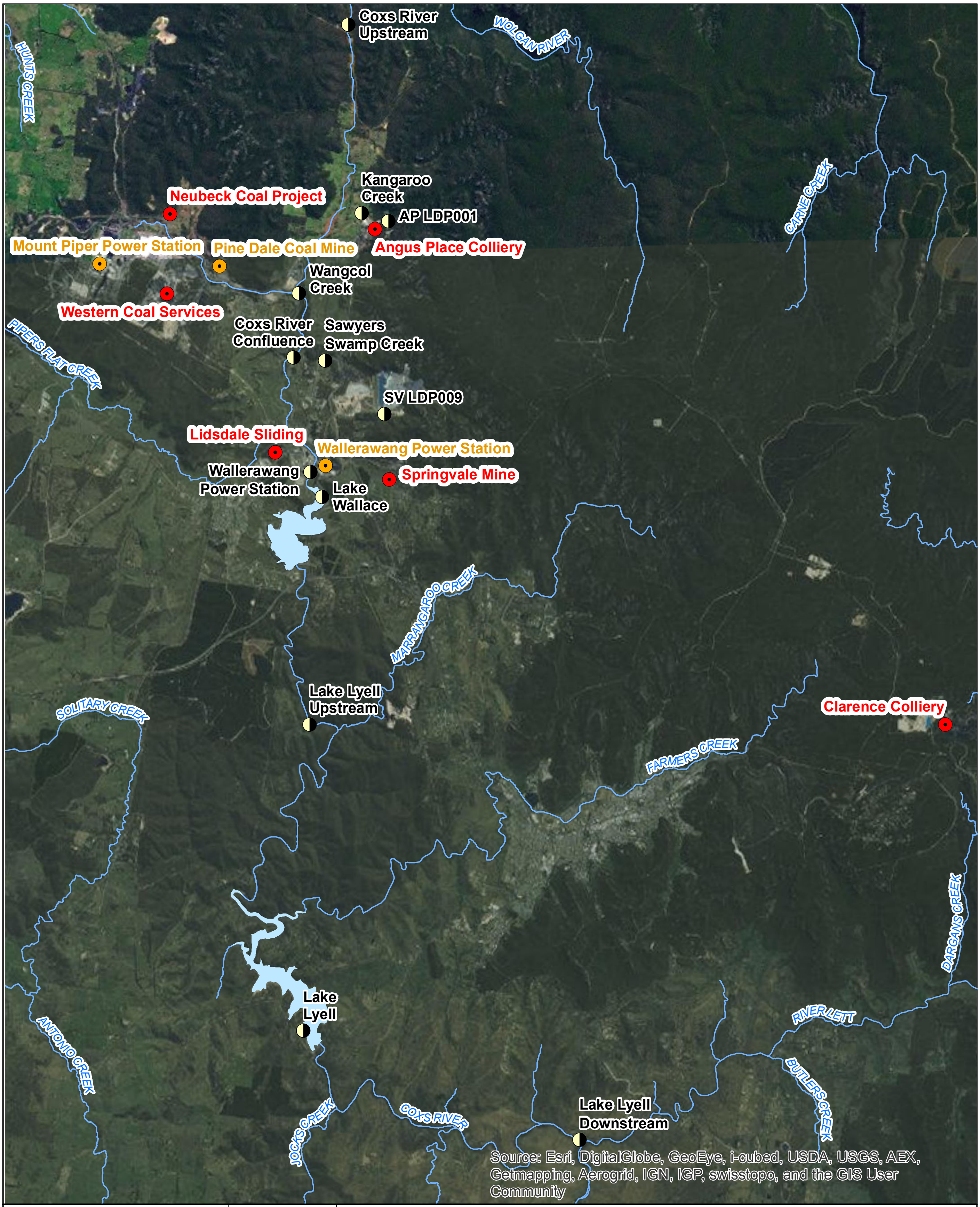
## 2.1 Sample Collection

Samples were collected on the 21 and 22 August 2014 at the following locations, as shown in Figure 2-1:

- Coxs River upstream – Coxs River upstream of Angus Place Colliery and Springvale Mine (at the same location tested by the NSW EPA).
- AP LDP001 – Mine water discharge from AP LDP001, which receives underground mine water and catchment runoff.
- Kangaroo Creek – Kangaroo Creek downstream of AP LDP001.
- Wangcol Creek – Wangcol Creek upstream of the confluence with Coxs River.
- SV LDP009 – Mine water discharge from SV LDP009, which receives underground mine water from both Angus Place Colliery and Springvale Mine.
- Sawyers Swamp Creek – Sawyers Swamp Creek downstream of discharges from SV LDP009 and upstream of confluence with Coxs River.
- Coxs River confluence – Coxs River downstream of the confluence with Sawyers Swamp Creek and discharges from Angus Place Colliery and Springvale Mine.
- Wallerawang Power Station – Coxs River downstream of discharges from Wallerawang Power Station.
- Lake Wallace – Upper portion of Lake Wallace.
- Lake Lyell upstream – Coxs River downstream of Lake Wallace and upstream of Lake Lyell.
- Lake Lyell – Upper portion of Lake Lyell.
- Lake Lyell downstream – Coxs River downstream of Lake Lyell.

A total of 45 L of water was collected at SV LDP009, 10 L at AP LDP001 and 1 L at all other sites with samples put on ice and immediately transferred to the Ecotox Services Australasia (ESA) laboratory in Sydney for toxicity testing. Samples from each location were also sent to the ALS Environmental Division laboratory in Sydney for water quality analysis.

Approximately 47.5 mm of rainfall was recorded at the Lithgow (Cooerwull) Bureau of Meteorology (BOM) station in the five days prior to sampling, as shown in Figure 2-2. The LDP discharges recorded at each Centennial site on the 21 and 22 August 2014 are presented in Table 2-1. Approximately 1 ML/day was discharged through AP LDP001 and 23 ML/day was discharged through SV LDP009.



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

1:125,000 for A4

0 0.4 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

GHD

LEGEND

| | |
|---|---|
| ● Non Centennial Site | — Waterway |
| ● Centennial Site | ▨ Waterbody |
| ◐ Sampling Site | |

| | |
|---|---|
| LOCATION | - |
| SEAM | NA |
| DRAWN | S.M. |
| CHECKED | |
| APPROVED | S.Gray |
| SCALE | Refer to scalebar |

# Coxs River
# Ecotoxicology Assesssment

## Sampling Locations

Centennial Coal

DATE 29/09/2014

Figure 2-1

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Western\Angus Place\2217471\2217471_002_SamplingSites_A.mxd

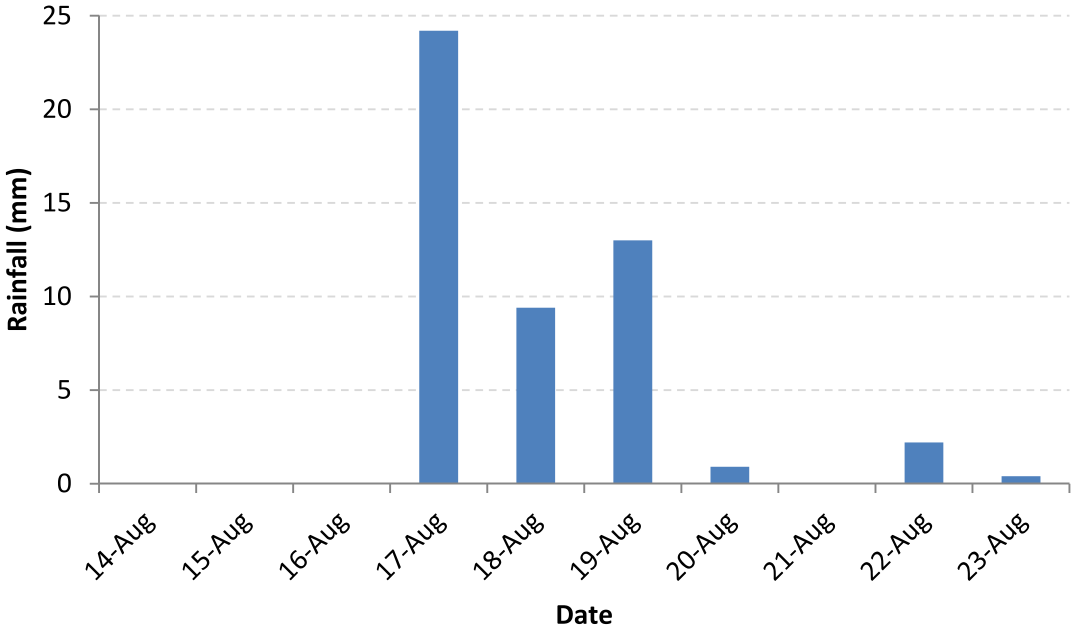


Figure 2-2 Recorded Rainfall Prior To and During Site Visit

Table 2-1 Recorded Discharges during Site Visit

| Location | Discharge (ML/day) | |
|---|---|---|
| | 21 August 2014 | 22 August 2014 |
| **Angus Place Colliery** | | |
| LDP001 | 1.017 | 1.184 |
| LDP002 | 0.008 | 0.009 |
| LDP003 | No discharge | No discharge |
| **Lidsdale Siding** | | |
| LDP004 | No discharge | No discharge |
| **Springvale Mine** | | |
| LDP001 | 1.183 | 1.232 |
| LDP009 | 22.507 | 22.794 |
| **Western Coal Services** | | |
| LDP006 | 0.105 | 0.063 |

## 2.2 Ecotoxicology Assessment

### 2.2.1 Direct Toxicity Assessment

Direct toxicity assessment (DTA) is a common method used to determine the toxicity of mixtures of compounds in ambient waters. The method provides an integrated measure of effects and accounts for interactions (synergistic, additive and ameliorative) within a mixture, therefore closely simulating the effects in the receiving waterway. To ensure a close simulation of the toxic effects of the discharge, site-specific testing was undertaken using species indigenous to, or representative of, the receiving ecosystem.

DTA was undertaken for the mine water discharge samples from AP LDP001 and SV LDP009. Toxicity testing at all other locations was conducted using screening tests with the freshwater cladoceran, which has been found to be the most sensitive test species in previous toxicity testing conducted by Centennial in the region.

Toxicity testing involves exposing laboratory test species to a range of concentrations of sampled water for a specified exposure period. At the end of the exposure period, specific end points are assessed, such as species survival, reproduction or growth. Statistical analysis of the results provide the effect concentration (EC) of the sample where 10% ($EC_{10}$) and 50% ($EC_{50}$) of test organisms exhibit the specific end point and the no observable effect concentration (NOEC), which represents the highest concentration that has no effect upon the test species.

### 2.2.2 Species Tested

Toxicity testing of sampled water was performed using the ANZECC and ARMCANZ (2000) protocol with species endemic to, or representative of, the receiving environment. Where possible, chronic bioassays were performed using National Association of Testing Authorities (NATA) accredited tests.

The following freshwater species and test protocols were used to test the sample collected from SV LDP009 at Springvale Mine:

- Seven day partial life-cycle (chronic) test using the freshwater cladoceran *Ceriodaphnia cf. dubia*, based on the USEPA (2002) and Bailey *et al*. (2000) protocols.
- 72 hour microalgal growth inhibition (chronic) test using the green alga *Selanastrum capricornutum*, based on the USEPA (2002) protocol.
- 96 hour growth inhibition (chronic) test using the freshwater aquatic duckweed *Lemna disperma*, based on the OECD (2006) protocol.
- 96 hour population growth (acute) test using the freshwater hydra *Hydra viridissima*, based on Riethmuller *et al.* (2003).
- 96 hour imbalance (acute) test using the freshwater eastern rainbowfish *Melanotaenia splendida splendida*, based on USEPA (2002).

For the remaining 11 samples, the seven day partial life-cycle (chronic) toxicity test using the freshwater cladoceran *Ceriodaphnia cf. dubia* based on the protocol specified by USEPA (2002) was conducted. The cladoceran bioassay was selected as it has been found to be the most sensitive test species in previous toxicity testing conducted by Centennial in the region.

### 2.2.3 Concentrations Tested

ESA recommended the use of laboratory dilution water to provide a more accurate indication of the toxicity of the samples. ESA used in-house diluents for all dilutions and controls to ensure the toxicity observed can be attributed directly to the sample tested. All samples were serially diluted with the appropriate diluent to achieve the test concentration. This is important as toxicity tests conducted by the NSW EPA indicated that upstream samples may have a similar toxicity to the SV LDP009 discharge in some bioassays (NSW EPA, 2014).

For the samples of water collected at AP LDP001 at Angus Place Colliery and at SV LDP009 at Springvale Mine, the concentrations used in the toxicity testing were 0%, 6.3%, 12.5%, 25%, 50%, and 100%.

For the remaining 10 samples, screening tests with the cladoceran bioassay were conducted at 100% concentration (i.e. no dilution of samples).

## 2.3 Water Quality Assessment

Water samples were tested for the parameters listed in Table 2-2 at the NATA accredited facilities at the ALS Environmental Division Laboratory. This suite of analysis includes the parameters recently specified by the NSW EPA in Springvale Mine’s EPL 3607. In addition, the dissolved oxygen (DO), electrical conductivity, pH, redox potential and turbidity were measured in the field prior to sample collection.

Table 2-2 Water Quality Parameters

| Category | Parameter |
|---|---|
| Physicochemical parameters | Electrical conductivity, pH, total dissolved solids (TDS), total suspended solids (TSS). |
| Nutrients | Ammonia, dissolved organic carbon (DOC), nitrate and nitrite, total Kjeldahl nitrogen, total nitrogen, total phosphorus. |
| Anions | Alkalinity, chloride, sulfate. |
| Cations | Calcium, magnesium, potassium, sodium. |
| Metals (total and dissolved) | Aluminium, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, strontium, vanadium and zinc. |
| Other | Bromide, cyanide (total and free), fluoride, oil and grease, silica. |

The results were compared to site-specific trigger values (SSTVs) derived for discharge from AP LDP001 and SV LDP009 and limits specified by EPL 467 for AP LDP001 and EPL 3607 for SV LDP009, as shown in Table 2-3. The SSTVs adopted were based on a review of the water quality observed at a monitoring site on Kangaroo Creek upstream of Angus Place Colliery as presented by RPS (2014b; 2014c) and default trigger values recommended by ANZECC and ARMCANZ (2000). The numbers indicated in bold are those selected as the adopted trigger value for each parameter. SSTVs have been taken as the largest of the default trigger values (which have been hardness corrected where appropriate) and the 80th percentile upstream concentrations, in accordance with the methodology recommended by ANZECC and ARMCANZ (2000).

Table 2-3 Trigger Values and EPL Limits for Assessment of Water Quality

| Parameter | Unit | 80th percentile upstream value | Default trigger value | Adopted trigger value | AP LDP001 EPL limits | SV LDP009 EPL limits |
|---|---|---|---|---|---|---|
| **Physicochemical parameters** | | | | | | |
| pH | pH units | **5.9(a)**–6.8 | 6.5–**8.0** | 5.9–8.0 | 6.5–9.0 | 6.5–9.0 |
| Electrical conductivity | µS/cm | 89 | **350** | 350 | – | 1,200 |
| TSS | mg/L | 10 | **25** | 25 | 30 | 50 |
| Turbidity | NTU | 19.2 | **25** | 25 | – | 50 |
| **Nutrients** | | | | | | |
| Ammonia | mg/L | 0.03 | **0.9** | 0.9 | – | – |
| Nitrogen (total) | mg/L | **0.6** | 0.25 | 0.6 | – | – |
| Phosphorus (total) | mg/L | **0.06** | 0.02 | 0.6 | – | – |
| **Anions** | | | | | | |
| Bicarbonate alkalinity | mg/L | 20.8 | – | 225(b) | – | – |
| Sulfate | mg/L | 6 | – | 644(c) | – | – |
| **Filtered metals** | | | | | | |
| Aluminium | mg/L | **0.204** | 0.055 | 0.204 | – | 0.45 |
| Arsenic | mg/L | 0.001(d) | **0.024** | 0.024 | – | 0.024 |
| Barium | mg/L | **0.0368** | – | 0.0368 | – | – |
| Boron | mg/L | **0.05**(d) | – | 0.05 | – | – |
| Cadmium | mg/L | 0.0001(d) | **0.0005(e)** | 0.0005 | – | – |
| Chromium | mg/L | **0.001**(d) | – | 0.001 | – | – |
| Cobalt | mg/L | **0.005** | – | 0.005 | – | – |
| Copper | mg/L | **0.004** | 0.003(e) | 0.004 | – | 0.007 |
| Iron | mg/L | **4.002** | 0.3 | 4.002 | – | 0.4 |
| Lead | mg/L | 0.001(d) | **0.011(e)** | 0.011 | – | – |

| Parameter | Unit | 80th percentile upstream value | Default trigger value | Adopted trigger value | AP LDP001 EPL limits | SV LDP009 EPL limits |
|---|---|---|---|---|---|---|
| Manganese | mg/L | 0.4526 | **1.9** | 1.9 | – | 1.7 |
| Mercury | mg/L | – | **0.0006** | 0.0006 | – | – |
| Nickel | mg/L | 0.002 | **0.025**(e) | 0.025 | – | 0.047 |
| Selenium | mg/L | 0.01(d) | **0.11** | 0.11 | – | – |
| Zinc | mg/L | **0.019** | 0.018(e) | 0.019 | – | 0.05 |
| **Other parameters** | | | | | | |
| Cyanide (total) | mg/L | 0.004(d) | **0.007** | 0.007 | – | – |
| Fluoride | mg/L | **0.1(d)** | – | 0.1 | – | 1.8 |
| Oil and grease | mg/L | **5(d)** | – | **5** | 10 | 10 |

(a) 20th percentile value

(b) NSW OEH (2012)

(c) Elphick *et al.* (2011)

(d) Limit of reporting

(e) Hardness correction applied

The NSW OEH (2012) reports that bicarbonate is one of the more potentially toxic major ions to aquatic organisms. Bicarbonate has been found to be about two to 2.5 times more acutely toxic to cladoceran than chloride. There remains uncertainty regarding the most appropriate trigger value for bicarbonate in freshwater. A 95% species protection trigger value for bicarbonate of 225 mg/L was calculated by NSW OEH (2012) based on NOEC data generated from North American species described by Farag and Harper (2012).

A 95% species protection trigger value for sulfate of 644 mg/L was calculated using results from a suite of freshwater species bioassays for temperate freshwater systems with various hardness concentrations (Elphick *et al.* 2011). Elphick *et al.* (2011) used the $EC_{10}$ results from a suite of nine species, many of them used in routine bioassays for DTA by Australian laboratories for temperate freshwater ecosystems. As shown by Elphick *et al.* (2011), increasing hardness reduces the toxicity of sulfate to freshwater temperate organisms similar to those living in the Coxs River and its tributaries.

## 2.4 Catchment Dilution Assessment

### 2.4.1 Statistical Analysis of Ecotoxicology Results

The BurrliOZ statistical analytical program (Campbell *et al.*, 2000) used the $EC_{10}$ results from the sample collected at SV LDP009 to calculate the concentration of mine water discharge to protect 99%, 95%, 90% and 90% of species in the receiving environment from a 10% reduction in growth or reproduction. Dilution factors were then calculated for each species protection level, which can be used to assist in deriving site-specific concentrations of contaminants that will not adversely impact organisms within the receiving ecosystem. Concentrations of individual contaminants cannot be extrapolated from toxicity testing results for use as trigger values. However, concentrations can be used for monitoring purposes to ensure that the dilution factors are met at the appropriate monitoring site.

### 2.4.2 Catchment Runoff

An estimate of the runoff contributing to the Coxs River was obtained from the water balance model developed by RPS (2014a). The model represented all catchments contributing to Lake Burragorang, as shown in Figure 2-3, using the Australian Water Balance Model (AWBM) within the GoldSim Version 10.50 software modelling package. The AWBM is a catchment water balance model that calculates runoff from rainfall after allowing for relevant losses and storage. The AWBM is widely used throughout Australia and has been verified through comparison with large amounts of recorded streamflow data.

The catchments within the water balance model were categorised into the following land use types, each modelled with different AWBM parameters (RPS, 2014a):

- Natural.
- Pasture.
- Urban.
- Disturbed.
- Channel.

The AWBM parameters for each land use type were calibrated using historical rainfall data from the BOM and flow data from gauges on the Coxs River over the period from 1 January 1979 to 30 June 2014. Further details on the model methodology, calibration, parameters and data used are provided by RPS (2014a).

The daily catchment runoff volume were determined for 16 locations extending downstream of SV LDP009 at Springvale Mine to Lake Burragorang shown in Figure 2-4 using the median rainfall dataset applied within the water balance model by RPS (2014a). Catchment runoff was obtained from the water balance model without the contribution of other operations (Mount Piper Power Station, proposed Neubecks Coal Project and Pine Dale Coal Mine).

### 2.4.3 Dilution Factor

The estimated catchment runoff to the Coxs River at each location was compared to the predicted maximum daily discharge volume from AP LDP001 and SV LDP009 to determine the expected dilution of discharge within the river. The dilution factor was assessed for the three water management strategies discussed in Section 1.4.

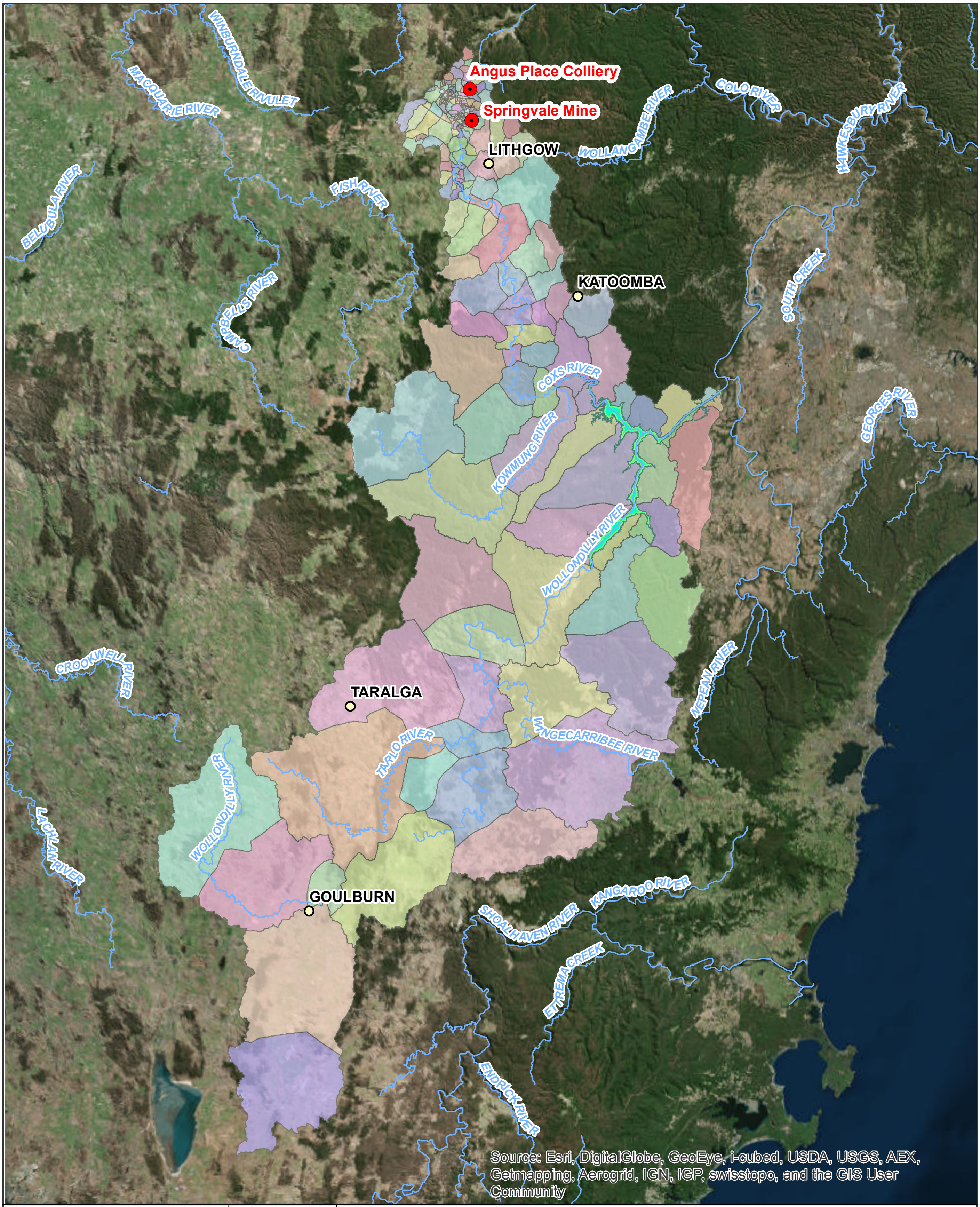
The predicted maximum daily discharge volumes from AP LDP001 and SV LDP009 over the life of each mine for the three water management strategies are presented in Table 2-4. These values were obtained from the water balance model provided by RPS (2014a).

Table 2-4 Predicted Maximum Daily Discharge through AP LDP001 and SV LDP009 (RPS, 2014a)

| Water strategy | AP LDP001 discharge (ML/day) | SV LDP009 discharge (ML/day) | Total discharge (ML/day) |
|---|---|---|---|
| WS1 | 30.8 | 18.8 | 45.4* |
| WS2a | 15.4 | 30 | 45.4 |
| WS2b | 2 | 43.4 | 45.4 |

* Peak daily discharges from AP LDP001 and SV LDP009 occur at different points in time, so the maximum total discharge does not equal the sum of the maximum discharge from the individual LDPs.

The predicted dilution within the Coxs River was compared to the dilution factor determined by the results of toxicity testing using the BurrliOZ statistical analytical program (Campbell *et al.*, 2000).



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

1:1,000,000 for A4

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

LEGEND

- ● Centennial Site
- 🟩 Lake Burragorang
- — Waterway

| | |
|---|---|
| LOCATION | - |
| SEAM | NA |
| DRAWN | S.M. |
| CHECKED | |
| APPROVED | S.Gray |
| SCALE | Refer to scalebar |

## Coxs River
## Ecotoxicology Assesssment
## Catchments within
## Water Balance Model (RPS, 2014a)

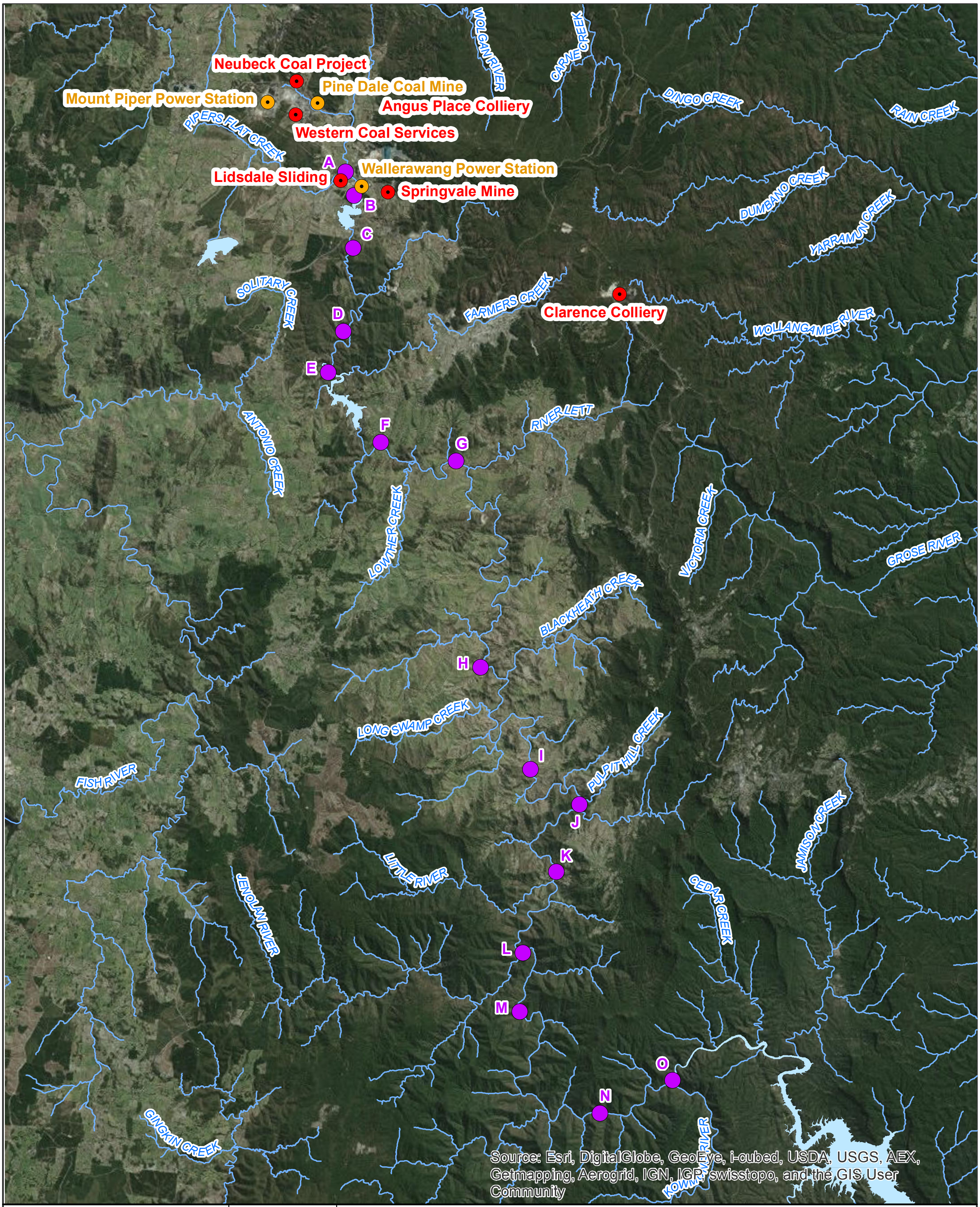
Centennial Coal

DATE 29/09/2014

Figure 2-3

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Western\Angus Place\2217471\2217471_008_ModelCatchments_B.mxd

© Commonwealth of Australia (Geoscience Australia): 250K Topographic Data Series 3 2006; LPI: DTDB 2012



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

1:300,000 for A4

0 0.75 1.5 3 4.5 6

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

GHD

LEGEND

- ● Non Centennial Site
- ● Centennial Site
- ● Modelled Catchment Runoff Location
- — Waterway
- ▭ Waterbody

| | |
|---|---|
| LOCATION | - |
| SEAM | NA |
| DRAWN | S.M. |
| CHECKED | |
| APPROVED | S.Gray |
| SCALE | Refer to scalebar |

Coxs River
Ecotoxicology Assesssment

Catchment Runoff Locations

Centennial
Coal

DATE 29/09/2014

Figure 2-4

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Western\Angus Place\2217471\2217471_006_CatchmentRunoff_A.mxd

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# 3. Results and Discussion

## 3.1 Ecotoxicology Assessment

The toxicity testing conducted by ESA fulfilled the criteria for NATA accredited tests with all quality assurance/quality control parameters being met. A copy of the toxicity report is provided in Appendix B and a summary of the results is presented in Table 3-1 for the samples collected at AP LDP001 and SV LDP009 and

Table 3-2 for the screening tests with the cladoceran bioassay. Screening bioassay results are considered to show toxicity if the results are <80% of the controls. This is based on the quality control parameter used by the testing laboratory.

As discussed in Section 2.2.1, statistical analysis of the toxicity testing results provide the concentration of the sample where 10% ($EC_{10}$) and 50% ($EC_{50}$) of test organisms exhibit the specific end point of the bioassay.

Table 3-1 Summary of AP LDP001 and SV LDP009 Ecotoxicology Results

| Bioassay | Concentration (95% confidence limits) | |
|---|---|---|
| | $EC_{10}$ | $EC_{50}$ |
| **SV LDP009 discharge** | | |
| Eight day cladoceran reproduction | 9.3%<br>(5.2%–16.0%) | 29.1%<br>(16.3%–50.3%) |
| 72 hour microalgal growth inhibition | 3.7%<br>(2.3%–3.8%) | 6.0%<br>(5.5%–6.7%) |
| 96 hour duckweed growth inhibition | >100% | >100% |
| 96 hour hydra population growth | 5.1%<br>(2.4%–7.3%) | 18.0%<br>(13.9%–24.8%) |
| 96 hour eastern rainbowfish imbalance | 25%<br>(0.0%–34.2%) | 50%<br>(41.7%–59.2%) |
| **AP LDP001 discharge** | | |
| Eight day cladoceran reproduction | >100% | >100% |

The results of toxicity testing of SV LDP009 discharge presented in Table 3-1 indicate that the discharge is toxic to the test species, with the alga, cladoceran and hydra species showing significant toxicity to the discharge. The alga was observed to have the most sensitivity to the discharge from SV LDP009. The duckweed test showed no toxicity to the discharge and the fish bioassay showed only slight sensitivity.

The results of testing of the sample collected at AP LDP001 indicate that the discharge of mine water from Angus Place Colliery is not toxic to the test species with the reproduction showing no difference to the control organisms at 100% concentration.

### Table 3-2 Summary of Screening Ecotoxicology Results

| Site | Location description | Reproduction (% of control) | Survival (%) | EC (µS/cm) |
|---|---|---|---|---|
| Laboratory control | | 100 | 90 | 187 |
| Coxs River upstream | Coxs River upstream of Angus Place Colliery and Springvale Mine | 1 | 40 | 42 |
| AP LDP001 | Mine water discharge from AP LDP001 | 140 | 90 | 1,038 |
| Kangaroo Creek* | Kangaroo Creek downstream of AP LDP001 | No data | No data | 558 |
| Wangcol Creek | Wangcol Creek upstream of the confluence with Coxs River | 70 | 100 | 806 |
| SV LDP009 | Mine water discharge from SV LDP009 | 0 | 0 | 1,180 |
| Sawyers Swamp Creek | Sawyers Swamp Creek downstream of discharges from SV LDP009 and upstream of confluence with Coxs River | 4 | 80 | 1,089 |
| Coxs River confluence | Coxs River downstream of the confluence with Sawyers Swamp Creek and discharges from Angus Place Colliery and Springvale Mine | 29 | 100 | 1,007 |
| Wallerawang Power Station | Coxs River downstream of discharges from Wallerawang Power Station | 66 | 100 | 949 |
| Lake Wallace | Upper portion of Lake Wallace | 116 | 100 | 986 |
| Lake Lyell upstream | Coxs River downstream of Lake Wallace and upstream of Lake Lyell | 106 | 100 | 1,049 |
| Lake Lyell | Upper portion of Lake Lyell | 107 | 90 | 547 |
| Lake Lyell downstream | Coxs River downstream of Lake Lyell | 113 | 100 | 506 |

* Ecotoxicology testing was not possible during this round of testing and will be repeated as part of following rounds.

## 3.1 Water Quality Assessment

The water quality testing conducted by ALS fulfilled the criteria for NATA accredited tests with all quality assurance/quality control parameters being met, with the exception of pH and nitrite due to testing not being conducted within the appropriate holding times. A copy of the full report is provided in Appendix C and a summary of the results is presented in Table 3-3. The results are compared to SSTVs derived for discharge from AP LDP001 and SV LDP009 and limits specified by EPL 467 for AP LDP001 and EPL 3607 for SV LDP009, as shown in Table 2-3. Exceedances of the adopted trigger values have been shown in bold.

## Table 3-3 Summary of Water Quality Assessment Results

| Parameter | Unit | Coxs River upstream | AP LDP001 | Kangaroo Creek | Wangcol Creek | SV LDP009 | Sawyers Swamp Creek | Coxs River confluence | Wallerawang Power Station | Lake Wallace | Lake Lyell upstream | Lake Lyell | Lake Lyell downstream |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Physicochemical parameters** | | | | | | | | | | | | | |
| pH (field) | pH units | 6.47 | 7.84 | 8.33 | 7.82 | 8.04 | 9.00 | 8.50 | 9.04 | 9.55 | 9.53 | 9.50 | 9.40 |
| pH (lab) | | 5.69 | 8.01 | 8.28 | 6.98 | 8.21 | 8.73 | 8.47 | 8.4 | 8.41 | 8.65 | 8.42 | 8.28 |
| DO | % | 72 | 3.7 | 80 | 85 | 94.7 | 88.9 | 88.4 | 62.7 | 76.5 | 83.7 | 93.3 | 96.6 |
| | mg/L | 8.22 | 0.4 | 9 | 9.72 | 8.1 | 8.32 | 8.83 | 6.64 | 8.57 | 9.45 | 10.62 | 11.15 |
| Electrical conductivity (field) | µS/cm | 44.8 | 1,000 | 558 | 554 | 1,148 | 1,055 | 799 | 931 | 1,033 | 1,029 | 534 | 493 |
| Electrical conductivity (lab) | | 39 | 1,050 | 591 | 823 | 1,200 | 1,100 | 1,030 | 973 | 1,010 | 1,080 | 557 | 516 |
| Redox potential | mV | 162 | 63 | 75 | 49 | 9.6 | -22.8 | 51.3 | -4.4 | -11.9 | -17.1 | -13.7 | -19.2 |
| TDS | mg/L | 25 | 682 | 384 | 535 | 780 | 715 | 670 | 632 | 656 | 702 | 362 | 335 |
| Temperature | °C | 9.4 | 9.4 | 6.9 | 9.5 | 22.9 | 18.5 | 15.2 | 12 | 10 | 9.8 | 9.4 | 9.3 |
| Total hardness | mg/L | <1 | 116 | 64 | 244 | 2 | 7 | 76 | 101 | 96 | 82 | 50 | 65 |
| TSS | mg/L | 22 | <5 | 13 | 5 | 19 | 10 | 10 | <5 | <5 | <5 | <5 | <5 |

| Parameter | Unit | Coxs River upstream | AP LDP001 | Kangaroo Creek | Wangcol Creek | SV LDP009 | Sawyers Swamp Creek | Coxs River confluence | Wallerawang Power Station | Lake Wallace | Lake Lyell upstream | Lake Lyell | Lake Lyell downstream |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Turbidity | NTU | 0.0 | 0.0 | 0.0 | – | 13.5 | 10.5 | – | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Nutrients** | | | | | | | | | | | | | |
| Ammonia | mg/L | <0.01 | <0.01 | <0.01 | 0.02 | 0.44 | 0.09 | 0.06 | 0.04 | 0.03 | <0.01 | <0.01 | <0.01 |
| DOC | mg/L | 48 | 17 | 14 | 7 | 55 | 66 | 6 | 5 | 6 | 42 | 20 | 24 |
| Nitrite + nitrate | mg/L | 0.24 | 0.34 | 0.02 | <0.01 | 0.21 | 0.45 | 0.42 | 0.32 | 0.13 | <0.01 | 0.14 | 0.04 |
| Total Kjeldahl nitrogen | mg/L | <0.1 | <0.1 | <0.1 | <0.1 | 0.6 | 0.1 | 0.2 | 0.2 | 0.3 | 0.2 | 0.3 | 0.2 |
| Nitrogen (total) | mg/L | 0.2 | 0.3 | <0.1 | <0.1 | 0.8 | 0.6 | 0.6 | 0.5 | 0.4 | 0.2 | 0.4 | 0.2 |
| Phosphorus (total) | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 |
| **Anions** | | | | | | | | | | | | | |
| Bicarbonate alkalinity | mg/L | 1 | 538 | 291 | 16 | 625 | 512 | 392 | 359 | 336 | 348 | 111 | 128 |
| Total alkalinity | mg/L | 1 | 538 | 291 | 16 | 625 | 572 | 414 | 375 | 352 | 388 | 113 | 128 |
| Chloride | mg/L | 8 | 10 | 10 | 34 | 6 | 6 | 15 | 16 | 20 | 18 | 16 | 16 |

| Parameter | Unit | Coxs River upstream | AP LDP001 | Kangaroo Creek | Wangcol Creek | SV LDP009 | Sawyers Swamp Creek | Coxs River confluence | Wallerawang Power Station | Lake Wallace | Lake Lyell upstream | Lake Lyell | Lake Lyell downstream |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sulfate | mg/L | 3 | 25 | 17 | 341 | 34 | 34 | 142 | 126 | 160 | 164 | 117 | 107 |
| **Cations** | | | | | | | | | | | | | |
| Calcium | mg/L | <1 | 20 | 11 | 45 | 1 | 1 | 14 | 19 | 17 | 13 | 10 | 13 |
| Magnesium | mg/L | <1 | 16 | 9 | 32 | <1 | 1 | 10 | 13 | 13 | 12 | 6 | 8 |
| Potassium | mg/L | <1 | 32 | 19 | 7 | 9 | 10 | 10 | 11 | 12 | 13 | 7 | 8 |
| Sodium | mg/L | 4 | 182 | 98 | 59 | 291 | 280 | 208 | 202 | 192 | 209 | 75 | 73 |
| **Dissolved metals** | | | | | | | | | | | | | |
| Aluminium | mg/L | 0.03 | <0.01 | 0.02 | 0.02 | 0.01 | 0.03 | 0.02 | 0.02 | 0.01 | <0.01 | <0.01 | <0.01 |
| Arsenic | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | 0.024 | 0.021 | 0.014 | 0.01 | 0.006 | 0.004 | <0.001 | <0.001 |
| Barium | mg/L | 0.016 | 0.178 | 0.092 | 0.014 | 0.028 | 0.021 | 0.02 | 0.023 | 0.026 | 0.025 | 0.026 | 0.023 |
| Beryllium | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Boron | mg/L | <0.05 | 0.06 | <0.05 | 0.14 | 0.07 | 0.07 | 0.1 | 0.08 | 0.12 | 0.18 | 0.09 | 0.08 |
| Cadmium | mg/L | <0.0001 | <0.0001 | <0.0001 | 0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Chromium | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cobalt | mg/L | <0.001 | <0.001 | <0.001 | 0.006 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Copper | mg/L | <0.001 | 0.001 | 0.002 | 0.003 | <0.001 | <0.001 | <0.001 | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 |

| Parameter | Unit | Coxs River upstream | AP LDP001 | Kangaroo Creek | Wangcol Creek | SV LDP009 | Sawyers Swamp Creek | Coxs River confluence | Wallerawang Power Station | Lake Wallace | Lake Lyell upstream | Lake Lyell | Lake Lyell downstream |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iron | mg/L | 0.09 | <0.05 | 0.06 | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Lead | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Manganese | mg/L | 0.057 | 0.003 | 0.01 | 0.812 | 0.008 | 0.013 | 0.113 | 0.077 | 0.04 | 0.011 | 0.002 | 0.008 |
| Mercury | mg/L | 0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Molybdenum | mg/L | <0.001 | 0.012 | 0.006 | <0.001 | 0.038 | 0.034 | 0.022 | 0.018 | 0.015 | 0.016 | 0.005 | 0.004 |
| Nickel | mg/L | 0.004 | 0.003 | 0.002 | 0.021 | 0.004 | 0.003 | 0.01 | 0.007 | 0.007 | 0.004 | 0.002 | 0.002 |
| Selenium | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Strontium | mg/L | 0.009 | 0.117 | 0.079 | 0.188 | 0.03 | 0.028 | 0.083 | 0.088 | 0.117 | 0.139 | 0.12 | 0.109 |
| Vanadium | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | mg/L | 0.011 | 0.016 | 0.012 | 0.037 | 0.007 | 0.005 | 0.012 | 0.016 | 0.047 | 0.005 | <0.005 | 0.005 |
| **Total metals** | | | | | | | | | | | | | |
| Aluminium | mg/L | 0.05 | 0.02 | 0.05 | 0.11 | 0.19 | 0.19 | 0.14 | 0.1 | 0.07 | 0.06 | 0.02 | 0.04 |
| Arsenic | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | 0.023 | 0.022 | 0.014 | 0.01 | 0.006 | 0.004 | <0.001 | <0.001 |
| Barium | mg/L | 0.016 | 0.194 | 0.089 | 0.011 | 0.027 | 0.024 | 0.023 | 0.022 | 0.025 | 0.025 | 0.023 | 0.02 |
| Beryllium | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Boron | mg/L | <0.05 | 0.07 | <0.05 | 0.16 | 0.06 | 0.08 | 0.1 | 0.09 | 0.12 | 0.19 | 0.11 | 0.09 |

| Parameter | Unit | Coxs River upstream | AP LDP001 | Kangaroo Creek | Wangcol Creek | SV LDP009 | Sawyers Swamp Creek | Coxs River confluence | Wallerawang Power Station | Lake Wallace | Lake Lyell upstream | Lake Lyell | Lake Lyell downstream |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cadmium | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Chromium | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cobalt | mg/L | <0.001 | <0.001 | <0.001 | 0.005 | <0.001 | 0.002 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Copper | mg/L | 0.002 | <0.001 | 0.002 | <0.001 | 0.003 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.001 | <0.001 |
| Iron | mg/L | 0.61 | <0.05 | 0.23 | 0.3 | 0.3 | 0.24 | 0.31 | 0.2 | 0.1 | 0.05 | <0.05 | 0.1 |
| Lead | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Manganese | mg/L | 0.058 | 0.006 | 0.012 | 0.859 | 0.014 | 0.059 | 0.154 | 0.09 | 0.059 | 0.031 | 0.006 | 0.013 |
| Mercury | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Molybdenum | mg/L | <0.001 | 0.014 | 0.005 | <0.001 | 0.036 | 0.039 | 0.026 | 0.021 | 0.017 | 0.018 | 0.005 | 0.005 |
| Nickel | mg/L | <0.001 | 0.002 | 0.001 | 0.02 | 0.003 | 0.004 | 0.011 | 0.007 | 0.006 | 0.004 | 0.002 | 0.002 |
| Selenium | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Strontium | mg/L | 0.007 | 0.117 | 0.066 | 0.18 | 0.015 | 0.025 | 0.081 | 0.087 | 0.116 | 0.131 | 0.106 | 0.097 |
| Vanadium | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | mg/L | 0.009 | 0.01 | 0.014 | 0.027 | 0.017 | 0.009 | 0.014 | 0.008 | <0.005 | <0.005 | <0.005 | <0.005 |
| **Other parameters** | | | | | | | | | | | | | |
| Bromide | mg/L | <0.010 | 0.067 | 0.035 | 0.092 | 0.046 | 0.057 | 0.082 | 0.082 | 0.074 | 0.065 | 0.076 | 0.063 |

| Parameter | Unit | Coxs River upstream | AP LDP001 | Kangaroo Creek | Wangcol Creek | SV LDP009 | Sawyers Swamp Creek | Coxs River confluence | Wallerawang Power Station | Lake Wallace | Lake Lyell upstream | Lake Lyell | Lake Lyell downstream |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyanide (free) | mg/L | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| Cyanide (total) | mg/L | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| Fluoride | mg/L | <0.1 | 1 | 0.7 | 0.2 | 1.5 | 1.8 | 1.3 | 1.1 | 1.1 | 1.1 | 0.6 | 0.6 |
| Oil and grease | mg/L | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Silica | mg/L | 9.4 | 8.6 | 9.7 | 7.5 | 8.6 | 8.5 | 7.8 | 7.8 | 3.9 | 1 | 0.2 | 1.8 |

As seen in Table 3-3, water quality results show that the majority of sites exceed the adopted trigger values for pH, electrical conductivity, total nitrogen, total phosphorus, bicarbonate alkalinity and bromide. AP LDP001 exceeded the adopted trigger value for barium and the value for dissolved zinc was exceeded at Lake Wallace and Wangcol Creek.

The underground water discharges from Angus Place Colliery and Springvale Mine via AP LDP001 and SV LDP009 were found to be slightly alkaline and fresh to slightly brackish, with a sodium bicarbonate (Na-$HCO_3$) type.

The change in water type throughout the catchment is shown by the Stiff diagrams in Figure 3-1. A Stiff diagram is a graphical representation of major ion concentrations in water. The greater the area of the polygon presented in the Stiff diagram, the higher the ionic concentration (or electrical conductivity) of the water.

As shown in Figure 3-1, the upper Coxs River catchment is sodium magnesium chloride (Na-Mg-Cl) type water. Mixing of inputs from Wangcol Creek (Mg-Na-Ca-$SO_4$ water type) and discharges from Angus Place Colliery and Springvale Mine result in a sodium bicarbonate sulfate (Na-$HCO_3$-$SO_4$) water type. This is the dominant water type from the confluence of Sawyers Swamp Creek with Coxs River to downstream of Lake Lyell, with the electrical conductivity reducing with distance downstream.

## 3.2 Catchment Dilution Assessment

### 3.2.1 Statistical Analysis of Ecotoxicology Results

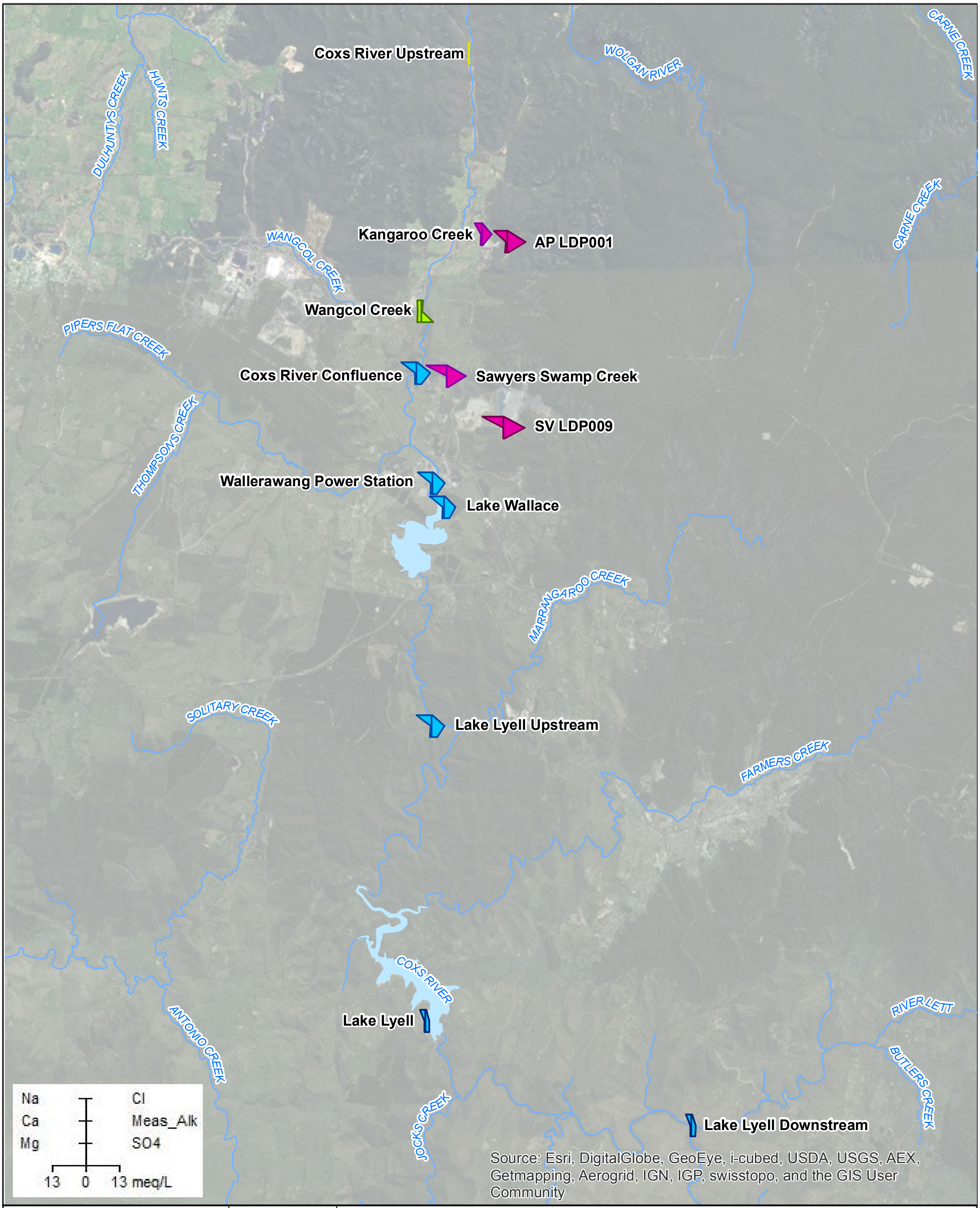
The $EC_{10}$ values presented in Table 3-1 for SV LDP009 discharge were analysed in the BurrliOZ software package (Campbell *et al*., 2000) and the concentration for varying species protection levels were calculated, as shown in Table 3-4. A concentration of SV LDP009 discharge of 2.7% was determined to provide protection to 95% of species in the downstream ecosystem. To reach a concentration of 2.7%, a dilution factor of 1:37 is required.

Table 3-4 Dilution Factor Determined from Ecotoxicology Results

| Species protection (%) | Concentration of SV LDP009 (%) | Dilution factor |
|---|---|---|
| 80 | 5.1 | 1:20 |
| 90 | 3.6 | 1:28 |
| 95 | 2.7 | 1:37 |
| 99 | 1.7 | 1:59 |

### 3.2.1 Catchment Runoff

The daily catchment runoff determined at locations A to O presented in Figure 2-4 are provided in Table 3-5. Median results are presented along with 10th percentile and 90th percentile values to provide an indication of the possible range of values expected. The median, or 50th percentile, represents the value at which half of the modelled outputs were less than this value. Similarly, the 10th and 90th percentile results represent the values at which 10% and 90% of the modelled outputs were less than these values respectively. The 10th percentile and 90th percentile results have been used (rather than absolute minimum and maximum values) to remove the impact of skewing by infrequent to extreme wet and dry conditions.



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

1:130,000 for A4

0 0.4 0.8 1.6 2.4 3.2
Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

GHD

LEGEND
- Waterway
- Waterbody
- Mg-Na-Ca-$SO_4$
- Na-Mg-Cl
- Na-$HCO_3$-$SO_4$
- Na-$HCO_3$

| | |
|---|---|
| LOCATION | - |
| SEAM | NA |
| DRAWN | S.M. |
| CHECKED | |
| APPROVED | S.Gray |
| SCALE | Refer to scalebar |

Coxs River
Ecotoxicology Assesssment

Stiff Diagrams

Centennial Coal

DATE 29/09/2014

Figure 3-1

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Western\Angus Place\2217471\2217471_003_StiffDiagrams_A.mxd

Table 3-5 Modelled Catchment Runoff

| Location | Catchment runoff volume (ML/day) | | |
|---|---|---|---|
| | 10th percentile | 50th percentile | 90th percentile |
| A | 0.63 | 2.33 | 23.58 |
| B | 1.18 | 3.19 | 40.29 |
| C | 0.70 | 0.70 | 39.76 |
| D | 1.54 | 4.14 | 67.03 |
| E | 1.83 | 5.07 | 72.84 |
| F | 2.29 | 7.67 | 39.68 |
| G | 2.32 | 8.31 | 67.03 |
| H | 2.42 | 10.36 | 181.12 |
| I | 2.44 | 11.56 | 243.86 |
| J | 2.46 | 13.16 | 310.72 |
| K | 3.83 | 24.33 | 399.82 |
| L | 5.45 | 30.68 | 471.66 |
| M | 10.84 | 51.90 | 594.91 |
| N | 15.20 | 68.74 | 692.29 |
| O | 16.07 | 71.70 | 717.06 |

### 3.2.2 Dilution Factor

The predicted dilution of SV LDP009 discharges by catchment runoff for each location is presented in Table D-1, Table D-2 and Table D-3 of Appendix D for water strategy WS1, WS2a and WS2b respectively. The predicted dilution of total discharges from AP LDP001 and SV LDP009 is presented in Table D-4 of Appendix D. The results presented in Table D-4 apply to all three water strategies, as the predicted total maximum daily discharge of 45.4 ML/day is the same for each strategy.

## 3.3 Discussion

### 3.3.1 Ecotoxicology Assessment

The water quality results for SV LDP009 shown in Table 3-3 do not indicate any parameters that are present in concentrations that could cause the significant toxicity observed in the ecotoxicology results presented in Table 3-1. Furthermore, the chemistry of discharge from AP LDP001, which did not show any toxicity in the cladoceran bioassay, was found to be very similar to that of SV LDP009. The cause of the toxicity of SV LDP009 discharge observed may be related to treatment with flocculants prior to discharge. This potential cause of toxicity is recommended to be investigated, as the treatment is the only difference between AP LDP001 discharges (no toxicity) and SV LDP009 discharges (significant toxicity).

The screening bioassay results show that the Coxs River upstream site exhibits significant toxicity to cladoceran reproduction and survival tests. This site had low electrical conductivity and the associated ionic imbalance may be responsible for the observed toxicity, as it places the organisms under osmotic stress.

AP LDP001 discharges showed no significant difference in cladoceran survival and an increased reproduction when compared to the control. The Kangaroo Creek site was not tested for toxicity in this study; however the sampling conducted by the NSW EPA in May 2014 did not show any toxicity at this site with an electrical conductivity of 820 µS/cm.

The Wangcol Creek sample showed that there was a slight toxic impact on the cladoceran with a 37% decrease in reproduction. It is unlikely that the slightly elevated zinc detected at this site would be contributing to all of the observed toxicity.

The sample taken at Sawyers Swamp Creek showed an improvement in cladoceran survival when compared to the SV LDP009 discharge with an 80% survival rate; however reproduction was still significantly decreased. Further downstream in the Coxs River, the cladoceran survival rate improved and was not significantly different from control test at this and all the other downstream sampling locations. The cladoceran reproduction rate was still significantly impacted at the sites on the Coxs River downstream of Sawyers Swamp Creek confluence and downstream of Wallerawang Power Station. The rate of cladoceran reproduction was above the control rate from the upper portion of Lake Wallace and at all other sites downstream of this location.

The electrical conductivity results for each site and the associated cladoceran reproduction toxicity results are shown in Figure 3-2. A linear regression has been conducted on the results, which shows an $R^2$ value of 0.0018, indicating that there is no correlation between toxicity and electrical conductivity.

Bicarbonate alkalinity has also been suggested by the NSW OEH (2012) as a potential toxicant in coal mine discharge water. The bicarbonate alkalinity results for each site and the associated cladoceran reproduction toxicity results are shown in Figure 3-3. A linear regression has been conducted on the results, which shows an $R^2$ value of 0.0099, indicating that there is no correlation between toxicity and bicarbonate alkalinity.

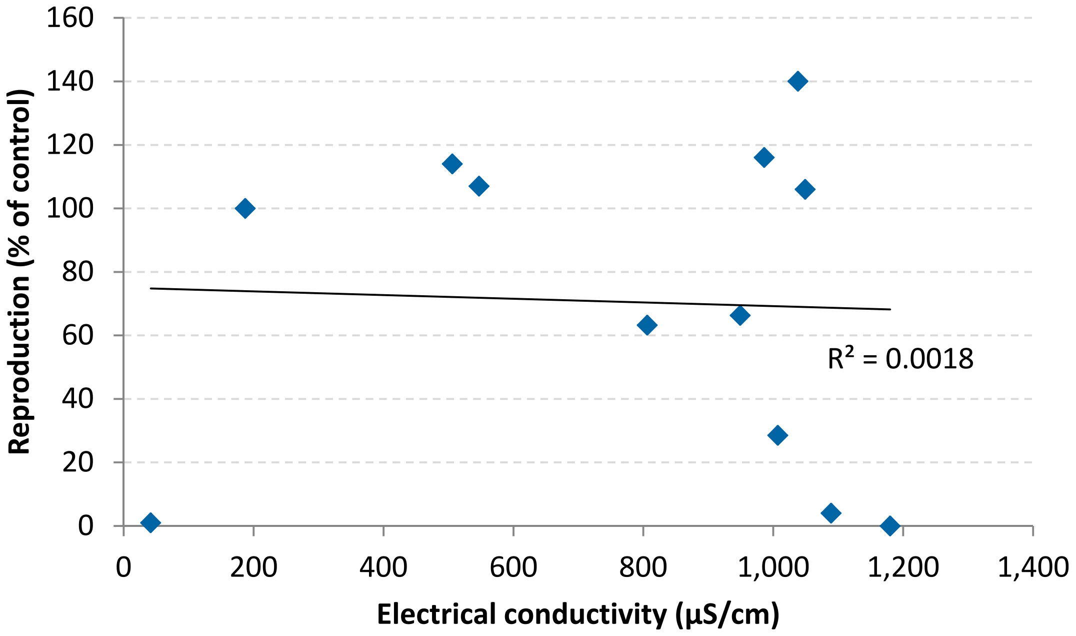


Figure 3-2 Reproduction Toxicity and Electrical Conductivity Results

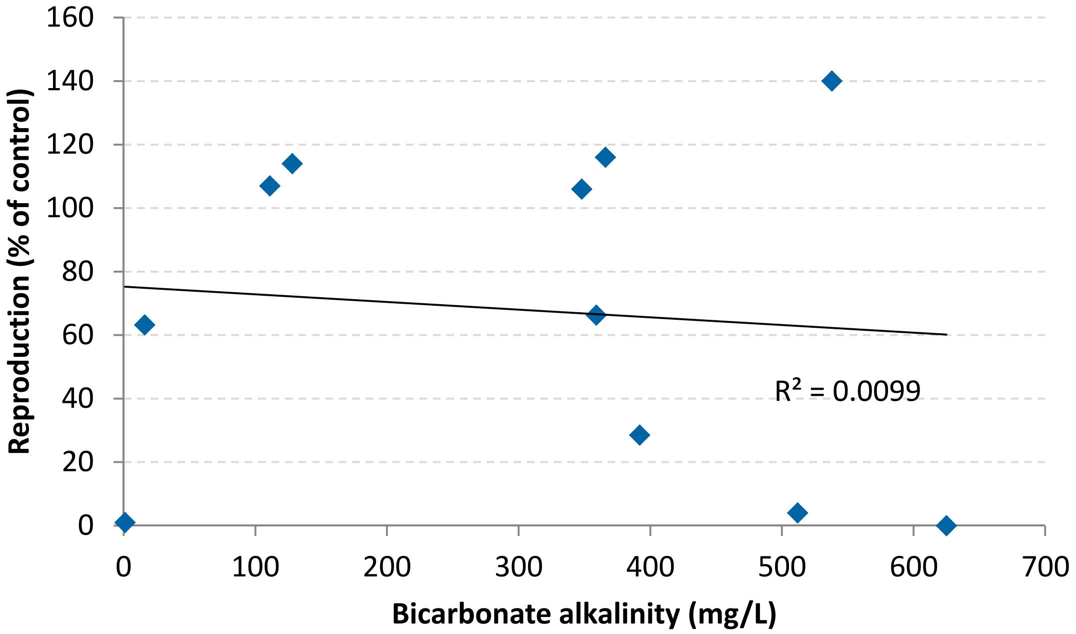


Figure 3-3 Reproduction Toxicity and Bicarbonate Alkalinity Results

### 3.3.2 Dilution Factor

The target dilution of SV LDP009 discharge to 2.7% (refer Section 3.2.1) is not met under median rainfall conditions. Under 90th percentile rainfall conditions, the target dilution is achieved for water strategy WS1 from Location N, which is situated approximately 5 km upstream of Lake Burragorang. The results indicate that the target dilution of SV LDP009 discharge is not met for water strategies WS2a or WS2b or for the total maximum discharge (AP LDP001 plus SV LDP009 discharges) under any rainfall conditions.

### 3.3.3 Integrated Catchment Assessment

The aquatic ecological health of the Coxs River has been reported by Cardno (2014a; 2014b), based on monitoring conducted in accordance with the Australian Rivers Assessment System (AUSRIVAS) protocols (Turak *et al.*, 2004). Monitoring of the following four sites on the Coxs River, as shown in Figure 3-4 has been conducted from 2010 to 2012:

- CR1 – Located 700 m upstream of AP LDP001.
- CR2 – Located at the Mount Piper Haul Road crossing, approximately 1 km downstream of AP LDP001.
- CR4 – Located at the Maddox Lane road crossing downstream of AP LDP001, SV LDP009 and discharges from Western Coal Services.
- CR5 – Located at the Main Street road crossing downstream of AP LDP001, SV LDP009 and discharges from Wallerawang Power Station.

Table 3-6 presents the electrical conductivity at each sampling site during aquatic ecology monitoring. Electrical conductivity was found to increase at CR2 downstream of AP LDP001 discharges. However, there were no significant spatial or temporal trends in electrical conductivity during the sampling period between CR2, CR4 and CR5.

Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

1:45,000 for A4

0 0.125 0.25 0.5 0.75 1

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

LEGEND

- ● Non Centennial Site
- ● Centennial Site
- ○ Aquatic Ecology Monitoring Location
- — Waterway
- ▭ Waterbody

| | |
|---|---|
| LOCATION | - |
| SEAM | NA |
| DRAWN | S.M. |
| CHECKED | |
| APPROVED | S.Gray |
| SCALE | Refer to scalebar |

# Coxs River
# Ecotoxicology Assesssment

## Aquatic Ecology Monitoring Locations (Cardno, 2014a, 2014b)

Centennial Coal

DATE 29/09/2014

Figure 3-4

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Western\Angus Place\2217471\2217471_009_AquaticEcologyMonitoring_A.mxd

© Commonwealth of Australia (Geoscience Australia): 250K Topographic Data Series 3 2006; LPI: DTDB 2012; Cardno: Aquatic Monitoring Location (2014a, 2014b)

Table 3-6 Electrical Conductivity Recorded at Aquatic Ecology Monitoring Points (Cardno, 2014a; 2014b)

| Monitoring round | Electrical conductivity (µS/cm) | | | |
|---|---|---|---|---|
| | CR1 | CR2 | CR4 | CR5 |
| Autumn 2010 | – | 944 | – | 829 |
| Spring 2010 | 186 | 560 | 666 | 558 |
| Autumn 2011 | 141 | 749 | 930 | 860 |
| Spring 2011 | 182 | 939 | 853 | 764 |
| Autumn 2012 | 92 | 542 | 640 | 704 |
| Spring 2012 | 99 | 891 | 837 | 817 |

The assessment of aquatic ecology by Cardno (2014a; 2014b) used a number of indices to assess the condition of each monitoring site, including the following:

- SIGNAL 2 biotic index.
- NSW AUSRIVAS model results.

The SIGNAL2 score (Stream Invertebrate Grade Number Average Level) is a biotic index based on pollution sensitivity values (grade numbers) assigned to aquatic macroinvertebrate families. Each taxon is assigned a grade from 1 (tolerant) to 10 (sensitive) based on ecotoxicity assessment data. A score of less than 4 indicates severe degradation. The average SIGNAL 2 scores for each of the aquatic ecology monitoring sites is presented in Table 3-7. The results show there is a general trend for macroinvertebrate community assemblage improvement at CR2 and a slight decrease at CR5. However, all sites fit in the moderately degraded category and there are no significant differences between the aquatic ecology community health at all sites.

Table 3-7 Aquatic Ecology SIGNAL 2 Score (Cardno, 2014a; 2014b)

| Monitoring round | CR1 | CR2 | CR4 | CR5 |
|---|---|---|---|---|
| Autumn 2010 | – | 3.6 | – | 4.0 |
| Spring 2010 | 4.0 | 4.0 | 4.1 | 4.3 |
| Autumn 2011 | 4.1 | 4.7 | 4.1 | 4.0 |
| Spring 2011 | 4.2 | 4.4 | 4.6 | 3.9 |
| Autumn 2012 | 4.4 | 4.3 | 4.6 | 3.9 |
| Spring 2012 | 3.9 | 4.6 | 3.9 | 3.7 |

The NSW AUSRIVAS model provides a river health assessment based on predictive models of macroinvertebrate distribution. Physical and chemical data at each site was used to determine the predicted composition of the macroinvertebrate fauna. The AUSRIVAS morel compares the macroinvertebrate collected at a site (i.e. observed) to those predicted to occur (i.e. expected) at undisturbed reference sites with similar environmental characteristics. An OE50 score was generated, which is a probability score based on predicted occurrence of macroinvertebrate species which ranges from 0 to 1. A score close to 0 indicates an impoverished assemblage and a score close to 1 indicates similarity to the reference site. The following bands are derived from OE50 scores which indicate the level of impact at a site:

- Band A – equivalent to reference condition.
- Band B – below reference condition (significantly impaired).
- Band C – well below reference condition (severely impaired).
- Band D – impoverished (i.e. extremely impaired).
- Band X – richer macroinvertebrate assemblage than reference condition.

Table 3-8 presents the AUSRIVAS bands for each of the aquatic ecology monitoring sites reported by Cardno (2014a; 2014b). The results indicate that prior to spring 2012, the upstream Coxs River site CR1 was below the reference condition that was expected for an uncontaminated site. The results also show an improvement within macroinvertebrate communities during the sampling periods upstream of CR5.

Table 3-8 Aquatic Ecology AUSRIVAS Bands (Cardno, 2014a; 2014b)

| Monitoring round | CR1 | CR2 | CR4 | CR5 |
|---|---|---|---|---|
| Autumn 2011 | B | B | B | A |
| Spring 2011 | B | B | B | A |
| Autumn 2012 | B | A | B | B |
| Spring 2012 | A | A | A | B |

# 4. Conclusions

## 4.1 Ecotoxicology Assessment

The spatial distribution of the sample locations and the toxicity and water quality testing methodologies are considered sufficient to provide information on impacts of mine water discharge from Angus Place Colliery and Springvale Mine on the receiving environment. The results show that the discharge at SV LDP009 is having an acute impact on cladoceran at the Sawyers Swamp Creek site; however this acute toxicity is ameliorated as the discharge enters the Coxs River. Impacts on cladoceran reproduction show a decreasing trend in the Coxs River with distance downstream of the SV LDP009 discharge point until no toxic impacts are detected in the upper portion of Lake Wallace.

The toxicity of the SV LDP009 discharge cannot be attributed to any of the water quality parameters tested. The water quality results indicate that the chemistry of the non-toxic AP LDP001 discharge is not significantly different from the toxic SV LDP009 discharge. The toxicity observed is not able to be attributed to electrical conductivity or to bicarbonate alkalinity. Further investigations are required to determine the source of the toxicity. Once the source of the toxicity has been identified, management actions can be applied to ensure that the toxicity of the discharge is reduced, thus reducing the impact on the Coxs River.

## 4.2 Integrated Catchment Assessment

The aquatic ecology monitoring results provide supporting evidence that the discharges from AP LDP001 and SV LDP009 are not adversely impacting the aquatic health of the Coxs River. This information supports the findings of the ecotoxicological assessment showing that the electrical conductivity of the Coxs River is not adversely impacting the health of the aquatic ecosystem. Further, the sites downstream of discharges from AP LDP001 were found to have more pollution sensitive taxa present in the macroinvertebrate assemblages (CR2 = 9; CR4 = 6; CR5 = 6) than the upstream CR1 site, which had five pollution sensitive taxa present.

## 4.3 Coxs River Restoration Program

Centennial has developed the Coxs River Restoration Program as part of a regional biodiversity strategy (RPS, 2014d) that is aimed at further enhancing the biodiversity values of the Coxs River catchment and ameliorating the cumulative impacts associated with Centennial projects and non-Centennial operations in the catchment. Works to improve the terrestrial and aquatic biodiversity value of the Coxs River include the following:

- Watercourse stabilisation activities.
- Removal of grazing pressures.
- Weed removal/control (including blackberry and willow).
- Restoration of riparian areas.
- Revegetation activities with native species.

Further information on the Coxs River Restoration Program is provided by RPS (2014d).

## 4.4 Assessment Review

It is proposed that Centennial repeat the sampling for this ecotoxicology assessment on a three yearly basis dependent upon water quality results from the assessment locations.

# 5. References

ANZECC and ARMCANZ (2000), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment and Conservation Council and Agricultural and Resource Management Council of Australia and New Zealand.

Campbell, E., Palmer, M. J., Shao, Q., Warne, M. and Wilson D. (2000), *BurrliOZ: A computer program for calculating toxicant trigger values for the ANZECC and ARMCANZ water quality guidelines*, Perth, Western Australia.

Cardno (2014a), *Aquatic Ecology and Stygofauna Assessment: Angus Place Mine Extension Project*, prepared by Cardno Pty Ltd for Centennial Angus Place Pty Limited.

Cardno (2014b), *Aquatic Ecology and Stygofauna Assessment: Springvale Mine Extension Project*, prepared by Cardno Pty Ltd for Springvale Coal Pty Limited.

Elphick, R. R., Davies, M., Gilron, G., Canaria, E. C., Lo, B. and Bailey, H. C. (2011), *An aquatic ecotoxicological evaluation of sulfate: The case for considering hardness as a modifying factor in setting water quality guidelines*, Environmental Toxicology and Chemistry, 30(1):247-253.

Farag, A.M. and Harper, D.D., eds. (2012), *The potential effects of sodium bicarbonate, a major constituent from coalbed natural gas production, on aquatic life*, US Geological Survey, Scientific Investigations Report 2012–5008.

GHD (2014), *Springvale EPA Water Quality and Toxicity Assessment: Interpretive Report*, prepared by GHD Pty Ltd for Springvale Coal Pty Ltd.

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NSW OEH (2012), *Chemical and Ecotoxicological Assessment of Discharge Waters from West Cliff Mine: Report to the NSW Environment Protection Authority*, NSW Government Office of Environment and Heritage.

RPS (2014a), *Regional Water Quality Impact Assessment: Angus Place and Springvale Mine Extension Projects*, prepared by RPS Aquaterra Pty Ltd for Centennial Coal Company Limited.

RPS (2014b), *Angus Place Colliery LDP001 SSTV Assessment*, prepared by RPS Aquaterra Pty Ltd for Centennial Coal Company Limited.

RPS (2014c), *Springvale Mine LDP009 SSTV Assessment*, prepared by RPS Aquaterra Pty Ltd for Centennial Coal Company Limited.

RPS (2014d), *Regional Biodiversity Strategy: Western Projects*, prepared by RPS Australia Pty Ltd for Centennial Coal Pty Ltd.

Turak, E., Waddell, N. and Jahnstone, G. (2004), *New South Wales (NSW) Australian River Assessment System (AUSRIVAS): Sampling and Processing Manual 2004*, Department of Environment and Conservation.

# Appendices

# Appendix A – Flow Gauge Figures

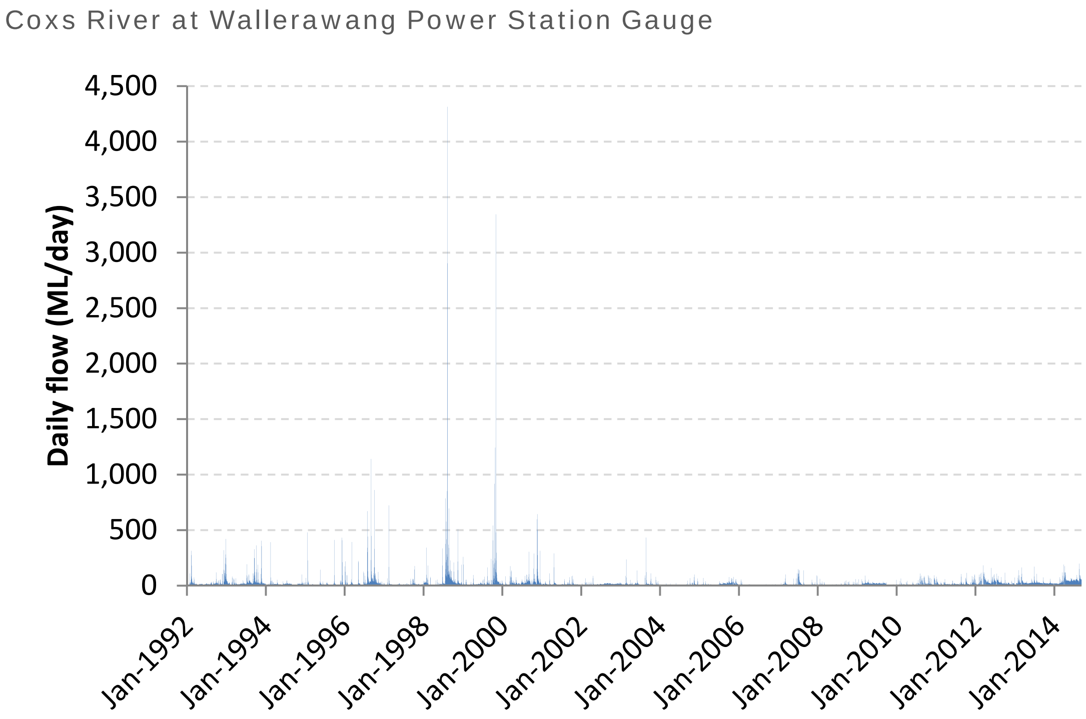

Figure A-1 Observed Flows for Coxs River at Wallerawang Power Station Gauge

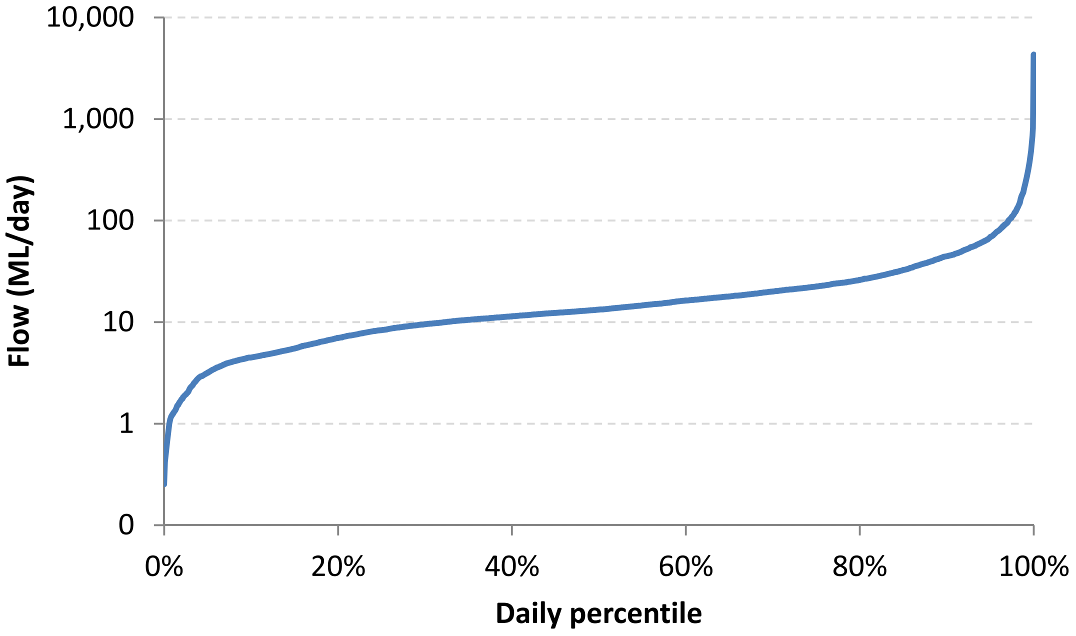

Figure A-2 Daily Flow Percentiles for Coxs River at Wallerawang Power Station Gauge

Coxs River at Bathurst Road Gauge

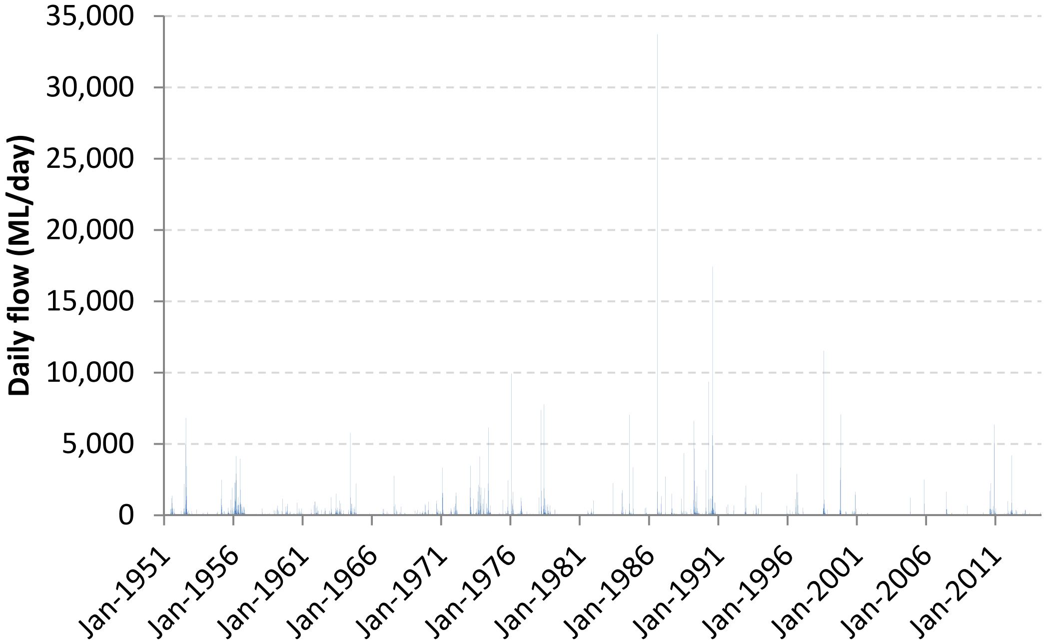

Figure A-3 Observed Flows for Coxs River at Bathurst Road Gauge

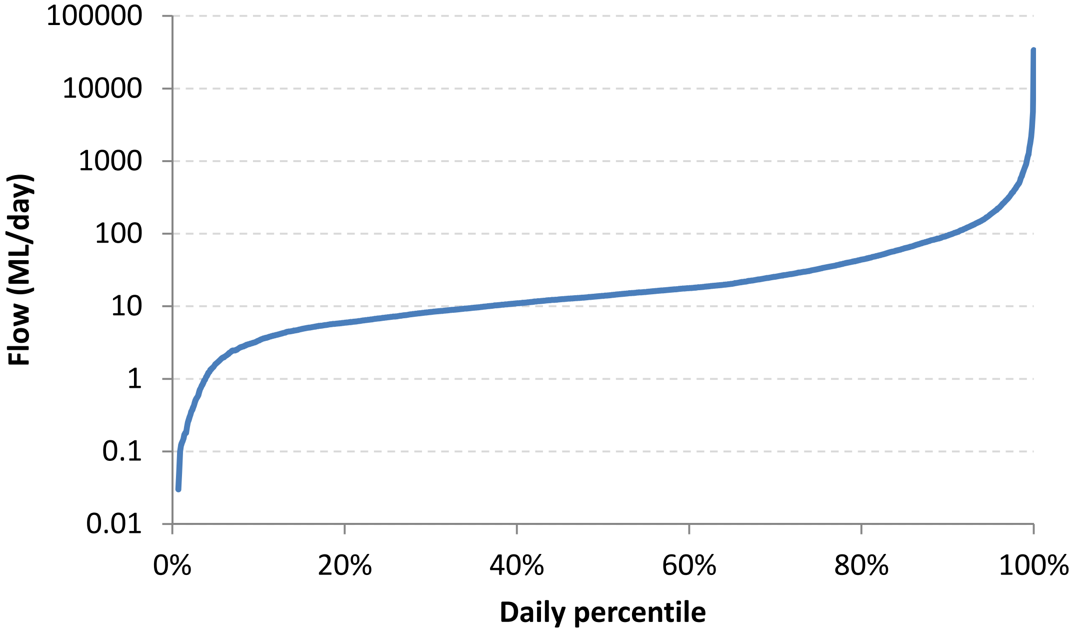

Figure A-4 Daily Flow Percentiles for Coxs River at Bathurst Road Gauge

## Coxs River at Upstream Lake Lyell Gauge

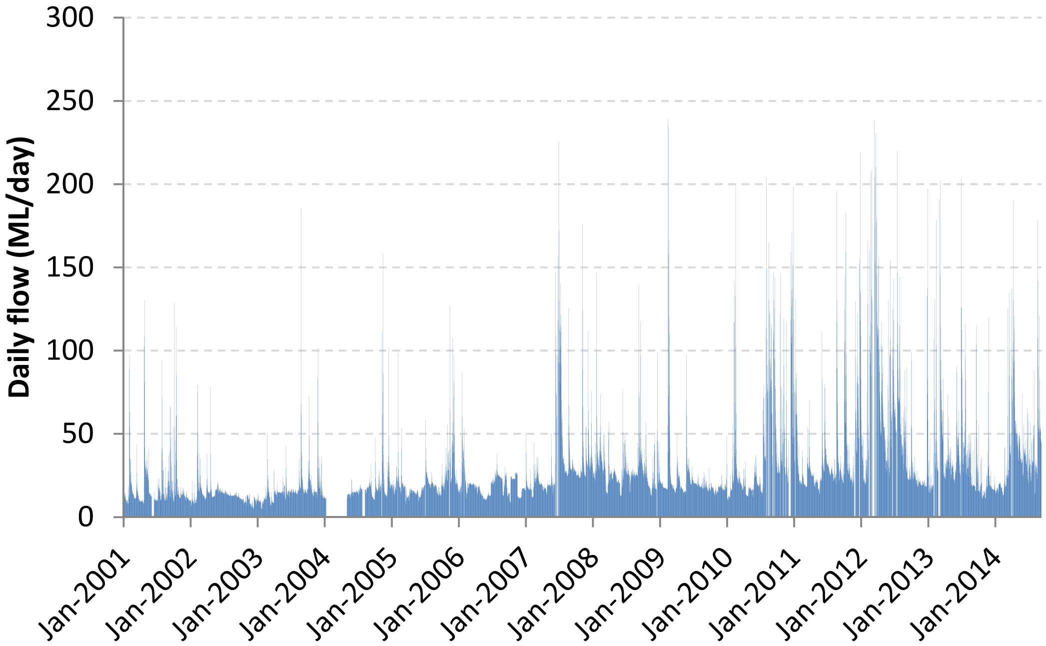

Figure A-5 Observed Flows for Coxs River at Upstream Lake Lyell Gauge

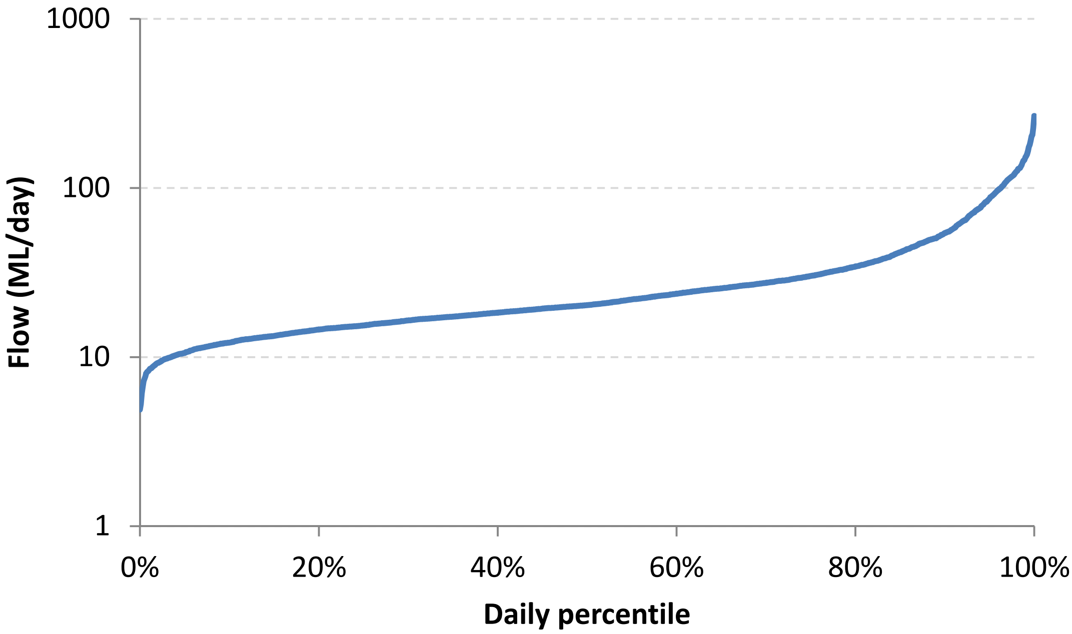

Figure A-6 Daily Flow Percentiles for Coxs River at Upstream Lake Lyell Gauge

## Coxs River at Lithgow Gauge

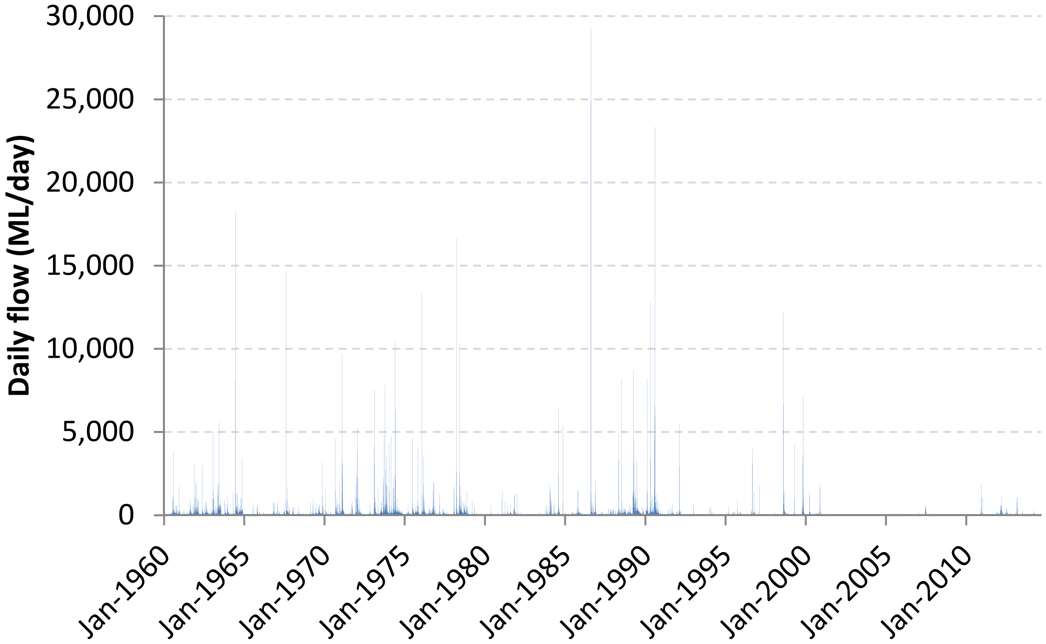

Figure A-7 Observed Flows for Coxs River at Lithgow Gauge

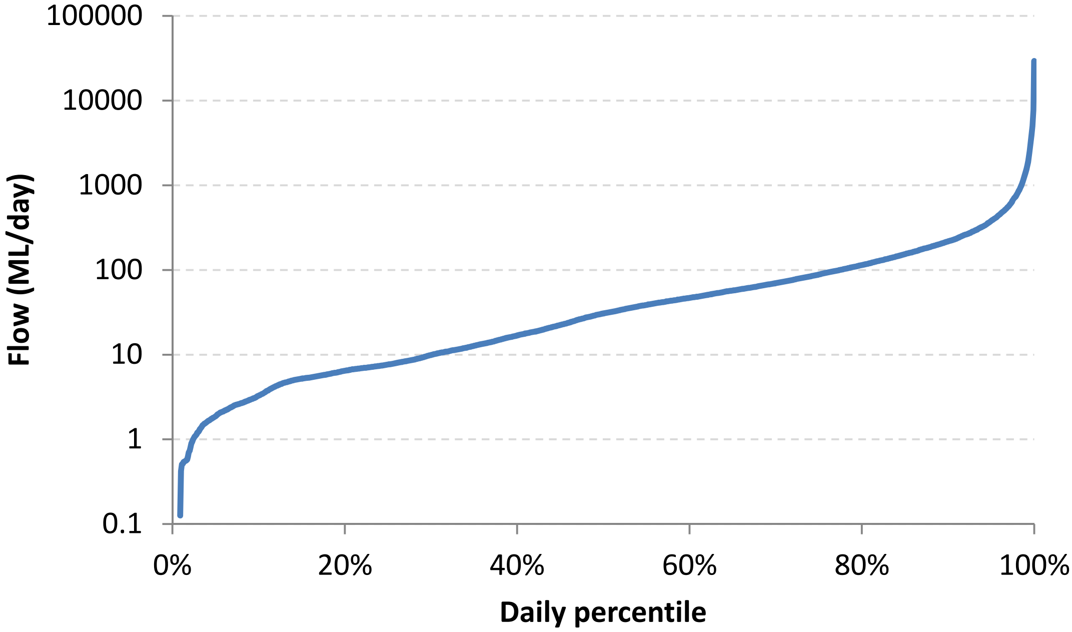

Figure A-8 Daily Flow Percentiles for Coxs River at Lithgow Gauge

Coxs River at Island Hill

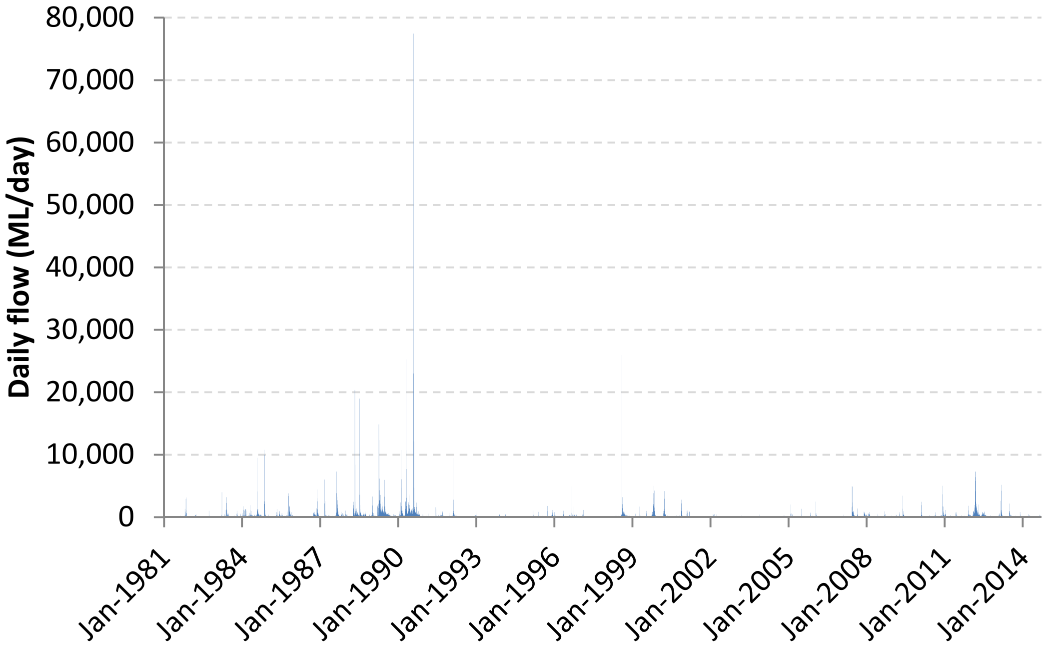

Figure A-9 Observed Flows for Coxs River at Island Hill Gauge

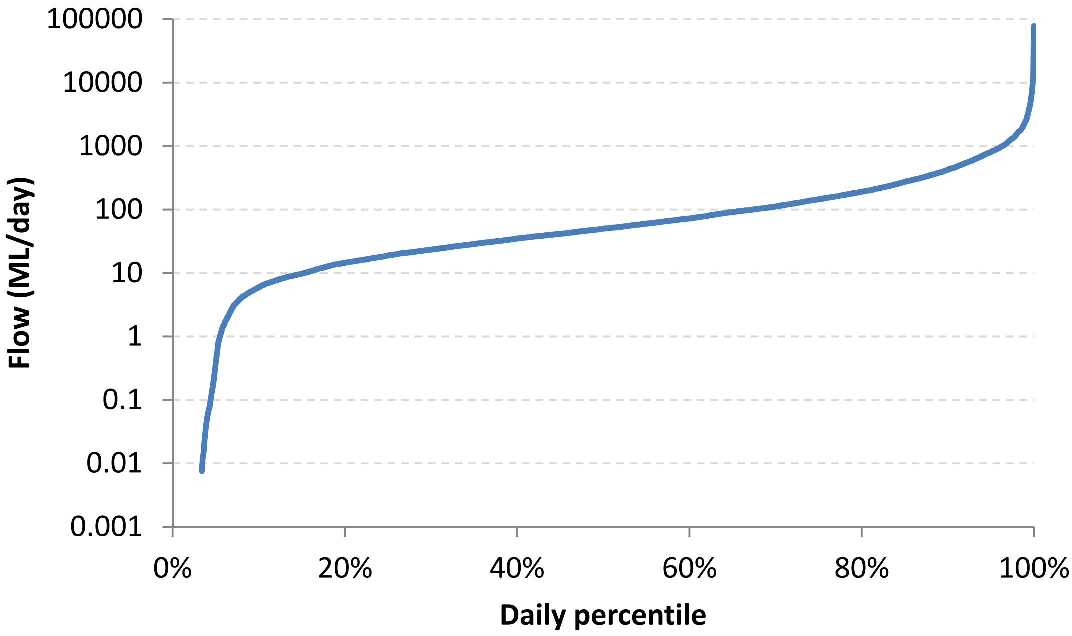

Figure A-10 Daily Flow Percentiles for Coxs River at Island Hill Gauge

# Appendix B – Ecotoxicology Report

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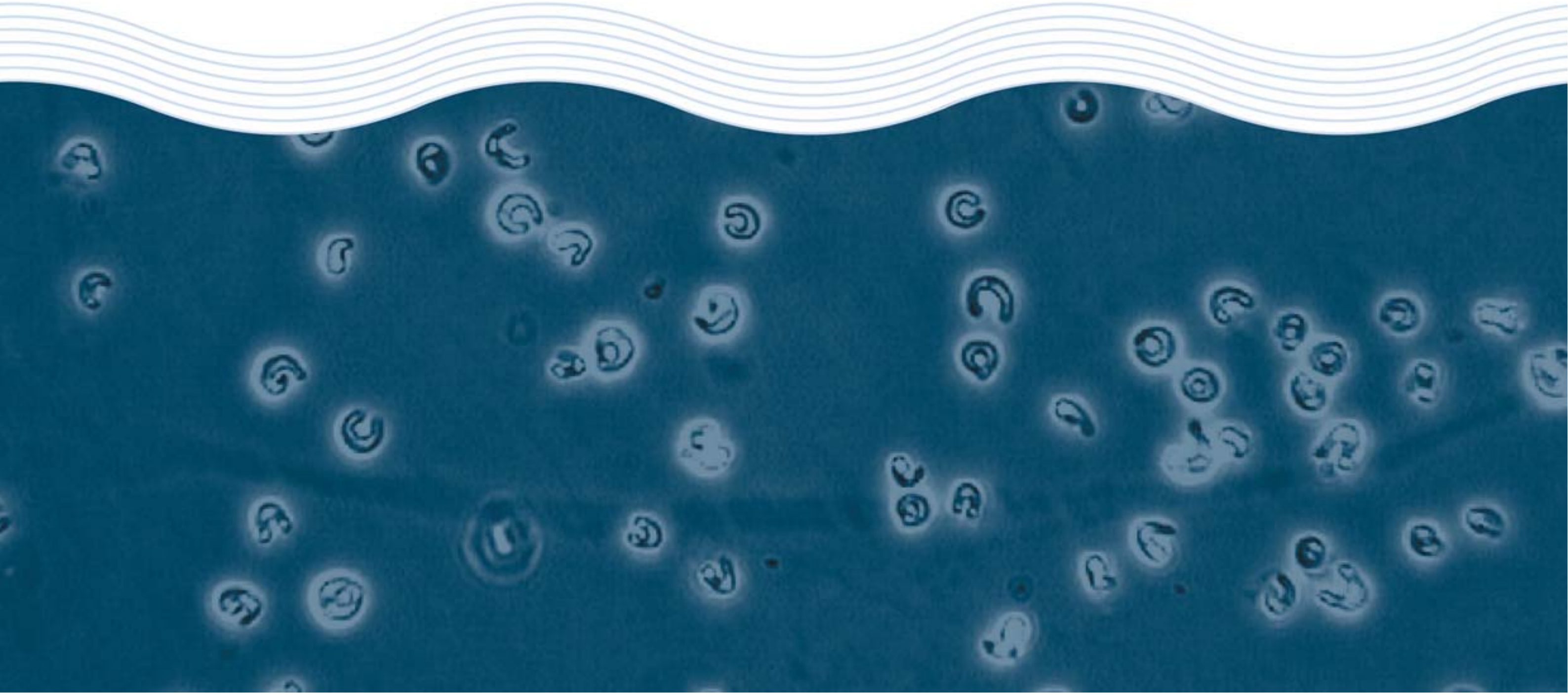
# Toxicity Assessment of Freshwater Samples

## GHD Pty Ltd

## Test Report

**September 2014**



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SERVICES AUSTRALASIA

# Toxicity Assessment of Freshwater Samples

## GHD Pty Ltd

## Test Report

September 2014

ECOTOX Services Australasia Pty Ltd ABN>45 094 714 904
unit 27/2 chaplin drive lane cove nsw 2066 T>61 2 9420 9481 F>61 2 9420 9484 W>www.ecotox.com.au

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SERVICES AUSTRALASIA

# Toxicity Test Report: TR1223/1 (Page 1 of 2)

Accredited for compliance with ISO/IEC 17025

| | | | |
|---|---|---|---|
| **Client:** | GHD Pty Ltd<br>GHD Tower, 24 Honeysuckle Drive<br>Newcastle NSW 2300 | **ESA Job #:**<br>**Date Sampled:**<br>**Date Received:** | PR1223<br>21 August 2014<br>25 August 2014 |
| **Attention:** | Stuart Gray | **Sampled By:** | Client |
| **Client Ref:** | Not supplied | **ESA Quote #:** | PL1223_q01 |

| **Lab ID No.:** | **Sample Name:** | **Sample Description:** |
|---|---|---|
| 6808 | SVLDP009 | Aqueous sample, pH 8.3*, conductivity 1175µS/cm*, total ammonia <2.0mg/L*. Sample received at 16ºC* in apparent good condition. |

*NATA accreditation does not cover the performance of this service

| | |
|---|---|
| **Test Performed:** | 72-hr microalgal growth inhibition test using the green alga *Selenastrum capricornutum* |
| **Test Protocol:** | ESA SOP 103 (ESA 2013), based on USEPA (2002) |
| **Test Temperature:** | The test was performed at 25±1°C. |
| **Deviations from Protocol:** | Nil |
| **Comments on Solution Preparation:** | The sample was filtered to 0.45 µm and then serially diluted with USEPA media. A USEPA control was tested concurrently with the sample. |
| **Source of Test Organisms:** | ESA Laboratory culture, originally sourced from CSIRO Microalgal Supply Service, TAS |
| **Test Initiated:** | 29 August 2014 at 1115h |

Sample 6808: *SVLDP009*

| **Concentration (%)** | **Cell Yield $\times 10^4$ cells/mL (Mean ± SD)** |
|---|---|
| USEPA Control | 38.2 ± 5.8 |
| 3.1 | 38.8 ± 2.8 |
| 6.3 | 17.5 ± 2.4 * |
| 12.5 | 9.9 ± 0.7 * |
| 25 | 7.5 ± 1.3 * |
| 50 | 7.9 ± 0.4 * |
| 100 | 3.9 ± 1.6 * |

**72-hr IC10 = 3.7%****
**72-hr IC50 = 6.0 (5.5-6.7)%**
**NOEC = 3.1%**
**LOEC = 6.3%**

*Significantly lower cell yield compared with the USEPA Control (Wilcoxon Rank Sum Test, 1-tailed, P=0.05)
**95% confidence limits are not reliable

# Toxicity Test Report: TR1223/1 (Page 2 of 2)

| QA/QC Parameter | Criterion | This Test | Criterion met? |
|---|---|---|---|
| Control mean cell density | ≥16.0x$10^4$ cells/mL | 39.2x$10^4$ cells/mL | Yes |
| Control coefficient of variation | <20% | 15.2% | Yes |
| Reference Toxicant within cusum chart limits | 1.5-6.2g KCl/L | 2.4g KCl/L | Yes |

Test Report Authorised by: Dr Rick Krassoi, Director on 25 September 2014

Results are based on the samples in the condition as received by ESA.

**NATA Accredited Laboratory Number: 14709**

This document shall not be reproduced except in full.

**Citations:**

ESA (2013) *ESA SOP 103 – Green Alga, Selenastrum capricornutum, Growth Test*. Issue No 10. Ecotox Services Australasia, Sydney, NSW.

USEPA (2002) *Short-term methods for estimating the chronic toxicity of effluents and receiving waters to freshwater organisms*. Fourth Edition. EPA-821-R-02-013. United States Environmental Protection Agency, Office of Research and Development, Washington DC, USA,

# Toxicity Test Report: TR1223/2

(Page 1 of 2)

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| | | | |
|---|---|---|---|
| **Client:** | GHD Pty Ltd<br>GHD Tower, 24 Honeysuckle Drive<br>Newcastle NSW 2300 | **ESA Job #:**<br>**Date Sampled:**<br>**Date Received:** | PR1223<br>21 August 2014<br>25 August 2014 |
| **Attention:** | Stuart Gray | **Sampled By:** | Client |
| **Client Ref:** | Not supplied | **ESA Quote #:** | PL1223_q01 |

| **Lab ID No.:** | **Sample Name:** | **Sample Description:** |
|---|---|---|
| 6808 | SVLDP009 | Aqueous sample, pH 8.3*, conductivity 1175µS/cm*, total ammonia <2.0mg/L*. Sample received at 16ºC* in apparent good condition. |

*NATA accreditation does not cover the performance of this service

| | |
|---|---|
| **Test Performed:** | 7-day Growth inhibition of the freshwater aquatic duckweed *Lemna disperma* |
| **Test Protocol:** | ESA SOP 112 (ESA 2012), based on OECD method 221 (2006) |
| **Test Temperature:** | The test was performed at 25±2°C. |
| **Deviations from Protocol:** | Nil |
| **Comments on Solution Preparation:** | The sample was serially diluted with Swedish standard medium (SIS) to achieve the test concentrations. A SIS control was tested concurrently with the sample. |
| **Source of Test Organisms:** | ESA Laboratory culture |
| **Test Initiated:** | 27 August 2014 at 1100h |

Sample 6808: *SVLDP009*

| **Concentration (%)** | **Specific Growth Rate (Mean ± SD)** | *Vacant* | *Vacant* |
|---|---|---|---|
| SIS Control | 0.29 ± 0.04 | | |
| 3.1 | 0.21 ± 0.02 * | | |
| 6.1 | 0.24 ± 0.03 | | |
| 12.1 | 0.27 ± 0.01 | | |
| 24.2 | 0.22 ± 0.04 * | | |
| 48.4 | 0.26 ± 0.01 | | |
| 96.8 | 0.29 ± 0.04 | | |

**7 day IC10 = <3.1%**
**7 day IC50 = >96.8%**
**NOEC = 96.8%**
**LOEC = >96.8%**

*Significantly lower specific growth rate compared with the SIS Control (Bonferroni t Test, 1-tailed, P=0.05)
**95% confidence limits are not available

# Toxicity Test Report: TR1223/2

| QA/QC Parameter | Criterion | This Test | Criterion met? |
|---|---|---|---|
| Control specific growth rate | >0.275 | 0.287 | Yes |
| Reference Toxicant within cusum chart limits | 2.3-6.0g KCl/L | 3.3g KCl/L | Yes |

Test Report Authorised by: Dr Rick Krassoi, Director on 25 September 2014

Results are based on the samples in the condition as received by ESA.

**NATA Accredited Laboratory Number: 14709**

This document shall not be reproduced except in full.

**Citations:**

ESA (2012) *SOP 112 – Duckweed Growth Inhibition Test.* Issue No. 5. Ecotox Services Australasia, Sydney NSW

OECD (2006) *Lemna sp*. Growth Inhibition Test. Method 221. OECD Guideline for the Testing of Chemicals. Organisation for Economic Cooperation and Development, Paris

# Toxicity Test Report: TR1223/3

**(Page 1 of 2)**

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| | | | |
|---|---|---|---|
| **Client:** | GHD Pty Ltd<br>GHD Tower, 24 Honeysuckle Drive<br>Newcastle NSW 2300 | **ESA Job #:**<br>**Date Sampled:**<br>**Date Received:** | PR1223<br>21 August 2014<br>25 August 2014 |
| **Attention:** | Stuart Gray | **Sampled By:** | Client |
| **Client Ref:** | Not supplied | **ESA Quote #:** | PL1223_q01 |

| **Lab ID No.:** | **Sample Name:** | **Sample Description:** |
|---|---|---|
| 6808 | SVLDP009 | Aqueous sample, pH 8.3*, conductivity 1175µS/cm*, total ammonia <2.0mg/L*. Sample received at 16ºC* in apparent good condition. |

*NATA accreditation does not cover the performance of this service

| | |
|---|---|
| **Test Performed:** | 96-hr fish imbalance toxicity test using the eastern rainbowfish *Melanotaenia splendida splendida* |
| **Test Protocol:** | ESA SOP 117 (ESA 2013), based on USEPA (2002) |
| **Test Temperature:** | The test was performed at 25±1°C. |
| **Deviations from Protocol:** | Nil |
| **Comments on Solution Preparation:** | The sample was serially diluted with dilute mineral water (DMW) to achieve the test concentrations. A DMW control was tested concurrently with the sample. |
| **Source of Test Organisms:** | In-house cultures |
| **Test Initiated:** | 9 September 2014 at 1300h |

| Sample 6808: *SVLDP009* | | *Vacant* | *Vacant* |
|---|---|---|---|
| **Concentration (%)** | **% Unaffected (Mean ± SD)** | | |
| DMW Control | 100 ± 0.0 | | |
| 3.1 | 95.0 ± 10.0 | | |
| 6.3 | 95.0 ± 10.0 | | |
| 12.5 | 95.0 ± 10.0 | | |
| 25 | 90.0 ± 11.6 | | |
| 50 | 50.0 ± 11.6 * | | |
| 100 | 10.0 ± 11.6 * | | |
| **96-hr IC10 = 25.0%****<br>**96-hr EC50 = 50.0 (40.5-61.7)%**<br>**NOEC = 25%**<br>**LOEC = 50%** | | | |

*Significantly lower percentage of unaffected larval fish compared with the DMW Control (Steel's Many-One Rank Test, 1-tailed, P=0.05)
**95% confidence limits are not reliable

| **QA/QC Parameter** | **Criterion** | **This Test** | **Criterion met?** |
|---|---|---|---|
| Control mean % unaffected | ≥80.0% | 100% | Yes |
| Reference Toxicant within cusum chart limits | 5.7-79.3µg Cu/L | 47.4µg Cu/L | Yes |

# Toxicity Test Report: TR1223/3

Test Report Authorised by: Dr Rick Krassoi, Director on 25 September 2014

Results are based on the samples in the condition as received by ESA.

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**Citations:**

ESA (2013) SOP 117 –*Freshwater and Marine Fish Imbalance Test*. Issue No 10. Ecotox Services Australasia, Sydney, NSW

USEPA (2002) Methods for measuring the acute toxicity of effluents and receiving waters to freshwater and marine organisms. Fifth edition EPA-821-R-02-012. United States Environmental Protection Agency, Office of Research and Development, Washington FC, USA

# Toxicity Test Report: TR1223/4

(Page 1 of 2)

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| | | | |
|---|---|---|---|
| **Client:** | GHD Pty Ltd<br>GHD Tower, 24 Honeysuckle Drive<br>Newcastle NSW 2300 | **ESA Job #:**<br>**Date Sampled:**<br>**Date Received:** | PR1223<br>21 August 2014<br>25 August 2014 |
| **Attention:** | Stuart Gray | **Sampled By:** | Client |
| **Client Ref:** | Not supplied | **ESA Quote #:** | PL1223_q01 |

| **Lab ID No.:** | **Sample Name:** | **Sample Description:** |
|---|---|---|
| 6808 | SVLDP009 | Aqueous sample, pH 8.3*, conductivity 1175µS/cm*, total ammonia <2.0mg/L*. Sample received at 16ºC* in apparent good condition. |

*NATA accreditation does not cover the performance of this service

| | |
|---|---|
| **Test Performed:** | 96-hr acute toxicity test using the freshwater hydra *hydra viridissima* |
| **Test Protocol:** | ESA SOP 125 (2013), based on Riethmuller et al. (2003) |
| **Test Temperature:** | The test was performed at 27±1°C. |
| **Deviations from Protocol:** | Nil |
| **Comments on Solution Preparation:** | The sample was serially diluted with Laboratory Water to achieve the test concentrations. A Laboratory Water control was tested concurrently with the sample. |
| **Source of Test Organisms:** | ESA Laboratory culture |
| **Test Initiated:** | 26 August 2014 at 1330h |

| Sample 6808: *SVLDP009* | | *Vacant* | *Vacant* |
|---|---|---|---|
| **Concentration (%)** | **Population Growth Rate (Mean ± SD)** | | |
| Lab Control | 0.37 ± 0.0 | | |
| 3.1 | 0.35 ± 0.02 | | |
| 6.3 | 0.33 ± 0.02 * | | |
| 12.5 | 0.25 ± 0.04 * | | |
| 25 | 0.11 ± 0.06 * | | |
| 50 | 0.03 ± 0.03 * | | |
| 100 | 0.00 ± 0.00 | | |
| **96-hr EC10 = 5.1%**<br>**96-hr EC50 = 18.0 (14.0-24.8)%**<br>**NOEC = 3.1%**<br>**LOEC = 6.3%** | | | |

*Significantly lower population growth rate compared with the Lab Control (Steel's Many-One Rank Test, 1-tailed, P=0.05)
**95% confidence limits are not reliable

# Toxicity Test Report: TR1223/4 (Page 2 of 2)

| QA/QC Parameter | Criterion | This Test | Criterion met? |
|---|---|---|---|
| Control mean population growth rate | ≥0.25 | 0.374 | Yes |
| Reference Toxicant within cusum chart limits | 0.9-12.6µg Cu/L | 5.8µg Cu/L | Yes |

Test Report Authorised by: Dr Rick Krassoi, Director on 25 September 2014

Results are based on the samples in the condition as received by ESA.

**NATA Accredited Laboratory Number: 14709**

This document shall not be reproduced except in full.

**Citations:**

ESA (2013) SOP 125 –*Hydra Population Growth Test.* Issue No 3. Ecotox Services Australasia, Sydney, NSW

Riethmuller N, Camilleri C, Franklin N, Hogan A, King A, Koch A, Markich SJ, Turley C and van Dam R (2003). Green Hydra Population Growth Test. In: *Ecotoxicological testing protocols for Australian tropical freshwater ecosystems*. Supervising Scientist Report 173, Supervising Scientist, Darwin NT.

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# Toxicity Test Report: TR1223/5

(Page 1 of 2)

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| | | | |
|---|---|---|---|
| **Client:** | GHD Pty Ltd<br>GHD Tower, 24 Honeysuckle Drive<br>Newcastle NSW 2300 | **ESA Job #:**<br>**Date Sampled:**<br>**Date Received:** | PR1223<br>21 August 2014<br>25 August 2014 |
| **Attention:** | Stuart Gray | **Sampled By:** | Client |
| **Client Ref:** | Not supplied | **ESA Quote #:** | PL1223_q01 |

| **Lab ID No.:** | **Sample Name:** | **Sample Description:** |
|---|---|---|
| 6808 | SVLDP009 | Aqueous sample, pH 8.3*, conductivity 1175µS/cm*, total ammonia <2.0mg/L*. Sample received at 16ºC* in apparent good condition. |

*NATA accreditation does not cover the performance of this service

| | |
|---|---|
| **Test Performed:** | Partial life-cycle toxicity test using the freshwater cladoceran *Ceriodaphnia cf dubia* |
| **Test Protocol:** | ESA SOP 102 (ESA 2013), based on USEPA (2002) and Bailey *et al*. (2000) |
| **Test Temperature:** | The test was performed at 25±1°C. |
| **Deviations from Protocol:** | The test was extended to 8 days |
| **Comments on Solution Preparation:** | The sample was serially diluted with Dilute Mineral Water (DMW) to achieve the test concentrations. A DMW control was tested concurrently with the sample. |
| **Source of Test Organisms:** | ESA Laboratory culture |
| **Test Initiated:** | 28 August 2014 at 1330h |

Sample 6808: *SVLDP009*

| **Concentration (%)** | **% Survival at 8 days (Mean ± SD)** |
|---|---|
| DMW Control | 90.0 ± 31.6 |
| 3.1 | 80.0 ± 42.2 |
| 6.3 | 100 ± 0.0 |
| 12.5 | 100 ± 0.0 |
| 25 | 90.0 ± 31.6 |
| 50 | 70.0 ± 48.3 |
| 100 | 0.0 ± 0.0 |

**8 day IC10 (survival) = 34.0%***
**8 day EC50 (survival) = 58.6 (48.0-71.7)%**
**NOEC = 50%**
**LOEC = 100%**

Sample 6808: *SVLDP009*

| **Concentration (%)** | **Number of Young (Mean ± SD)** | |
|---|---|---|
| DMW Control | 15.3 ± 6.2 | |
| 3.1 | 18.1 ± 5.5 | |
| 6.3 | 18.3 ± 4.5 | |
| 12.5 | 13.7 ± 8.3 | |
| 25 | 9.2 ± 5.2 | |
| 50 | 5.6 ± 5.4 | ** |
| 100 | 0.0 ± 0.0 | |

**8 day IC10 (reproduction) = 9.3 (5.2-16.0)%**
**8 day IC50 (reproduction) = 29.1 (16.3-50.3)%**
**NOEC = 25%**
**LOEC = 50%**

*95% confidence limits are not reliable
**Significantly lower young compared with the DMW Control (Dunnett's Test, 1-tailed, P=0.05)

| **QA/QC Parameter** | **Criterion** | **This Test** | **Criterion met?** |
|---|---|---|---|
| Control mean % survival | ≥80.0% | 90.0% | Yes |
| Control mean number of young | ≥15.0 | 16.6 | Yes |
| Reference Toxicant within cusum chart limits | 138.8-478.6KCl/L | 219.6mg KCl/L | Yes |

Test Report Authorised by: Dr Rick Krassoi, Director on 25 September 2014

Results are based on the samples in the condition as received by ESA.

**NATA Accredited Laboratory Number: 14709**

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## Citations:

Bailey, H.C., Krassoi, R., Elphick, J.R., Mulhall, A., Hunt, P., Tedmanson, L. and Lovell, A. (2000) Application of *Ceriodaphnia cf. dubia* for whole effluent toxicity tests in the Hawkesbury-Nepean watershed, New South Wales, Australia: method development and validation. *Environmental Toxicology and Chemistry* 19:88-93.

ESA (2013) ESA SOP 102 – *Acute Toxicity Test Using Ceriodaphnia dubia.* Issue No 9. Ecotox Services Australasia, Sydney, NSW.

USEPA (2002) *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms.4th Ed.* United States Environmental Protection Agency, Office of Water, Washington DC.

# Toxicity Test Report: TR1223/6 (Page 1 of 2)

Accredited for compliance with ISO/IEC 17025

| | | | |
|---|---|---|---|
| **Client:** | GHD Pty Ltd<br>GHD Tower, 24 Honeysuckle Drive<br>Newcastle NSW 2300 | **ESA Job #:**<br>**Date Sampled:**<br>**Date Received:** | PR1223<br>21 August 2014<br>25 August 2014 |
| **Attention:** | Stuart Gray | **Sampled By:** | Client |
| **Client Ref:** | Not supplied | **ESA Quote #:** | PL1223_q01 |

| **Lab ID No.:** | **Sample Name:** | **Sample Description:** |
|---|---|---|
| 6807 | APLDP001 | Aqueous sample, pH8.0*, conductivity 1038µS/cm. Sample received at 16ºC* in apparent good condition. |

*NATA accreditation does not cover the performance of this service

| | |
|---|---|
| **Test Performed:** | Partial life-cycle toxicity test using the freshwater cladoceran *Ceriodaphnia cf dubia* |
| **Test Protocol:** | ESA SOP 102 (ESA 2013), based on USEPA (2002) and Bailey *et al*. (2000) |
| **Test Temperature:** | The test was performed at 25±1°C. |
| **Deviations from Protocol:** | The test was extended to 8 days |
| **Comments on Solution Preparation:** | The sample was serially diluted with Dilute Mineral Water (DMW) to achieve the test concentrations. A DMW control was tested concurrently with the sample. |
| **Source of Test Organisms:** | ESA Laboratory culture |
| **Test Initiated:** | 4 September 2014 at 1500h |

Sample 6807: *APLDP001*

| **Concentration (%)** | **% Survival at 8 days (Mean ± SD)** |
|---|---|
| DMW Control | 90.0 ± 31.6 |
| 3.1 | 90.0 ± 31.6 |
| 6.3 | 100 ± 0.0 |
| 12.5 | 100 ± 0.0 |
| 25 | 90.0 ± 31.6 |
| 50 | 100 ± 0.0 |
| 100 | 90.0 ± 31.6 |

**8 day EC10 (survival) = >100%**
**8 day EC50 (survival) = >100%**
**NOEC = 100%**
**LOEC = >100%**

Sample 6807: *APLDP001*

| **Concentration (%)** | **Number of Young (Mean ± SD)** |
|---|---|
| DMW Control | 13.6 ± 6.0 |
| 3.1 | 16.1 ± 7.3 |
| 6.3 | 15.2 ± 5.3 |
| 12.5 | 20.1 ± 5.8 |
| 25 | 17.4 ± 7.6 |
| 50 | 25.2 ± 4.2 |
| 100 | 19.1 ± 9.1 |

**8 day IC10 (reproduction) = >100%**
**8 day IC50 (reproduction) = >100%**
**NOEC = 100%**
**LOEC = >100%**

*95% confidence limits not reliable

| **QA/QC Parameter** | **Criterion** | **This Test** | **Criterion met?** |
|---|---|---|---|
| Control mean % survival | ≥80.0% | 90.0% | Yes |
| Control mean number of young | ≥15.0 | 15.1 | Yes |
| Reference Toxicant within cusum chart limits | 137.8-480.2mg KCl/L | 238.0mg KCl/L | Yes |

Test Report Authorised by: Dr Rick Krassoi, Director on 25 September 2014

Results are based on the samples in the condition as received by ESA.

**NATA Accredited Laboratory Number: 14709**

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**Citations:**

Bailey, H.C., Krassoi, R., Elphick, J.R., Mulhall, A., Hunt, P., Tedmanson, L. and Lovell, A. (2000) Application of *Ceriodaphnia cf. dubia* for whole effluent toxicity tests in the Hawkesbury-Nepean watershed, New South Wales, Australia: method development and validation. *Environmental Toxicology and Chemistry* 19:88-93.

ESA (2013) ESA SOP 102 – *Acute Toxicity Test Using Ceriodaphnia dubia.* Issue No 9. Ecotox Services Australasia, Sydney, NSW.

USEPA (2002) *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms.4th Ed.* United States Environmental Protection Agency, Office of Water, Washington DC.

# Toxicity Test Report: TR1223/7

Accredited for compliance with ISO/IEC 17025

| | | | |
|---|---|---|---|
| **Client:** | GHD Pty Ltd<br>GHD Tower, 24 Honeysuckle Drive<br>Newcastle NSW 2300 | **ESA Job #:** | PR1223 |
| | | **Date Sampled:** | 21 & 22 August 2014 |
| | | **Date Received:** | 25 August 2014 |
| **Attention:** | Stuart Gray | **Sampled By:** | Client |
| **Client Ref:** | Not supplied | **ESA Quote #:** | PL1223_q01 |

| **Lab ID No.:** | **Sample Name:** | **Sample Description:** |
|---|---|---|
| 6809 | SVLDP009 DS | Aqueous sample, pH 8.8*, conductivity 1089µS/cm*. Sample received at 16ºC* in apparent good condition. |
| 6810 | MADDOX | Aqueous sample, pH 8.6*, conductivity 1007µS/cm*. Sample received at 16ºC* in apparent good condition. |
| 6811 | LAKE WALLACE | Aqueous sample, pH 8.5*, conductivity 986µS/cm*. Sample received at 16ºC* in apparent good condition. |
| 6812 | WANGOL | Aqueous sample, pH 7.7*, conductivity 806µS/cm*. Sample received at 16ºC* in apparent good condition. |
| 6813 | COXS DS LYELL | Aqueous sample, pH 8.3*, conductivity 506µS/cm*. Sample received at 16ºC* in apparent good condition. |
| 6814 | COXS US LYELL | Aqueous sample, pH 8.7*, conductivity 1049µS/cm*. Sample received at 16ºC* in apparent good condition. |
| 6815 | LAKE LYELL | Aqueous sample, pH 8.4*, conductivity 547µS/cm*. Sample received at 16ºC* in apparent good condition. |
| 6816 | WPS | Aqueous sample, pH 8.4*, conductivity 949µS/cm*. Sample received at 16ºC* in apparent good condition. |
| 6817 | COXS US | Aqueous sample, pH 6.6*, conductivity 41.5µS/cm*. Sample received at 16ºC* in apparent good condition. |

*NATA accreditation does not cover the performance of this service

| | |
|---|---|
| **Test Performed:** | Partial life-cycle toxicity test using the freshwater cladoceran *Ceriodaphnia cf dubia* |
| **Test Protocol:** | ESA SOP 102 (ESA 2013), based on USEPA (2002) and Bailey *et al*. (2000) |
| **Test Temperature:** | The test was performed at 25±1°C. |
| **Deviations from Protocol:** | The test was extended to 8 days |
| **Comments on Solution Preparation:** | The samples were tested without dilution (i.e. 100% only). A DMW control was tested concurrently with the samples. |
| **Source of Test Organisms:** | ESA Laboratory culture |
| **Test Initiated:** | 11 September 2014 at 1415h |

# Toxicity Test Report: TR1223/7

Sample 6809-6817: *Various*

| Sample ID | % Survival at 8 days (Mean ± SD) | |
|---|---|---|
| DMW Control | 90.0 ± 31.6 | |
| SVLDP009 DS | 80.0 ± 42.2 | |
| MADDOX | 100 ± 0.0 | |
| LAKE WALLACE | 100 ± 0.0 | |
| WANGOL | 100 ± 0.0 | |
| COXS DS LYELL | 100 ± 0.0 | |
| COXS UD LYELL | 100 ± 0.0 | |
| LAKE LYELL | 90.0 ± 31.6 | |
| WPS | 100 ± 0.0 | |
| COXS US | 40.0 ± 51.6 | * |

Sample 6809-6817: *Various*

| Sample ID | Number of Young (Mean ± SD) | |
|---|---|---|
| DMW Control | 19.3 ± 7.2 | |
| SVLDP009 DS | 0.8 ± 1.7 | ** |
| MADDOX | 5.5 ± 5.2 | ** |
| LAKE WALLACE | 22.3 ± 6.2 | |
| WANGOL | 13.6 ± 4.8 | |
| COXS DS LYELL | 21.9 ± 4.6 | |
| COXS UD LYELL | 20.5 ± 8.2 | |
| LAKE LYELL | 20.6 ± 7.7 | |
| WPS | 12.8 ± 6.7 | |
| COXS US | 0.2 ± 0.6 | ** |

*Significantly lower percentage survival compared with the DMW Control (Bonferroni adjusted t Test, 1-tailed, P=0.05)
**Significantly lower young compared with the DMW Control (Bonferroni adjusted t Test, 1-tailed, P=0.05)

| QA/QC Parameter | Criterion | This Test | Criterion met? |
|---|---|---|---|
| Control mean % survival | ≥80.0% | 90.0% | Yes |
| Control mean number of young | ≥15.0 | 21.3 | Yes |
| Reference Toxicant within cusum chart limits | 137.8-479.6mg KCl/L | 274.3mg KCl/L | Yes |

Test Report Authorised by: Dr Rick Krassoi, Director on 25 September 2014

Results are based on the samples in the condition as received by ESA.

**NATA Accredited Laboratory Number: 14709**

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**Citations:**

Bailey, H.C., Krassoi, R., Elphick, J.R., Mulhall, A., Hunt, P., Tedmanson, L. and Lovell, A. (2000) Application of *Ceriodaphnia cf. dubia* for whole effluent toxicity tests in the Hawkesbury-Nepean watershed, New South Wales, Australia: method development and validation. *Environmental Toxicology and Chemistry* 19:88-93.

ESA (2013) ESA SOP 102 – *Acute Toxicity Test Using Ceriodaphnia dubia.* Issue No 9. Ecotox Services Australasia, Sydney, NSW.

USEPA (2002) *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms.4th Ed.* United States Environmental Protection Agency, Office of Water, Washington DC.

# Chain-of-Custody Documentation

Datasheet ID: 601.2
Last Revised: 30 April 2009

# Sample Receipt Notification

| | | |
|---|---|---|
| **Attention** | : | Tess Davies |
| **Client** | : | GHD Pty Ltd<br>GHD Tower, Level 3, 24 Hneysuckle Drive<br>Newcastle NSW 2300 |
| **Email** | : | tess.davies@ghd.com |
| **Telephone** | : | 02 49799993 |
| **Facsimile** | : | |
| **Date** | : | 25/08/2014 |
| **Re** | : | Receipt of Samples |

**Pages :** 3

**ESA Project** : PR1223 ☑ For Review ☐ Additional Documentation Required - Please Respond

---

## *Sample Delivery Details*

| | |
|---|---|
| **Completed Chain of Custody accompanied samples:** | **YES** |
| **Samples received in apparent good condition and correctly bottled:** | **YES** |
| **Security seals on sample bottles and esky intact:** | **YES** |

| | | |
|---|---|---|
| **Date samples received** | : | 25/08/2014 |
| **Time samples received** | : | 9:50 |
| **No. of samples received** | : | 12 |
| **Sample matrix** | : | Aqueous |
| **Sample temperature** | : | 16°C |

**Comments** :

Includes 2x5L APLDP001 (ESA ID# 6801, 9x5L SVLDP009 (ESA ID# 6808),
1x1L SV LDP009 DS (ESA ID# 6809), 1x1L MADDOX (ESA ID# 6810)
1x1L LAKE WALLACE (ESA ID# 6811), 1x1L WANGOL (ESA ID# 6812)
1x1L COXS DS LYELL (ESA ID# 6813), 1x1L COXS US LYELL (ESA ID# 6814)
1x1L LAKE LYELL (ESA ID# 6815), 1x1L WPS (ESA ID# 6816)
1x1L COXS US (ESA iD# 6817)

---

## *Contact Details*

Customer Services Officer : Tina Micevska
Telephone : 61 2 9420 9481
Facsimile : 61 2 9420 9484
Email : tmicevska@ecotox.com.au

Please contact customer services officer for all queries or issues regarding samples

**Note that the chain-of-custody provides definitive information on the tests to be performed**

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# Chain-of-Custody / Service Request Form

**ecotox**
SERVICES AUSTRALASIA

Datasheet ID: 601.1
Last Revised: 15 July 2014

Customer: GHD
Contact Name: Stuart Gray
Phone: 0401416936 Email: Stuart.gray@ghd.com (please provide an email address for sample receipt notification)
Sampled by: Stuart Gray
Ship To:
Attention:

| | Sample Date (day/month /year) | Sample Time | Sample Name (exactly as written on the sample vessel) | Sample Method (eg. Grab, composite etc.) | Number and Volume of Containers (eg 2 x 1L) | Tests Requested (See reverse for guidance): Chronic Cerio | Algal growth Sc | Duckweed Ld | Chronic fish | Hydra | | Comments / Instructions **Note that testing will be delayed if an incomplete chain of custody is received**<br>• Additional treatment of samples (i.e. spiking)<br>• Sub-contracted services (i.e. chemical analyses)<br>• Dilutions required (if different than 100% down to 6.25%)<br>• Sample holding time restriction (if applicable)<br>• Sample used for litigation (if applicable)<br>*Note: An MSDS must be attached if Available*<br>**ESA Project Number: PR** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6807 | 21/8 | | AP LDP001 | Grab | 2x 5L | X | ~~X~~ | ~~X~~ | ~~X~~ | | | All dilutions (3.125%) also |
| 808 | 21/8 | | SV LDP009 | │ | 9x 5L | X | X | X | X | X | | All dilutions (3.125% also) |
| 6817 ~~809~~ | 21/8 | | COXS US | │ | 1 x 1L | X | | | | | | 100% conc only |
| 209 | 21/8 | | SV LDP009 DS | │ | │ | │ | | | | | | │ |
| 6810 | 21/8 | | MADDOX | │ | │ | │ | | | | | | │ |
| 6811 | 22/8 | | LAKE WALLACE | │ | │ | │ | | | | | | │ |
| 6812 | 21/8 | | WANGCOL | │ | │ | │ | | | | | | │ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1) Released By: | Date: | 2) Received By: Tina | Date: 25/8/14 | 3) Released By: | Date: | 4) Received By: | Date: |
| Of: | Time: | Of: ESA | Time: 9:50 | Of: | Time: | Of: | Time: |

**Note that the chain-of-custody documentation will provide definitive information on the tests to be performed.**

Ecotox Services Australasia . Unit 27, 2 Chaplin Drive, Lane Cove NSW 2066 AUSTRALIA
Phone: 61 2 9420-9481 Fax 61 2 9420-9484 info@ecotox.com.au

Page ____ of ____

Datasheet ID: 601.1
Last Revised: 15 July 2014

# Chain-of-Custody / Service Request Form

**ecotox**
SERVICES AUSTRALASIA

Customer: GHD
Contact Name: Stuart Gray
Phone: 0401416936 Email: stuart.gray@ghd.com (please provide an email address for sample receipt notification)
Sampled by: Stuart Gray

Ship To:
Attention:

| | Sample Date (day/month /year) | Sample Time | Sample Name (exactly as written on the sample vessel) | Sample Method (eg. Grab, composite etc.) | Number and Volume of Containers (eg 2 x 1L) | Tests Requested (See reverse for guidance) | | | | | | Comments / Instructions<br>**Note that testing will be delayed if an incomplete chain of custody is received**<br>• Additional treatment of samples (i.e. spiking)<br>• Sub-contracted services (i.e. chemical analyses)<br>• Dilutions required (if different than 100% down to 6.25%)<br>• Sample holding time restriction (if applicable)<br>• Sample used for litigation (if applicable)<br>*Note: An MSDS must be attached if Available*<br>**ESA Project Number: PR** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Chronic cerio | | | | | | |
| 6813 | 22/8 | | COXS DS LYELL | Grab | 1 x 1L | x | | | | | | 100% Conc only |
| 6814 | 22/8 | | COXS US LYELL | \| | \| | \| | | | | | | \| |
| 6815 | 22/8 | | LAKE LYELL | \| | \| | \| | | | | | | \| |
| 6816 | 22/8 | | WPS | \| | \| | \| | | | | | | \| |
| | | | | | | | | | | | | |
| 16° | | | | | | | | | | | | |
| | | | | | | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1) Released By: | Date: | 2) Received By: | Date: | 3) Released By: | Date: | 4) Received By: | Date: |
| Of: | Time: | Of: | Time: | Of: | Time: | Of: | Time: |

**Note that the chain-of-custody documentation will provide definitive information on the tests to be performed.**

Ecotox Services Australasia . Unit 27, 2 Chaplin Drive, Lane Cove NSW 2066 AUSTRALIA
Phone: 61 2 9420-9481 Fax 61 2 9420-9484 info@ecotox.com.au

Page ___ of ___

ecotox
SERVICES AUSTRALASIA

# Statistical Printouts for the *Selenastrum* Growth Inhibition Tests

## Microalgal Growth inhibition Test-Growth-Cell Yield

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 29/08/2014 11:15 | Test ID: | PR1223/02 | Sample ID: | SV LDP009 |
| End Date: | 1/09/2014 10:30 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 103 | Test Species: | SC-Selenastrum capricornutum |
| Comments: | | | | | |

| Conc-% | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| USEPA Control | 479157.1 | 387157.1 | 349157.1 | 333157.1 | 391157.1 | 377157.1 | 443157.1 | 299157.1 |
| 3.1 | 369157.1 | 403157.1 | 419157.1 | 359157.1 | | | | |
| 6.3 | 163157.1 | 193157.1 | 195157.1 | 147157.1 | | | | |
| 12.5 | 105157.1 | 95157.1 | 91157.1 | 105157.1 | | | | |
| 25 | 91157.1 | 77157.1 | 69157.1 | 61157.1 | | | | |
| 50 | 77157.1 | 73157.1 | 81157.1 | 83157.1 | | | | |
| 100 | 25157.1 | 25157.1 | 51157.1 | 53157.1 | | | | |

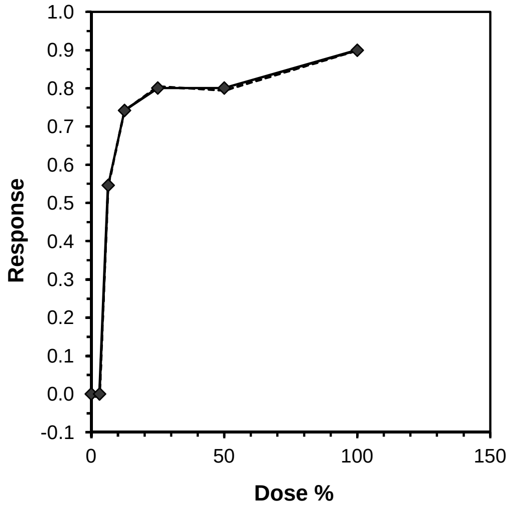
| | | | Transform: Untransformed | | | | | Rank | 1-Tailed | Isotonic | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Conc-% | Mean | N-Mean | Mean | Min | Max | CV% | N | Sum | Critical | Mean | N-Mean |
| USEPA Control | 382407.1 | 1.0000 | 382407.1 | 299157.1 | 479157.1 | 15.197 | 8 | | | 385032.1 | 1.0000 |
| 3.1 | 387657.1 | 1.0137 | 387657.1 | 359157.1 | 419157.1 | 7.276 | 4 | 28.00 | 12.00 | 385032.1 | 1.0000 |
| *6.3 | 174657.1 | 0.4567 | 174657.1 | 147157.1 | 195157.1 | 13.432 | 4 | 10.00 | 12.00 | 174657.1 | 0.4536 |
| *12.5 | 99157.1 | 0.2593 | 99157.1 | 91157.1 | 105157.1 | 7.179 | 4 | 10.00 | 12.00 | 99157.1 | 0.2575 |
| *25 | 74657.1 | 0.1952 | 74657.1 | 61157.1 | 91157.1 | 17.136 | 4 | 10.00 | 12.00 | 76657.1 | 0.1991 |
| *50 | 78657.1 | 0.2057 | 78657.1 | 73157.1 | 83157.1 | 5.638 | 4 | 10.00 | 12.00 | 76657.1 | 0.1991 |
| *100 | 38657.1 | 0.1011 | 38657.1 | 25157.1 | 53157.1 | 40.380 | 4 | 10.00 | 12.00 | 38657.1 | 0.1004 |

| Auxiliary Tests | Statistic | Critical | Skew | Kurt |
|---|---|---|---|---|
| Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.05) | 0.917041 | 0.93 | 0.474902 | 3.761286 |
| Bartlett's Test indicates unequal variances (p = 3.11E-04) | 25.21748 | 16.81189 | | |

| Hypothesis Test (1-tail, 0.05) | NOEC | LOEC | ChV | TU |
|---|---|---|---|---|
| Wilcoxon Rank Sum Test | 3.1 | 6.3 | 4.419276 | 32.25806 |
| Treatments vs USEPA Control | | | | |

### Linear Interpolation (200 Resamples)

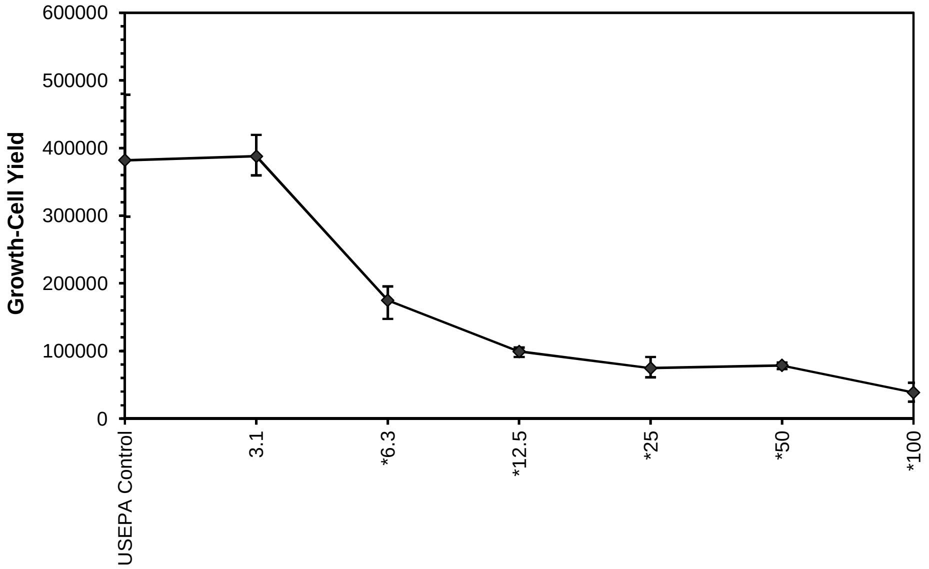
| Point | % | SD | 95% CL(Exp) | | Skew |
|---|---|---|---|---|---|
| IC05 | 3.3928 | 0.5185 | 0.2409 | 3.4425 | -2.4593 |
| IC10 | 3.6857 | 0.2528 | 2.3418 | 3.7851 | -3.6327 |
| IC15 | 3.9785 | 0.1891 | 3.0268 | 4.1276 | -2.1668 |
| IC20 | 4.2713 | 0.1764 | 3.4243 | 4.4702 | -1.6081 |
| IC25 | 4.5642 | 0.1722 | 3.7908 | 4.8127 | -1.3398 |
| IC40 | 5.4427 | 0.1737 | 4.8650 | 5.8404 | -0.4644 |
| IC50 | 6.0283 | 0.2106 | 5.4512 | 6.7251 | 0.7568 |



## Microalgal Growth inhibition Test-Growth-Cell Yield

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 29/08/2014 11:15 | Test ID: | PR1223/02 | Sample ID: | SV LDP009 |
| End Date: | 1/09/2014 10:30 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 103 | Test Species: | SC-Selenastrum capricornutum |
| Comments: | | | | | |

### Dose-Response Plot



## Microalgal Growth inhibition Test-Growth-Cell Yield

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 29/08/2014 11:15 | Test ID: | PR1223/02 | Sample ID: | SV LDP009 |
| End Date: | 1/09/2014 10:30 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 103 | Test Species: | SC-Selenastrum capricornutum |
| Comments: | | | | | |

| | | Auxiliary Data Summary | | | | | |
|---|---|---|---|---|---|---|---|
| **Conc-%** | **Parameter** | **Mean** | **Min** | **Max** | **SD** | **CV%** | **N** |
| USEPA Control | Cell Yield | 38.24 | 29.92 | 47.92 | 5.81 | 6.30 | 8 |
| 3.1 | | 38.77 | 35.92 | 41.92 | 2.82 | 4.33 | 4 |
| 6.3 | | 17.47 | 14.72 | 19.52 | 2.35 | 8.77 | 4 |
| 12.5 | | 9.92 | 9.12 | 10.52 | 0.71 | 8.51 | 4 |
| 25 | | 7.47 | 6.12 | 9.12 | 1.28 | 15.15 | 4 |
| 50 | | 7.87 | 7.32 | 8.32 | 0.44 | 8.47 | 4 |
| 100 | | 3.87 | 2.52 | 5.32 | 1.56 | 32.32 | 4 |
| USEPA Control | pH | 7.60 | 7.60 | 7.60 | 0.00 | 0.00 | 1 |
| 3.1 | | 7.70 | 7.70 | 7.70 | 0.00 | 0.00 | 1 |
| 6.3 | | 7.80 | 7.80 | 7.80 | 0.00 | 0.00 | 1 |
| 12.5 | | 8.00 | 8.00 | 8.00 | 0.00 | 0.00 | 1 |
| 25 | | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| 50 | | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| 100 | | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| USEPA Control | Conductivity uS/cm | 93.70 | 93.70 | 93.70 | 0.00 | 0.00 | 1 |
| 3.1 | | 131.50 | 131.50 | 131.50 | 0.00 | 0.00 | 1 |
| 6.3 | | 167.50 | 167.50 | 167.50 | 0.00 | 0.00 | 1 |
| 12.5 | | 243.00 | 243.00 | 243.00 | 0.00 | 0.00 | 1 |
| 25 | | 389.00 | 389.00 | 389.00 | 0.00 | 0.00 | 1 |
| 50 | | 673.00 | 673.00 | 673.00 | 0.00 | 0.00 | 1 |
| 100 | | 1231.00 | 1231.00 | 1231.00 | 0.00 | 0.00 | 1 |

# Statistical Printouts for the Duckweed Growth Inhibition Tests

## Duckweed Growth Inhibtion Test-Specific Growth Rate

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 27/08/2014 11:00 | Test ID: | PR1223/03 | Sample ID: | SV LDP009 |
| End Date: | 3/09/2014 10:30 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 112 | Test Species: | LD-Lemna disperma |
| Comments: | | | | | |

| Conc-% | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| SIS Control | 0.2728 | 0.2369 | 0.2830 | 0.2780 | 0.3253 | 0.3608 | 0.2499 |
| 3 | 0.1888 | 0.2299 | 0.2149 | 0.2149 | | | |
| 6.1 | 0.2499 | 0.2499 | 0.2560 | 0.1888 | | | |
| 12.1 | 0.2780 | 0.2780 | 0.2499 | 0.2560 | | | |
| 24.2 | 0.2618 | 0.1684 | 0.2067 | 0.2560 | | | |
| 48.4 | 0.2618 | 0.2780 | 0.2435 | 0.2618 | | | |
| 96.8 | 0.2925 | 0.3393 | 0.2878 | 0.2299 | | | |

| | | | Transform: Untransformed | | | | | 1-Tailed | | | Isotonic | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Conc-% | Mean | N-Mean | Mean | Min | Max | CV% | N | t-Stat | Critical | MSD | Mean | N-Mean |
| SIS Control | 0.2867 | 1.0000 | 0.2867 | 0.2369 | 0.3608 | 15.007 | 7 | | | | 0.2867 | 1.0000 |
| *3 | 0.2121 | 0.7399 | 0.2121 | 0.1888 | 0.2299 | 8.050 | 4 | 3.477 | 2.574 | 0.0552 | 0.2476 | 0.8637 |
| 6.1 | 0.2361 | 0.8237 | 0.2361 | 0.1888 | 0.2560 | 13.414 | 4 | 2.356 | 2.574 | 0.0552 | 0.2476 | 0.8637 |
| 12.1 | 0.2655 | 0.9260 | 0.2655 | 0.2499 | 0.2780 | 5.530 | 4 | 0.989 | 2.574 | 0.0552 | 0.2476 | 0.8637 |
| *24.2 | 0.2232 | 0.7786 | 0.2232 | 0.1684 | 0.2618 | 19.768 | 4 | 2.959 | 2.574 | 0.0552 | 0.2476 | 0.8637 |
| 48.4 | 0.2613 | 0.9114 | 0.2613 | 0.2435 | 0.2780 | 5.388 | 4 | 1.184 | 2.574 | 0.0552 | 0.2476 | 0.8637 |
| 96.8 | 0.2874 | 1.0025 | 0.2874 | 0.2299 | 0.3393 | 15.589 | 4 | -0.034 | 2.574 | 0.0552 | 0.2476 | 0.8637 |

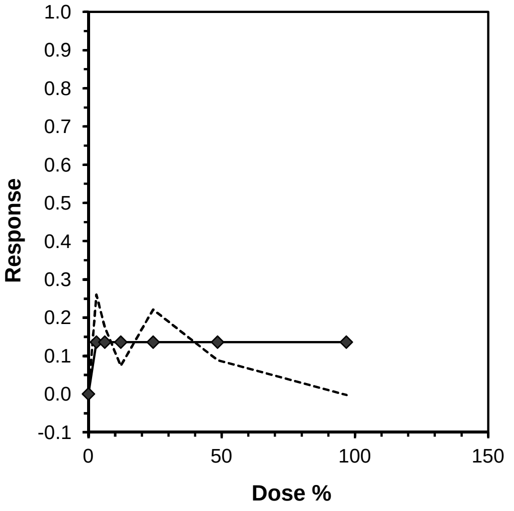
| Auxiliary Tests | Statistic | Critical | Skew | Kurt |
|---|---|---|---|---|
| Shapiro-Wilk's Test indicates normal distribution (p > 0.05) | 0.972848 | 0.929 | 0.075285 | 0.252535 |
| Bartlett's Test indicates equal variances (p = 0.23) | 8.178167 | 16.81189 | | |

| Hypothesis Test (1-tail, 0.05) | NOEC | LOEC | ChV | TU | MSDu | MSDp | MSB | MSE | F-Prob | df |
|---|---|---|---|---|---|---|---|---|---|---|
| Bonferroni t Test | 96.8 | >96.8 | | 1.033058 | 0.055189 | 0.192518 | 0.004095 | 0.001171 | 0.012518 | 6, 24 |
| Treatments vs SIS Control | | | | | | | | | | |

### Linear Interpolation (200 Resamples)

| Point | % | SD | 95% CL(Exp) | Skew |
|---|---|---|---|---|
| IC05* | 1.1006 | | | |
| IC10* | 2.2011 | | | |
| IC15 | >96.8 | | | |
| IC20 | >96.8 | | | |
| IC25 | >96.8 | | | |
| IC40 | >96.8 | | | |
| IC50 | >96.8 | | | |

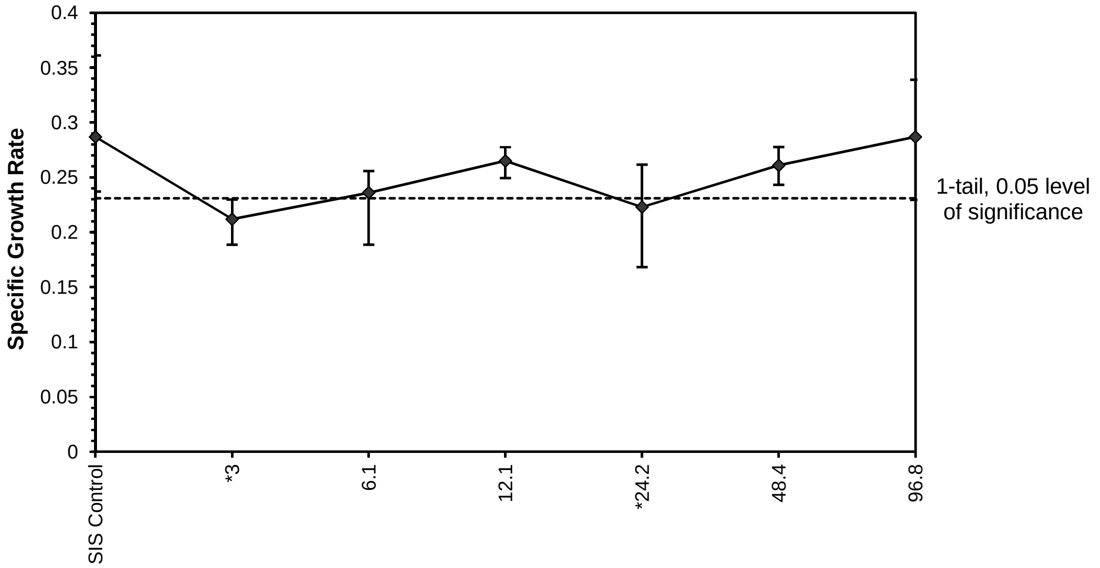
* indicates IC estimate less than the lowest concentration



## Duckweed Growth Inhibtion Test-Specific Growth Rate

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 27/08/2014 11:00 | Test ID: | PR1223/03 | Sample ID: | SV LDP009 |
| End Date: | 3/09/2014 10:30 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 112 | Test Species: | LD-Lemna disperma |
| Comments: | | | | | |

### Dose-Response Plot



## Duckweed Growth Inhibtion Test-Specific Growth Rate

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 27/08/2014 11:00 | Test ID: | PR1223/03 | Sample ID: | SV LDP009 |
| End Date: | 3/09/2014 10:30 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 112 | Test Species: | LD-Lemna disperma |
| Comments: | | | | | |

| | | Auxiliary Data Summary | | | | | |
|---|---|---|---|---|---|---|---|
| **Conc-%** | **Parameter** | **Mean** | **Min** | **Max** | **SD** | **CV%** | **N** |
| SIS Control | Specific growth rate | 0.29 | 0.24 | 0.36 | 0.04 | 72.35 | 7 |
| 3 | | 0.21 | 0.19 | 0.23 | 0.02 | 61.60 | 4 |
| 6.1 | | 0.24 | 0.19 | 0.26 | 0.03 | 75.37 | 4 |
| 12.1 | | 0.27 | 0.25 | 0.28 | 0.01 | 45.64 | 4 |
| 24.2 | | 0.22 | 0.17 | 0.26 | 0.04 | 94.11 | 4 |
| 48.4 | | 0.26 | 0.24 | 0.28 | 0.01 | 45.41 | 4 |
| 96.8 | | 0.29 | 0.23 | 0.34 | 0.04 | 73.65 | 4 |
| SIS Control | pH | 6.40 | 6.40 | 6.40 | 0.00 | 0.00 | 1 |
| 3 | | 6.70 | 6.70 | 6.70 | 0.00 | 0.00 | 1 |
| 6.1 | | 6.90 | 6.90 | 6.90 | 0.00 | 0.00 | 1 |
| 12.1 | | 7.20 | 7.20 | 7.20 | 0.00 | 0.00 | 1 |
| 24.2 | | 7.60 | 7.60 | 7.60 | 0.00 | 0.00 | 1 |
| 48.4 | | 7.90 | 7.90 | 7.90 | 0.00 | 0.00 | 1 |
| 96.8 | | 8.30 | 8.30 | 8.30 | 0.00 | 0.00 | 1 |
| SIS Control | Cond uS/cm | 309.00 | 309.00 | 309.00 | 0.00 | 0.00 | 1 |
| 3 | | 331.00 | 331.00 | 331.00 | 0.00 | 0.00 | 1 |
| 6.1 | | 362.00 | 362.00 | 362.00 | 0.00 | 0.00 | 1 |
| 12.1 | | 427.00 | 427.00 | 427.00 | 0.00 | 0.00 | 1 |
| 24.2 | | 563.00 | 563.00 | 563.00 | 0.00 | 0.00 | 1 |
| 48.4 | | 829.00 | 829.00 | 829.00 | 0.00 | 0.00 | 1 |
| 96.8 | | 1380.00 | 1380.00 | 1380.00 | 0.00 | 0.00 | 1 |

# Statistical Printouts for the Larval Fish Imbalance Tests

## Fish Acute Toxicity Test-96 hr Imbalance

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 9/09/2014 13:00 | Test ID: | PR1223/01 | Sample ID: | SV LDP009 |
| End Date: | 13/09/2014 17:45 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 117 | Test Species: | MS-Melanotaenia splendida |
| Comments: | | | | | |

| Conc-% | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| DMW Control | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 3.1 | 1.0000 | 0.8000 | 1.0000 | 1.0000 |
| 6.3 | 1.0000 | 1.0000 | 1.0000 | 0.8000 |
| 12.5 | 1.0000 | 1.0000 | 1.0000 | 0.8000 |
| 25 | 0.8000 | 1.0000 | 0.8000 | 1.0000 |
| 50 | 0.4000 | 0.6000 | 0.6000 | 0.4000 |
| 100 | 0.0000 | 0.2000 | 0.0000 | 0.2000 |

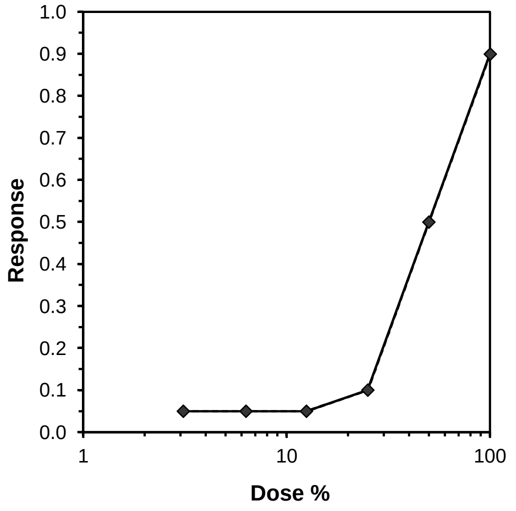
| | | | Transform: Arcsin Square Root | | | | | Rank | 1-Tailed | Isotonic | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Conc-% | Mean | N-Mean | Mean | Min | Max | CV% | N | Sum | Critical | Mean | N-Mean |
| DMW Control | 1.0000 | 1.0000 | 1.3453 | 1.3453 | 1.3453 | 0.000 | 4 | | | 1.0000 | 1.0000 |
| 3.1 | 0.9500 | 0.9500 | 1.2857 | 1.1071 | 1.3453 | 9.261 | 4 | 16.00 | 10.00 | 0.9500 | 0.9500 |
| 6.3 | 0.9500 | 0.9500 | 1.2857 | 1.1071 | 1.3453 | 9.261 | 4 | 16.00 | 10.00 | 0.9500 | 0.9500 |
| 12.5 | 0.9500 | 0.9500 | 1.2857 | 1.1071 | 1.3453 | 9.261 | 4 | 16.00 | 10.00 | 0.9500 | 0.9500 |
| 25 | 0.9000 | 0.9000 | 1.2262 | 1.1071 | 1.3453 | 11.212 | 4 | 14.00 | 10.00 | 0.9000 | 0.9000 |
| *50 | 0.5000 | 0.5000 | 0.7854 | 0.6847 | 0.8861 | 14.802 | 4 | 10.00 | 10.00 | 0.5000 | 0.5000 |
| *100 | 0.1000 | 0.1000 | 0.3446 | 0.2255 | 0.4636 | 39.900 | 4 | 10.00 | 10.00 | 0.1000 | 0.1000 |

| Auxiliary Tests | Statistic | Critical | Skew | Kurt |
|---|---|---|---|---|
| Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.05) | 0.854934 | 0.924 | -0.56904 | -1.15873 |
| Equality of variance cannot be confirmed | | | | |

| Hypothesis Test (1-tail, 0.05) | NOEC | LOEC | ChV | TU |
|---|---|---|---|---|
| Steel's Many-One Rank Test | 25 | 50 | 35.35534 | 4 |
| Treatments vs DMW Control | | | | |

**Log-Logit Interpolation (200 Resamples)**

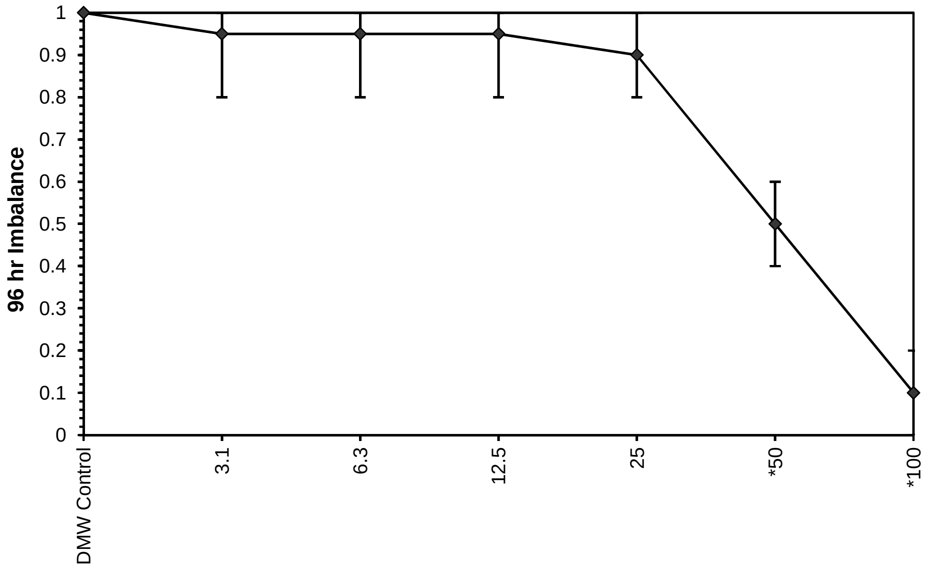
| Point | % | SD | 95% CL(Exp) | | Skew |
|---|---|---|---|---|---|
| IC05 | 12.500 | 7.862 | 0.000 | 34.882 | 0.6985 |
| IC10 | 25.000 | 6.597 | 0.000 | 34.148 | -0.7220 |
| IC15 | 28.963 | 3.832 | 15.611 | 37.652 | -0.3499 |
| IC20 | 32.340 | 3.259 | 20.596 | 39.986 | 0.0255 |
| IC25 | 35.414 | 2.902 | 24.994 | 42.605 | 0.0239 |
| IC40 | 44.038 | 2.603 | 37.982 | 53.577 | 0.1901 |
| IC50 | 50.000 | 2.893 | 41.870 | 59.165 | 0.1542 |



## Fish Acute Toxicity Test-96 hr Imbalance

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 9/09/2014 13:00 | Test ID: | PR1223/01 | Sample ID: | SV LDP009 |
| End Date: | 13/09/2014 17:45 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 117 | Test Species: | MS-Melanotaenia splendida |
| Comments: | | | | | |

### Dose-Response Plot



## Fish Acute Toxicity Test-96 hr Imbalance

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 9/09/2014 13:00 | Test ID: | PR1223/01 | Sample ID: | SV LDP009 |
| End Date: | 13/09/2014 17:45 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 117 | Test Species: | MS-Melanotaenia splendida |
| Comments: | | | | | |

| | | Auxiliary Data Summary | | | | | |
|---|---|---|---|---|---|---|---|
| **Conc-%** | **Parameter** | **Mean** | **Min** | **Max** | **SD** | **CV%** | **N** |
| DMW Control | % Unaffected | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 4 |
| 3.1 | | 95.00 | 80.00 | 100.00 | 10.00 | 3.33 | 4 |
| 6.3 | | 95.00 | 80.00 | 100.00 | 10.00 | 3.33 | 4 |
| 12.5 | | 95.00 | 80.00 | 100.00 | 10.00 | 3.33 | 4 |
| 25 | | 90.00 | 80.00 | 100.00 | 11.55 | 3.78 | 4 |
| 50 | | 50.00 | 40.00 | 60.00 | 11.55 | 6.80 | 4 |
| 100 | | 10.00 | 0.00 | 20.00 | 11.55 | 33.98 | 4 |
| DMW Control | pH | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| 3.1 | | 7.80 | 7.80 | 7.80 | 0.00 | 0.00 | 1 |
| 6.3 | | 7.90 | 7.90 | 7.90 | 0.00 | 0.00 | 1 |
| 12.5 | | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 25 | | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| 50 | | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| 100 | | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| DMW Control | DO % | 101.20 | 101.20 | 101.20 | 0.00 | 0.00 | 1 |
| 3.1 | | 100.30 | 100.30 | 100.30 | 0.00 | 0.00 | 1 |
| 6.3 | | 100.10 | 100.10 | 100.10 | 0.00 | 0.00 | 1 |
| 12.5 | | 100.50 | 100.50 | 100.50 | 0.00 | 0.00 | 1 |
| 25 | | 100.90 | 100.90 | 100.90 | 0.00 | 0.00 | 1 |
| 50 | | 102.50 | 102.50 | 102.50 | 0.00 | 0.00 | 1 |
| 100 | | 108.10 | 108.10 | 108.10 | 0.00 | 0.00 | 1 |
| DMW Control | Conductivity uS/cm | 173.60 | 173.60 | 173.60 | 0.00 | 0.00 | 1 |
| 3.1 | | 213.00 | 213.00 | 213.00 | 0.00 | 0.00 | 1 |
| 6.3 | | 246.00 | 246.00 | 246.00 | 0.00 | 0.00 | 1 |
| 12.5 | | 313.00 | 313.00 | 313.00 | 0.00 | 0.00 | 1 |
| 25 | | 440.00 | 440.00 | 440.00 | 0.00 | 0.00 | 1 |
| 50 | | 671.00 | 671.00 | 671.00 | 0.00 | 0.00 | 1 |
| 100 | | 1154.00 | 1154.00 | 1154.00 | 0.00 | 0.00 | 1 |

## Fish Acute Toxicity Test-96 hr Imbalance

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 9/09/2014 13:00 | Test ID: | PR1223/01 | Sample ID: | SV LDP009 |
| End Date: | 13/09/2014 17:45 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 117 | Test Species: | MS-Melanotaenia splendida |
| Comments: | | | | | |

| Conc-% | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| DMW Control | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 3.1 | 1.0000 | 0.8000 | 1.0000 | 1.0000 |
| 6.3 | 1.0000 | 1.0000 | 1.0000 | 0.8000 |
| 12.5 | 1.0000 | 1.0000 | 1.0000 | 0.8000 |
| 25 | 0.8000 | 1.0000 | 0.8000 | 1.0000 |
| 50 | 0.4000 | 0.6000 | 0.6000 | 0.4000 |
| 100 | 0.0000 | 0.2000 | 0.0000 | 0.2000 |

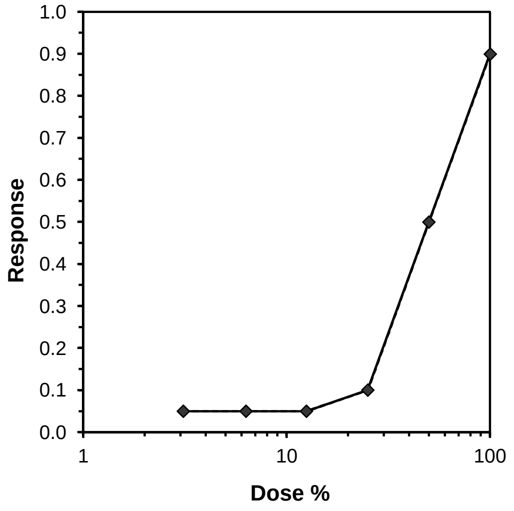
| | | | Transform: Arcsin Square Root | | | | | Rank | 1-Tailed | Number | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Conc-% | Mean | N-Mean | Mean | Min | Max | CV% | N | Sum | Critical | Resp | Number |
| DMW Control | 1.0000 | 1.0000 | 1.3453 | 1.3453 | 1.3453 | 0.000 | 4 | | | 0 | 20 |
| 3.1 | 0.9500 | 0.9500 | 1.2857 | 1.1071 | 1.3453 | 9.261 | 4 | 16.00 | 10.00 | 1 | 20 |
| 6.3 | 0.9500 | 0.9500 | 1.2857 | 1.1071 | 1.3453 | 9.261 | 4 | 16.00 | 10.00 | 1 | 20 |
| 12.5 | 0.9500 | 0.9500 | 1.2857 | 1.1071 | 1.3453 | 9.261 | 4 | 16.00 | 10.00 | 1 | 20 |
| 25 | 0.9000 | 0.9000 | 1.2262 | 1.1071 | 1.3453 | 11.212 | 4 | 14.00 | 10.00 | 2 | 20 |
| *50 | 0.5000 | 0.5000 | 0.7854 | 0.6847 | 0.8861 | 14.802 | 4 | 10.00 | 10.00 | 10 | 20 |
| *100 | 0.1000 | 0.1000 | 0.3446 | 0.2255 | 0.4636 | 39.900 | 4 | 10.00 | 10.00 | 18 | 20 |

| Auxiliary Tests | Statistic | Critical | Skew | Kurt |
|---|---|---|---|---|
| Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.05) | 0.854934 | 0.924 | -0.56904 | -1.15873 |
| Equality of variance cannot be confirmed | | | | |

| Hypothesis Test (1-tail, 0.05) | NOEC | LOEC | ChV | TU |
|---|---|---|---|---|
| Steel's Many-One Rank Test | 25 | 50 | 35.35534 | 4 |
| Treatments vs DMW Control | | | | |

### Trimmed Spearman-Karber

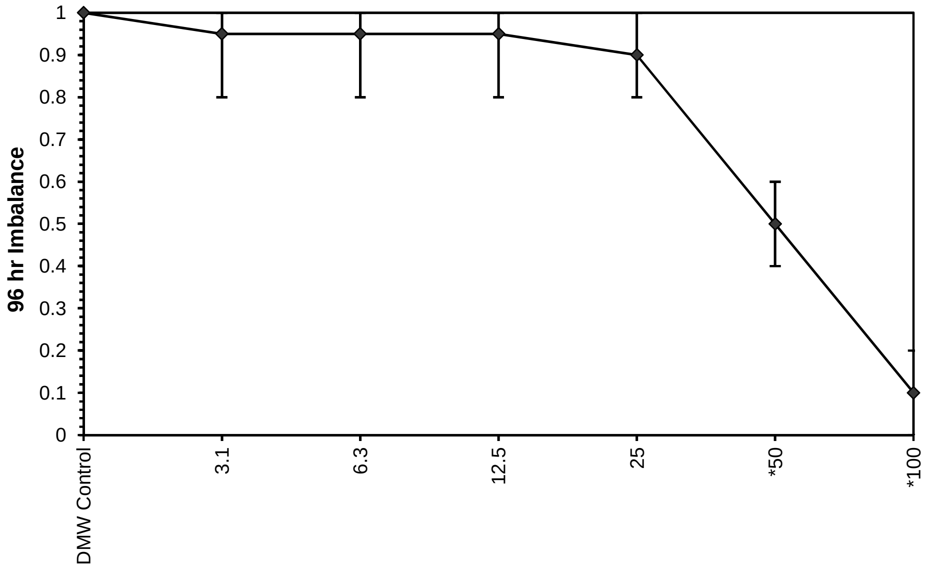
| Trim Level | EC50 | 95% CL | |
|---|---|---|---|
| 0.0% | | | |
| 5.0% | | | |
| 10.0% | 50.000 | 40.511 | 61.712 |
| 20.0% | 50.000 | 38.338 | 65.209 |
| Auto-10.0% | 50.000 | 40.511 | 61.712 |



## Fish Acute Toxicity Test-96 hr Imbalance

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 9/09/2014 13:00 | Test ID: | PR1223/01 | Sample ID: | SV LDP009 |
| End Date: | 13/09/2014 17:45 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 117 | Test Species: | MS-Melanotaenia splendida |
| Comments: | | | | | |

### Dose-Response Plot



## Fish Acute Toxicity Test-96 hr Imbalance

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 9/09/2014 13:00 | Test ID: | PR1223/01 | Sample ID: | SV LDP009 |
| End Date: | 13/09/2014 17:45 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 117 | Test Species: | MS-Melanotaenia splendida |
| Comments: | | | | | |

| | | Auxiliary Data Summary | | | | | |
|---|---|---|---|---|---|---|---|
| **Conc-%** | **Parameter** | **Mean** | **Min** | **Max** | **SD** | **CV%** | **N** |
| DMW Control | % Unaffected | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 4 |
| 3.1 | | 95.00 | 80.00 | 100.00 | 10.00 | 3.33 | 4 |
| 6.3 | | 95.00 | 80.00 | 100.00 | 10.00 | 3.33 | 4 |
| 12.5 | | 95.00 | 80.00 | 100.00 | 10.00 | 3.33 | 4 |
| 25 | | 90.00 | 80.00 | 100.00 | 11.55 | 3.78 | 4 |
| 50 | | 50.00 | 40.00 | 60.00 | 11.55 | 6.80 | 4 |
| 100 | | 10.00 | 0.00 | 20.00 | 11.55 | 33.98 | 4 |
| DMW Control | pH | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| 3.1 | | 7.80 | 7.80 | 7.80 | 0.00 | 0.00 | 1 |
| 6.3 | | 7.90 | 7.90 | 7.90 | 0.00 | 0.00 | 1 |
| 12.5 | | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 25 | | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| 50 | | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| 100 | | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| DMW Control | DO % | 101.20 | 101.20 | 101.20 | 0.00 | 0.00 | 1 |
| 3.1 | | 100.30 | 100.30 | 100.30 | 0.00 | 0.00 | 1 |
| 6.3 | | 100.10 | 100.10 | 100.10 | 0.00 | 0.00 | 1 |
| 12.5 | | 100.50 | 100.50 | 100.50 | 0.00 | 0.00 | 1 |
| 25 | | 100.90 | 100.90 | 100.90 | 0.00 | 0.00 | 1 |
| 50 | | 102.50 | 102.50 | 102.50 | 0.00 | 0.00 | 1 |
| 100 | | 108.10 | 108.10 | 108.10 | 0.00 | 0.00 | 1 |
| DMW Control | Conductivity uS/cm | 173.60 | 173.60 | 173.60 | 0.00 | 0.00 | 1 |
| 3.1 | | 213.00 | 213.00 | 213.00 | 0.00 | 0.00 | 1 |
| 6.3 | | 246.00 | 246.00 | 246.00 | 0.00 | 0.00 | 1 |
| 12.5 | | 313.00 | 313.00 | 313.00 | 0.00 | 0.00 | 1 |
| 25 | | 440.00 | 440.00 | 440.00 | 0.00 | 0.00 | 1 |
| 50 | | 671.00 | 671.00 | 671.00 | 0.00 | 0.00 | 1 |
| 100 | | 1154.00 | 1154.00 | 1154.00 | 0.00 | 0.00 | 1 |

Reviewed by:_____

# Statistical Printouts for *Hydra* Population Growth Tests

## Hydra Population Growth Test-Growth Rate

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 26/08/2014 13:30 | Test ID: | PR1223/02 | Sample ID: | SV LDP009 |
| End Date: | 30/08/2014 15:44 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 125 | Test Species: | HV-Hydra viridissima |
| Comments: | | | | | |

| Conc-% | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Lab Control | 0.3735 | 0.3735 | 0.3785 | 0.3683 |
| 3.1 | 0.3683 | 0.3408 | 0.3349 | 0.3577 |
| 6.3 | 0.3349 | 0.3033 | 0.3408 | 0.3289 |
| 12.5 | 0.2336 | 0.1950 | 0.2670 | 0.2894 |
| 25 | 0.1844 | 0.1366 | 0.0603 | 0.0603 |
| 50 | 0.0603 | 0.0000 | 0.0418 | 0.0218 |
| 100 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| | | | Transform: Untransformed | | | | | Rank | 1-Tailed | Isotonic | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Conc-% | Mean | N-Mean | Mean | Min | Max | CV% | N | Sum | Critical | Mean | N-Mean |
| Lab Control | 0.3735 | 1.0000 | 0.3735 | 0.3683 | 0.3785 | 1.116 | 4 | | | 0.3735 | 1.0000 |
| 3.1 | 0.3504 | 0.9384 | 0.3504 | 0.3349 | 0.3683 | 4.374 | 4 | 10.50 | 10.00 | 0.3504 | 0.9384 |
| *6.3 | 0.3270 | 0.8756 | 0.3270 | 0.3033 | 0.3408 | 5.061 | 4 | 10.00 | 10.00 | 0.3270 | 0.8756 |
| *12.5 | 0.2462 | 0.6593 | 0.2462 | 0.1950 | 0.2894 | 16.697 | 4 | 10.00 | 10.00 | 0.2462 | 0.6593 |
| *25 | 0.1104 | 0.2956 | 0.1104 | 0.0603 | 0.1844 | 55.309 | 4 | 10.00 | 10.00 | 0.1104 | 0.2956 |
| *50 | 0.0310 | 0.0829 | 0.0310 | 0.0000 | 0.0603 | 83.842 | 4 | 10.00 | 10.00 | 0.0310 | 0.0829 |
| 100 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.000 | 4 | | | 0.0000 | 0.0000 |

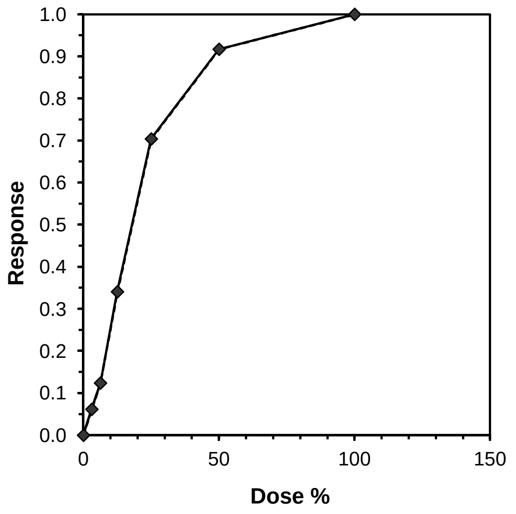
| Auxiliary Tests | Statistic | Critical | Skew | Kurt |
|---|---|---|---|---|
| Shapiro-Wilk's Test indicates normal distribution (p > 0.05) | 0.962848 | 0.916 | 0.208991 | 0.793682 |
| Bartlett's Test indicates unequal variances (p = 7.52E-03) | 15.77501 | 15.08627 | | |

| Hypothesis Test (1-tail, 0.05) | NOEC | LOEC | ChV | TU |
|---|---|---|---|---|
| Steel's Many-One Rank Test | 3.1 | 6.3 | 4.419276 | 32.25806 |
| Treatments vs Lab Control | | | | |

### Linear Interpolation (200 Resamples)

| Point | % | SD | 95% CL(Exp) | | Skew |
|---|---|---|---|---|---|
| IC05* | 2.516 | 0.648 | 1.094 | 4.743 | 0.5183 |
| IC10 | 5.056 | 0.810 | 2.373 | 7.276 | -0.3033 |
| IC15 | 7.033 | 0.585 | 4.993 | 9.004 | -0.1030 |
| IC20 | 8.467 | 0.702 | 6.785 | 11.378 | 0.8354 |
| IC25 | 9.901 | 0.989 | 7.936 | 13.861 | 0.7298 |
| IC40 | 14.539 | 1.485 | 10.347 | 18.967 | -0.0769 |
| IC50 | 17.976 | 1.666 | 13.979 | 24.777 | 0.7715 |

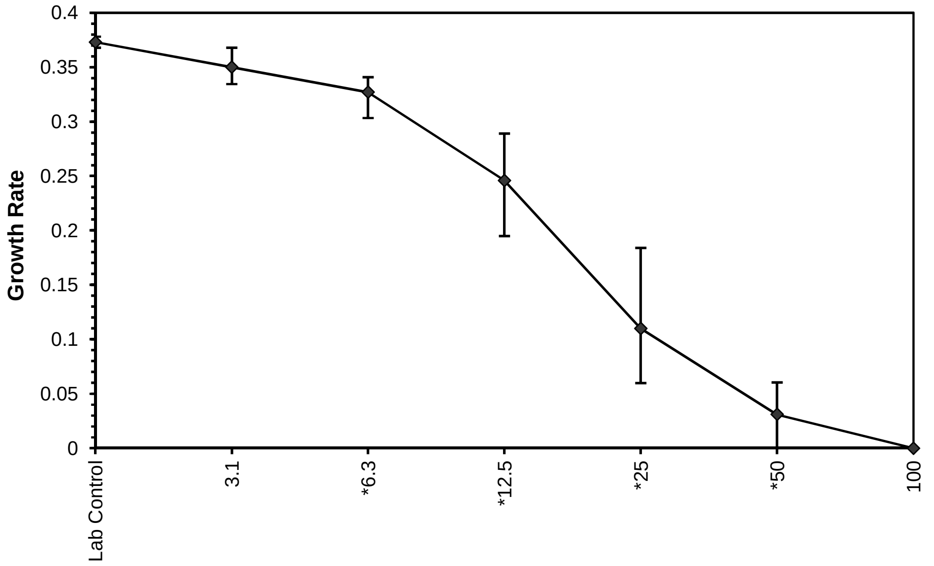
* indicates IC estimate less than the lowest concentration



## Hydra Population Growth Test-Growth Rate

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 26/08/2014 13:30 | Test ID: | PR1223/02 | Sample ID: | SV LDP009 |
| End Date: | 30/08/2014 15:44 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 125 | Test Species: | HV-Hydra viridissima |
| Comments: | | | | | |

### Dose-Response Plot



## Hydra Population Growth Test-Growth Rate

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 26/08/2014 13:30 | Test ID: | PR1223/02 | Sample ID: | SV LDP009 |
| End Date: | 30/08/2014 15:44 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 125 | Test Species: | HV-Hydra viridissima |
| Comments: | | | | | |

| | | Auxiliary Data Summary | | | | | |
|---|---|---|---|---|---|---|---|
| **Conc-%** | **Parameter** | **Mean** | **Min** | **Max** | **SD** | **CV%** | **N** |
| Lab Control | Growth Rate | 0.37 | 0.37 | 0.38 | 0.00 | 17.28 | 4 |
| 3.1 | | 0.35 | 0.33 | 0.37 | 0.02 | 35.33 | 4 |
| 6.3 | | 0.33 | 0.30 | 0.34 | 0.02 | 39.34 | 4 |
| 12.5 | | 0.25 | 0.20 | 0.29 | 0.04 | 82.35 | 4 |
| 25 | | 0.11 | 0.06 | 0.18 | 0.06 | 223.82 | 4 |
| 50 | | 0.03 | 0.00 | 0.06 | 0.03 | 520.46 | 4 |
| 100 | | 0.00 | 0.00 | 0.00 | 0.00 | | 4 |
| Lab Control | Conductivity | 26.50 | 26.50 | 26.50 | 0.00 | 0.00 | 1 |
| 3.1 | | 65.00 | 65.00 | 65.00 | 0.00 | 0.00 | 1 |
| 6.3 | | 104.80 | 104.80 | 104.80 | 0.00 | 0.00 | 1 |
| 12.5 | | 181.70 | 181.70 | 181.70 | 0.00 | 0.00 | 1 |
| 25 | | 332.00 | 332.00 | 332.00 | 0.00 | 0.00 | 1 |
| 50 | | 619.00 | 619.00 | 619.00 | 0.00 | 0.00 | 1 |
| 100 | | 1175.00 | 1175.00 | 1175.00 | 0.00 | 0.00 | 1 |
| Lab Control | pH | 7.00 | 7.00 | 7.00 | 0.00 | 0.00 | 1 |
| 3.1 | | 7.10 | 7.10 | 7.10 | 0.00 | 0.00 | 1 |
| 6.3 | | 7.30 | 7.30 | 7.30 | 0.00 | 0.00 | 1 |
| 12.5 | | 7.50 | 7.50 | 7.50 | 0.00 | 0.00 | 1 |
| 25 | | 7.90 | 7.90 | 7.90 | 0.00 | 0.00 | 1 |
| 50 | | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| 100 | | 8.30 | 8.30 | 8.30 | 0.00 | 0.00 | 1 |
| Lab Control | DO, % sat | 96.80 | 96.80 | 96.80 | 0.00 | 0.00 | 1 |
| 3.1 | | 98.50 | 98.50 | 98.50 | 0.00 | 0.00 | 1 |
| 6.3 | | 99.10 | 99.10 | 99.10 | 0.00 | 0.00 | 1 |
| 12.5 | | 99.10 | 99.10 | 99.10 | 0.00 | 0.00 | 1 |
| 25 | | 99.70 | 99.70 | 99.70 | 0.00 | 0.00 | 1 |
| 50 | | 100.70 | 100.70 | 100.70 | 0.00 | 0.00 | 1 |
| 100 | | 102.60 | 102.60 | 102.60 | 0.00 | 0.00 | 1 |

# Statistical Printouts for the 7-d Chronic Test with *Ceriodaphnia dubia*

## Ceriodaphnia Partial Life-Cycle Test-Reproduction

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 4/09/2014 15:00 | Test ID: | PR1223/02 | Sample ID: | AP LDP001 |
| End Date: | 12/09/2014 16:00 | Lab ID: | 6807 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

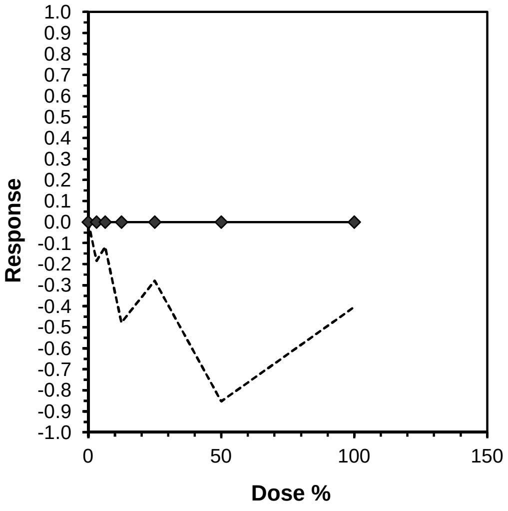
| Conc-% | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| DMW Control | 22.000 | 17.000 | 19.000 | 12.000 | 15.000 | 0.000 | 11.000 | 12.000 | 17.000 | 11.000 |
| 3.1 | 21.000 | 26.000 | 17.000 | 23.000 | 14.000 | 10.000 | 18.000 | 17.000 | 0.000 | 15.000 |
| 6.3 | 13.000 | 21.000 | 23.000 | 13.000 | 17.000 | 7.000 | 20.000 | 17.000 | 9.000 | 12.000 |
| 12.5 | 18.000 | 22.000 | 22.000 | 22.000 | 32.000 | 19.000 | 20.000 | 22.000 | 14.000 | 10.000 |
| 25 | 0.000 | 23.000 | 18.000 | 23.000 | 21.000 | 21.000 | 21.000 | 10.000 | 13.000 | 24.000 |
| 50 | 22.000 | 26.000 | 25.000 | 34.000 | 25.000 | 28.000 | 20.000 | 28.000 | 20.000 | 24.000 |
| 100 | 33.000 | 24.000 | 3.000 | 22.000 | 21.000 | 26.000 | 12.000 | 11.000 | 26.000 | 13.000 |

| | | | Transform: Untransformed | | | | | | 1-Tailed | | Isotonic | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Conc-% | Mean | N-Mean | Mean | Min | Max | CV% | N | t-Stat | Critical | MSD | Mean | N-Mean |
| DMW Control | 13.600 | 1.0000 | 13.600 | 0.000 | 22.000 | 44.416 | 10 | | | | 18.100 | 1.0000 |
| 3.1 | 16.100 | 1.1838 | 16.100 | 0.000 | 26.000 | 45.213 | 10 | -0.842 | 2.347 | 6.966 | 18.100 | 1.0000 |
| 6.3 | 15.200 | 1.1176 | 15.200 | 7.000 | 23.000 | 34.646 | 10 | -0.539 | 2.347 | 6.966 | 18.100 | 1.0000 |
| 12.5 | 20.100 | 1.4779 | 20.100 | 10.000 | 32.000 | 28.767 | 10 | -2.190 | 2.347 | 6.966 | 18.100 | 1.0000 |
| 25 | 17.400 | 1.2794 | 17.400 | 0.000 | 24.000 | 43.786 | 10 | -1.280 | 2.347 | 6.966 | 18.100 | 1.0000 |
| 50 | 25.200 | 1.8529 | 25.200 | 20.000 | 34.000 | 16.711 | 10 | -3.908 | 2.347 | 6.966 | 18.100 | 1.0000 |
| 100 | 19.100 | 1.4044 | 19.100 | 3.000 | 33.000 | 47.375 | 10 | -1.853 | 2.347 | 6.966 | 18.100 | 1.0000 |

| Auxiliary Tests | | | | | Statistic | | Critical | | Skew | Kurt |
|---|---|---|---|---|---|---|---|---|---|---|
| Kolmogorov D Test indicates normal distribution (p > 0.05) | | | | | 0.708442 | | 0.895 | | -0.62529 | 0.677564 |
| Bartlett's Test indicates equal variances (p = 0.37) | | | | | 6.518898 | | 16.81189 | | | |
| **Hypothesis Test (1-tail, 0.05)** | **NOEC** | **LOEC** | **ChV** | **TU** | **MSDu** | **MSDp** | **MSB** | **MSE** | **F-Prob** | **df** |
| Dunnett's Test | 100 | >100 | | 1 | 6.966141 | 0.512216 | 147.6 | 44.04286 | 0.006266 | 6, 63 |
| Treatments vs DMW Control | | | | | | | | | | |

### Linear Interpolation (200 Resamples)

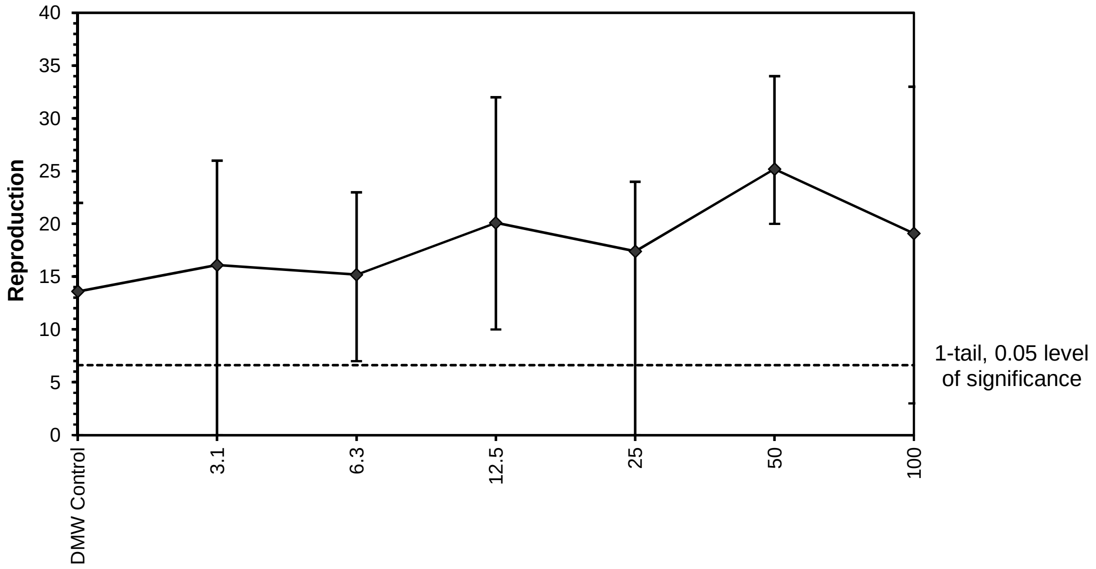
| Point | % | SD | 95% CL | Skew |
|---|---|---|---|---|
| IC05 | >100 | | | |
| IC10 | >100 | | | |
| IC15 | >100 | | | |
| IC20 | >100 | | | |
| IC25 | >100 | | | |
| IC40 | >100 | | | |
| IC50 | >100 | | | |



## Ceriodaphnia Partial Life-Cycle Test-Reproduction

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 4/09/2014 15:00 | Test ID: | PR1223/02 | Sample ID: | AP LDP001 |
| End Date: | 12/09/2014 16:00 | Lab ID: | 6807 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

### Dose-Response Plot



## Ceriodaphnia Partial Life-Cycle Test-Reproduction

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 4/09/2014 15:00 | Test ID: | PR1223/02 | Sample ID: | AP LDP001 |
| End Date: | 12/09/2014 16:00 | Lab ID: | 6807 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

| | | Auxiliary Data Summary | | | | | |
|---|---|---|---|---|---|---|---|
| **Conc-%** | **Parameter** | **Mean** | **Min** | **Max** | **SD** | **CV%** | **N** |
| DMW Control | No of Young | 13.60 | 0.00 | 22.00 | 6.04 | 18.07 | 10 |
| 3.1 | | 16.10 | 0.00 | 26.00 | 7.28 | 16.76 | 10 |
| 6.3 | | 15.20 | 7.00 | 23.00 | 5.27 | 15.10 | 10 |
| 12.5 | | 20.10 | 10.00 | 32.00 | 5.78 | 11.96 | 10 |
| 25 | | 17.40 | 0.00 | 24.00 | 7.62 | 15.86 | 10 |
| 50 | | 25.20 | 20.00 | 34.00 | 4.21 | 8.14 | 10 |
| 100 | | 19.10 | 3.00 | 33.00 | 9.05 | 15.75 | 10 |
| DMW Control | % survival | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| 3.1 | | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| 6.3 | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| 12.5 | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| 25 | | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| 50 | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| 100 | | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| DMW Control | pH | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 3.1 | | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 6.3 | | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 12.5 | | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 25 | | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 50 | | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 100 | | 8.00 | 8.00 | 8.00 | 0.00 | 0.00 | 1 |
| DMW Control | DO % | 101.00 | 101.00 | 101.00 | 0.00 | 0.00 | 1 |
| 3.1 | | 100.60 | 100.60 | 100.60 | 0.00 | 0.00 | 1 |
| 6.3 | | 100.40 | 100.40 | 100.40 | 0.00 | 0.00 | 1 |
| 12.5 | | 100.60 | 100.60 | 100.60 | 0.00 | 0.00 | 1 |
| 25 | | 104.30 | 104.30 | 104.30 | 0.00 | 0.00 | 1 |
| 50 | | 104.30 | 104.30 | 104.30 | 0.00 | 0.00 | 1 |
| 100 | | 106.00 | 106.00 | 106.00 | 0.00 | 0.00 | 1 |
| DMW Control | Cond uS/cm | 185.50 | 185.50 | 185.50 | 0.00 | 0.00 | 1 |
| 3.1 | | 213.00 | 213.00 | 213.00 | 0.00 | 0.00 | 1 |
| 6.3 | | 242.00 | 242.00 | 242.00 | 0.00 | 0.00 | 1 |
| 12.5 | | 298.00 | 298.00 | 298.00 | 0.00 | 0.00 | 1 |
| 25 | | 409.00 | 409.00 | 409.00 | 0.00 | 0.00 | 1 |
| 50 | | 625.00 | 625.00 | 625.00 | 0.00 | 0.00 | 1 |
| 100 | | 1038.00 | 1038.00 | 1038.00 | 0.00 | 0.00 | 1 |

Reviewed by:_____

## Ceriodaphnia Partial Life-Cycle Test-8 day survival

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 4/09/2014 15:00 | Test ID: | PR1223/02 | Sample ID: | AP LDP001 |
| End Date: | 12/09/2014 16:00 | Lab ID: | 6807 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

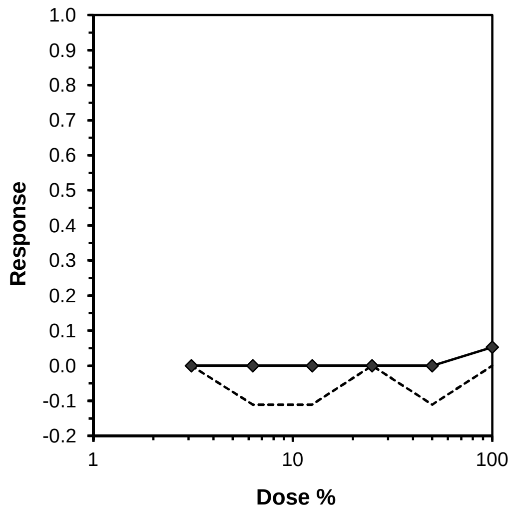
| Conc-% | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| DMW Control | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 3.1 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.0000 | 1.0000 |
| 6.3 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 12.5 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 25 | 0.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 50 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 100 | 1.0000 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |

| Conc-% | Mean | N-Mean | Resp | Not Resp | Total | N | Fisher's Exact P | 1-Tailed Critical | Isotonic Mean | Isotonic N-Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| DMW Control | 0.9000 | 1.0000 | 1 | 9 | 10 | 10 | | | 0.9500 | 1.0000 |
| 3.1 | 0.9000 | 1.0000 | 1 | 9 | 10 | 10 | 0.7632 | 0.0500 | 0.9500 | 1.0000 |
| 6.3 | 1.0000 | 1.1111 | 0 | 10 | 10 | 10 | 0.5000 | 0.0500 | 0.9500 | 1.0000 |
| 12.5 | 1.0000 | 1.1111 | 0 | 10 | 10 | 10 | 0.5000 | 0.0500 | 0.9500 | 1.0000 |
| 25 | 0.9000 | 1.0000 | 1 | 9 | 10 | 10 | 0.7632 | 0.0500 | 0.9500 | 1.0000 |
| 50 | 1.0000 | 1.1111 | 0 | 10 | 10 | 10 | 0.5000 | 0.0500 | 0.9500 | 1.0000 |
| 100 | 0.9000 | 1.0000 | 1 | 9 | 10 | 10 | 0.7632 | 0.0500 | 0.9000 | 0.9474 |

| Hypothesis Test (1-tail, 0.05) | NOEC | LOEC | ChV | TU |
|---|---|---|---|---|
| Fisher's Exact Test<br>Treatments vs DMW Control | 100 | >100 | | 1 |

### Log-Logit Interpolation (200 Resamples)

| Point | % | SD | 95% CL | Skew |
|---|---|---|---|---|
| IC05 | 97.438 | | | |
| IC10 | >100 | | | |
| IC15 | >100 | | | |
| IC20 | >100 | | | |
| IC25 | >100 | | | |
| IC40 | >100 | | | |
| IC50 | >100 | | | |

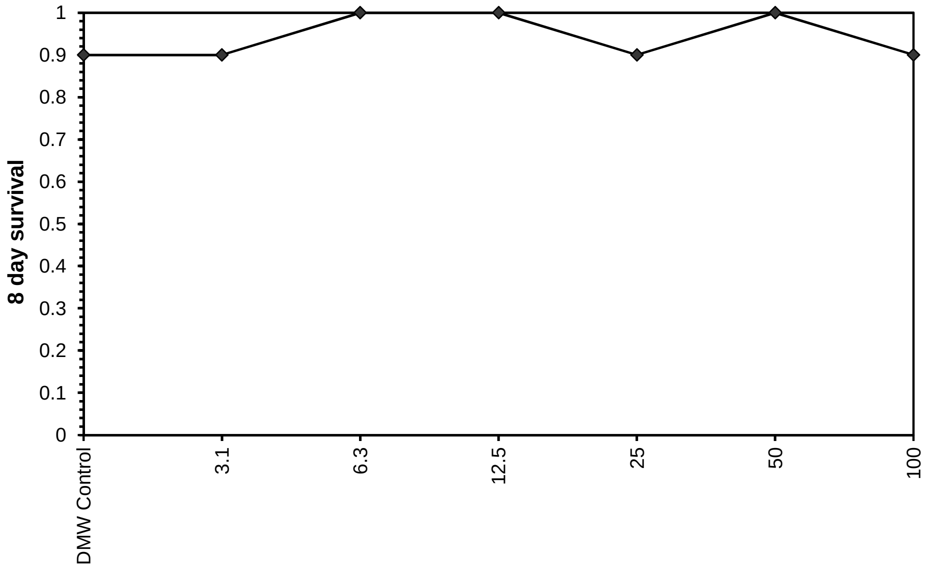


Reviewed by:_____

## Ceriodaphnia Partial Life-Cycle Test-8 day survival

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 4/09/2014 15:00 | Test ID: | PR1223/02 | Sample ID: | AP LDP001 |
| End Date: | 12/09/2014 16:00 | Lab ID: | 6807 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

### Dose-Response Plot



ToxCalc v5.0.23 Reviewed by:_____

## Ceriodaphnia Partial Life-Cycle Test-8 day survival

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 4/09/2014 15:00 | Test ID: | PR1223/02 | Sample ID: | AP LDP001 |
| End Date: | 12/09/2014 16:00 | Lab ID: | 6807 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

| | | Auxiliary Data Summary | | | | | |
|---|---|---|---|---|---|---|---|
| **Conc-%** | **Parameter** | **Mean** | **Min** | **Max** | **SD** | **CV%** | **N** |
| DMW Control | No of Young | 13.60 | 0.00 | 22.00 | 6.04 | 18.07 | 10 |
| 3.1 | | 16.10 | 0.00 | 26.00 | 7.28 | 16.76 | 10 |
| 6.3 | | 15.20 | 7.00 | 23.00 | 5.27 | 15.10 | 10 |
| 12.5 | | 20.10 | 10.00 | 32.00 | 5.78 | 11.96 | 10 |
| 25 | | 17.40 | 0.00 | 24.00 | 7.62 | 15.86 | 10 |
| 50 | | 25.20 | 20.00 | 34.00 | 4.21 | 8.14 | 10 |
| 100 | | 19.10 | 3.00 | 33.00 | 9.05 | 15.75 | 10 |
| DMW Control | % survival | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| 3.1 | | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| 6.3 | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| 12.5 | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| 25 | | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| 50 | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| 100 | | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| DMW Control | pH | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 3.1 | | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 6.3 | | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 12.5 | | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 25 | | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 50 | | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 100 | | 8.00 | 8.00 | 8.00 | 0.00 | 0.00 | 1 |
| DMW Control | DO % | 101.00 | 101.00 | 101.00 | 0.00 | 0.00 | 1 |
| 3.1 | | 100.60 | 100.60 | 100.60 | 0.00 | 0.00 | 1 |
| 6.3 | | 100.40 | 100.40 | 100.40 | 0.00 | 0.00 | 1 |
| 12.5 | | 100.60 | 100.60 | 100.60 | 0.00 | 0.00 | 1 |
| 25 | | 104.30 | 104.30 | 104.30 | 0.00 | 0.00 | 1 |
| 50 | | 104.30 | 104.30 | 104.30 | 0.00 | 0.00 | 1 |
| 100 | | 106.00 | 106.00 | 106.00 | 0.00 | 0.00 | 1 |
| DMW Control | Cond uS/cm | 185.50 | 185.50 | 185.50 | 0.00 | 0.00 | 1 |
| 3.1 | | 213.00 | 213.00 | 213.00 | 0.00 | 0.00 | 1 |
| 6.3 | | 242.00 | 242.00 | 242.00 | 0.00 | 0.00 | 1 |
| 12.5 | | 298.00 | 298.00 | 298.00 | 0.00 | 0.00 | 1 |
| 25 | | 409.00 | 409.00 | 409.00 | 0.00 | 0.00 | 1 |
| 50 | | 625.00 | 625.00 | 625.00 | 0.00 | 0.00 | 1 |
| 100 | | 1038.00 | 1038.00 | 1038.00 | 0.00 | 0.00 | 1 |

## Ceriodaphnia Partial Life-Cycle Test-Reproduction

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 28/08/2014 13:30 | Test ID: | PR1223/02 | Sample ID: | SV LDP009 |
| End Date: | 5/09/2014 13:24 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

| Conc-% | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| DMW Control | 18.000 | 22.000 | 27.000 | 13.000 | 13.000 | 14.000 | 4.000 | 12.000 | 17.000 | 13.000 |
| 3.1 | 22.000 | 21.000 | 8.000 | 12.000 | 20.000 | 22.000 | 18.000 | 12.000 | 24.000 | 22.000 |
| 6.3 | 17.000 | 22.000 | 21.000 | 22.000 | 20.000 | 10.000 | 16.000 | 16.000 | 14.000 | 25.000 |
| 12.5 | 19.000 | 21.000 | 3.000 | 16.000 | 11.000 | 26.000 | 23.000 | 5.000 | 6.000 | 7.000 |
| 25 | 0.000 | 12.000 | 8.000 | 6.000 | 10.000 | 14.000 | 18.000 | 8.000 | 12.000 | 4.000 |
| 50 | 6.000 | 0.000 | 15.000 | 4.000 | 11.000 | 0.000 | 5.000 | 3.000 | 0.000 | 12.000 |
| 100 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

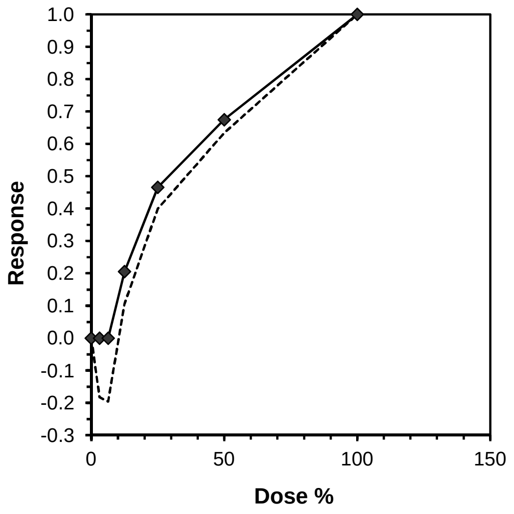
| | | | Transform: Untransformed | | | | | | 1-Tailed | | Isotonic | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Conc-% | Mean | N-Mean | Mean | Min | Max | CV% | N | t-Stat | Critical | MSD | Mean | N-Mean |
| DMW Control | 15.300 | 1.0000 | 15.300 | 4.000 | 27.000 | 40.648 | 10 | | | | 17.233 | 1.0000 |
| 3.1 | 18.100 | 1.1830 | 18.100 | 8.000 | 24.000 | 30.199 | 10 | -1.047 | 2.287 | 6.112 | 17.233 | 1.0000 |
| 6.3 | 18.300 | 1.1961 | 18.300 | 10.000 | 25.000 | 24.580 | 10 | -1.122 | 2.287 | 6.112 | 17.233 | 1.0000 |
| 12.5 | 13.700 | 0.8954 | 13.700 | 3.000 | 26.000 | 60.881 | 10 | 0.599 | 2.287 | 6.112 | 13.700 | 0.7950 |
| 25 | 9.200 | 0.6013 | 9.200 | 0.000 | 18.000 | 56.317 | 10 | 2.282 | 2.287 | 6.112 | 9.200 | 0.5338 |
| *50 | 5.600 | 0.3660 | 5.600 | 0.000 | 15.000 | 96.421 | 10 | 3.629 | 2.287 | 6.112 | 5.600 | 0.3250 |
| 100 | 0.000 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.000 | 10 | | | | 0.000 | 0.0000 |

| Auxiliary Tests | Statistic | Critical | Skew | Kurt |
|---|---|---|---|---|
| Kolmogorov D Test indicates normal distribution (p > 0.05) | 0.524712 | 0.895 | 0.021178 | -0.58724 |
| Bartlett's Test indicates equal variances (p = 0.52) | 4.232154 | 15.08627 | | |

| Hypothesis Test (1-tail, 0.05) | NOEC | LOEC | ChV | TU | MSDu | MSDp | MSB | MSE | F-Prob | df |
|---|---|---|---|---|---|---|---|---|---|---|
| Dunnett's Test | 25 | 50 | 35.35534 | 4 | 6.112369 | 0.399501 | 256.5467 | 35.72593 | 3.2E-05 | 5, 54 |
| Treatments vs DMW Control | | | | | | | | | | |

### Linear Interpolation (200 Resamples)

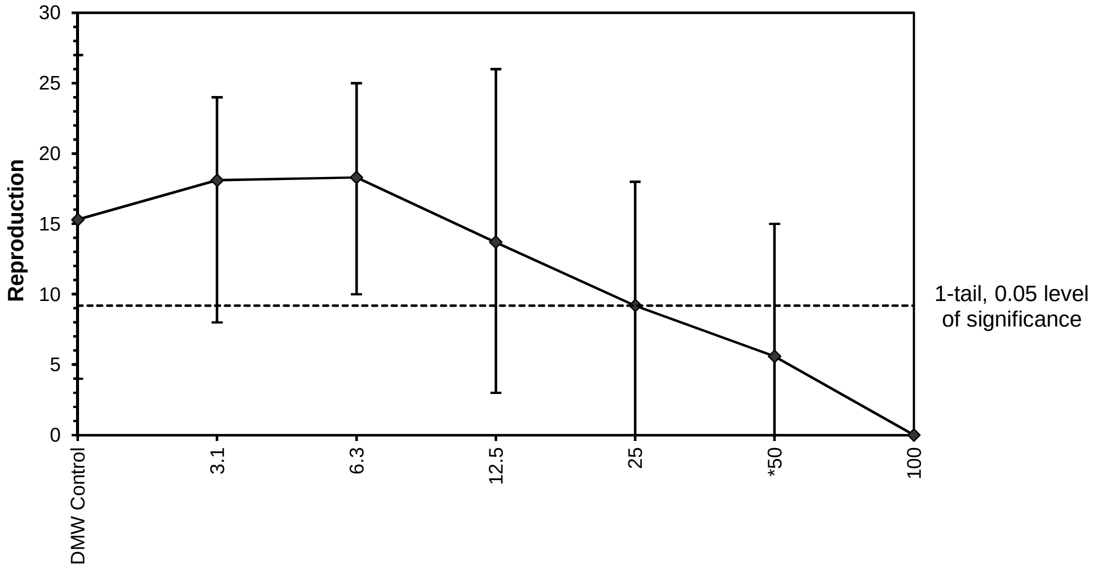
| Point | % | SD | 95% CL | | Skew |
|---|---|---|---|---|---|
| IC05 | 7.812 | 2.842 | 2.615 | 14.253 | 0.5186 |
| IC10 | 9.324 | 2.974 | 5.246 | 16.006 | 0.4828 |
| IC15 | 10.836 | 3.134 | 7.143 | 17.759 | 0.5046 |
| IC20 | 12.348 | 3.410 | 7.953 | 19.842 | 0.3988 |
| IC25 | 14.653 | 3.786 | 9.147 | 21.824 | 0.2875 |
| IC40 | 21.833 | 5.661 | 11.396 | 32.891 | 0.2519 |
| IC50 | 29.051 | 7.848 | 16.305 | 50.346 | 0.5915 |



## Ceriodaphnia Partial Life-Cycle Test-Reproduction

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 28/08/2014 13:30 | Test ID: | PR1223/02 | Sample ID: | SV LDP009 |
| End Date: | 5/09/2014 13:24 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

### Dose-Response Plot



## Ceriodaphnia Partial Life-Cycle Test-Reproduction

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 28/08/2014 13:30 | Test ID: | PR1223/02 | Sample ID: | SV LDP009 |
| End Date: | 5/09/2014 13:24 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

| | | Auxiliary Data Summary | | | | | |
|---|---|---|---|---|---|---|---|
| **Conc-%** | **Parameter** | **Mean** | **Min** | **Max** | **SD** | **CV%** | **N** |
| DMW Control | No of Young | 15.30 | 4.00 | 27.00 | 6.22 | 16.30 | 10 |
| 3.1 | | 18.10 | 8.00 | 24.00 | 5.47 | 12.92 | 10 |
| 6.3 | | 18.30 | 10.00 | 25.00 | 4.50 | 11.59 | 10 |
| 12.5 | | 13.70 | 3.00 | 26.00 | 8.34 | 21.08 | 10 |
| 25 | | 9.20 | 0.00 | 18.00 | 5.18 | 24.74 | 10 |
| 50 | | 5.60 | 0.00 | 15.00 | 5.40 | 41.49 | 10 |
| 100 | | 0.00 | 0.00 | 0.00 | 0.00 | | 10 |
| DMW Control | % survival | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| 3.1 | | 80.00 | 0.00 | 100.00 | 42.16 | 8.12 | 10 |
| 6.3 | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| 12.5 | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| 25 | | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| 50 | | 70.00 | 0.00 | 100.00 | 48.30 | 9.93 | 10 |
| 100 | | 0.00 | 0.00 | 0.00 | 0.00 | | 10 |
| DMW Control | pH | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 3.1 | | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| 6.3 | | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| 12.5 | | 8.30 | 8.30 | 8.30 | 0.00 | 0.00 | 1 |
| 25 | | 8.30 | 8.30 | 8.30 | 0.00 | 0.00 | 1 |
| 50 | | 8.40 | 8.40 | 8.40 | 0.00 | 0.00 | 1 |
| 100 | | 8.40 | 8.40 | 8.40 | 0.00 | 0.00 | 1 |
| DMW Control | DO % | 100.70 | 100.70 | 100.70 | 0.00 | 0.00 | 1 |
| 3.1 | | 100.60 | 100.60 | 100.60 | 0.00 | 0.00 | 1 |
| 6.3 | | 101.10 | 101.10 | 101.10 | 0.00 | 0.00 | 1 |
| 12.5 | | 100.70 | 100.70 | 100.70 | 0.00 | 0.00 | 1 |
| 25 | | 100.80 | 100.80 | 100.80 | 0.00 | 0.00 | 1 |
| 50 | | 101.70 | 101.70 | 101.70 | 0.00 | 0.00 | 1 |
| 100 | | 104.70 | 104.70 | 104.70 | 0.00 | 0.00 | 1 |
| DMW Control | Cond uS/cm | 185.10 | 185.10 | 185.10 | 0.00 | 0.00 | 1 |
| 3.1 | | 222.00 | 222.00 | 222.00 | 0.00 | 0.00 | 1 |
| 6.3 | | 252.00 | 252.00 | 252.00 | 0.00 | 0.00 | 1 |
| 12.5 | | 318.00 | 318.00 | 318.00 | 0.00 | 0.00 | 1 |
| 25 | | 445.00 | 445.00 | 445.00 | 0.00 | 0.00 | 1 |
| 50 | | 691.00 | 691.00 | 691.00 | 0.00 | 0.00 | 1 |
| 100 | | 1180.00 | 1180.00 | 1180.00 | 0.00 | 0.00 | 1 |

## Ceriodaphnia Partial Life-Cycle Test-8 day survival

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 28/08/2014 13:30 | Test ID: | PR1223/02 | Sample ID: | SV LDP009 |
| End Date: | 5/09/2014 13:24 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

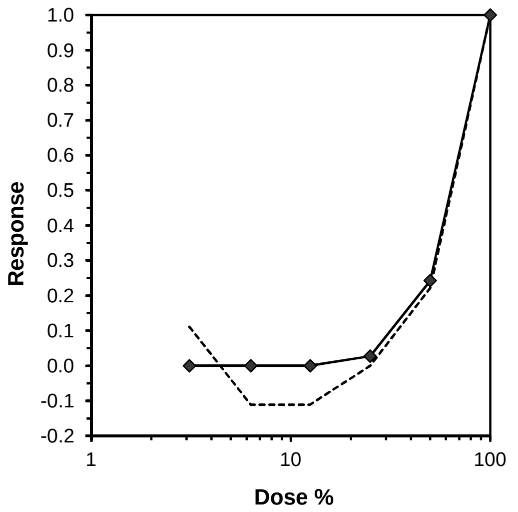
| Conc-% | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| DMW Control | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | 1.0000 |
| 3.1 | 1.0000 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.0000 | 1.0000 | 1.0000 |
| 6.3 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 12.5 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 25 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 50 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | 0.0000 | 1.0000 |
| 100 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| | | | | Not | | | Fisher's | 1-Tailed | Isotonic | |
|---|---|---|---|---|---|---|---|---|---|---|
| Conc-% | Mean | N-Mean | Resp | Resp | Total | N | Exact P | Critical | Mean | N-Mean |
| DMW Control | 0.9000 | 1.0000 | 1 | 9 | 10 | 10 | | | 0.9250 | 1.0000 |
| 3.1 | 0.8000 | 0.8889 | 2 | 8 | 10 | 10 | 0.5000 | 0.0500 | 0.9250 | 1.0000 |
| 6.3 | 1.0000 | 1.1111 | 0 | 10 | 10 | 10 | 0.5000 | 0.0500 | 0.9250 | 1.0000 |
| 12.5 | 1.0000 | 1.1111 | 0 | 10 | 10 | 10 | 0.5000 | 0.0500 | 0.9250 | 1.0000 |
| 25 | 0.9000 | 1.0000 | 1 | 9 | 10 | 10 | 0.7632 | 0.0500 | 0.9000 | 0.9730 |
| 50 | 0.7000 | 0.7778 | 3 | 7 | 10 | 10 | 0.2910 | 0.0500 | 0.7000 | 0.7568 |
| 100 | 0.0000 | 0.0000 | 10 | 0 | 10 | 10 | | | 0.0000 | 0.0000 |

| Hypothesis Test (1-tail, 0.05) | NOEC | LOEC | ChV | TU |
|---|---|---|---|---|
| Fisher's Exact Test | 50 | 100 | 70.71068 | 2 |
| Treatments vs DMW Control | | | | |

### Log-Logit Interpolation (200 Resamples)

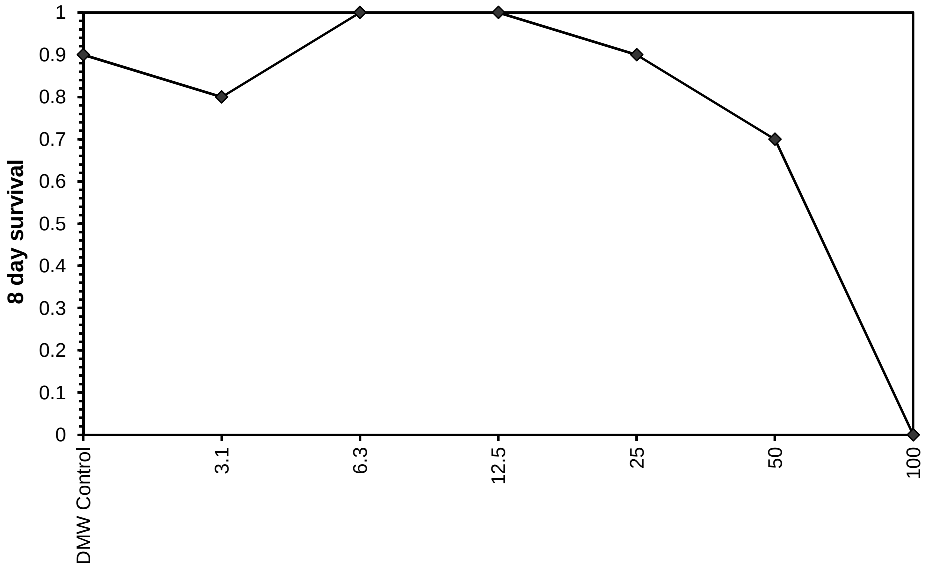
| Point | % | SD | 95% CL | | Skew |
|---|---|---|---|---|---|
| IC05 | 27.968 | 12.978 | 2.377 | 51.172 | -0.0598 |
| IC10 | 33.968 | 11.803 | 2.905 | 52.123 | -0.1779 |
| IC15 | 39.636 | 10.425 | 18.668 | 52.946 | -0.3769 |
| IC20 | 45.186 | 8.842 | 23.041 | 53.715 | -0.7060 |
| IC25 | 50.103 | 7.084 | 27.970 | 54.457 | -1.0713 |
| IC40 | 52.217 | 3.440 | 43.267 | 56.455 | -1.5101 |
| IC50 | 53.576 | 2.635 | 47.360 | 57.739 | -0.9084 |



## Ceriodaphnia Partial Life-Cycle Test-8 day survival

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 28/08/2014 13:30 | Test ID: | PR1223/02 | Sample ID: | SV LDP009 |
| End Date: | 5/09/2014 13:24 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

### Dose-Response Plot



## Ceriodaphnia Partial Life-Cycle Test-8 day survival

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 28/08/2014 13:30 | Test ID: | PR1223/02 | Sample ID: | SV LDP009 |
| End Date: | 5/09/2014 13:24 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

| | | Auxiliary Data Summary | | | | | |
|---|---|---|---|---|---|---|---|
| **Conc-%** | **Parameter** | **Mean** | **Min** | **Max** | **SD** | **CV%** | **N** |
| DMW Control | No of Young | 15.30 | 4.00 | 27.00 | 6.22 | 16.30 | 10 |
| 3.1 | | 18.10 | 8.00 | 24.00 | 5.47 | 12.92 | 10 |
| 6.3 | | 18.30 | 10.00 | 25.00 | 4.50 | 11.59 | 10 |
| 12.5 | | 13.70 | 3.00 | 26.00 | 8.34 | 21.08 | 10 |
| 25 | | 9.20 | 0.00 | 18.00 | 5.18 | 24.74 | 10 |
| 50 | | 5.60 | 0.00 | 15.00 | 5.40 | 41.49 | 10 |
| 100 | | 0.00 | 0.00 | 0.00 | 0.00 | | 10 |
| DMW Control | % survival | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| 3.1 | | 80.00 | 0.00 | 100.00 | 42.16 | 8.12 | 10 |
| 6.3 | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| 12.5 | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| 25 | | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| 50 | | 70.00 | 0.00 | 100.00 | 48.30 | 9.93 | 10 |
| 100 | | 0.00 | 0.00 | 0.00 | 0.00 | | 10 |
| DMW Control | pH | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 3.1 | | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| 6.3 | | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| 12.5 | | 8.30 | 8.30 | 8.30 | 0.00 | 0.00 | 1 |
| 25 | | 8.30 | 8.30 | 8.30 | 0.00 | 0.00 | 1 |
| 50 | | 8.40 | 8.40 | 8.40 | 0.00 | 0.00 | 1 |
| 100 | | 8.40 | 8.40 | 8.40 | 0.00 | 0.00 | 1 |
| DMW Control | DO % | 100.70 | 100.70 | 100.70 | 0.00 | 0.00 | 1 |
| 3.1 | | 100.60 | 100.60 | 100.60 | 0.00 | 0.00 | 1 |
| 6.3 | | 101.10 | 101.10 | 101.10 | 0.00 | 0.00 | 1 |
| 12.5 | | 100.70 | 100.70 | 100.70 | 0.00 | 0.00 | 1 |
| 25 | | 100.80 | 100.80 | 100.80 | 0.00 | 0.00 | 1 |
| 50 | | 101.70 | 101.70 | 101.70 | 0.00 | 0.00 | 1 |
| 100 | | 104.70 | 104.70 | 104.70 | 0.00 | 0.00 | 1 |
| DMW Control | Cond uS/cm | 185.10 | 185.10 | 185.10 | 0.00 | 0.00 | 1 |
| 3.1 | | 222.00 | 222.00 | 222.00 | 0.00 | 0.00 | 1 |
| 6.3 | | 252.00 | 252.00 | 252.00 | 0.00 | 0.00 | 1 |
| 12.5 | | 318.00 | 318.00 | 318.00 | 0.00 | 0.00 | 1 |
| 25 | | 445.00 | 445.00 | 445.00 | 0.00 | 0.00 | 1 |
| 50 | | 691.00 | 691.00 | 691.00 | 0.00 | 0.00 | 1 |
| 100 | | 1180.00 | 1180.00 | 1180.00 | 0.00 | 0.00 | 1 |

## Ceriodaphnia Partial Life-Cycle Test-8 day survival

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 28/08/2014 13:30 | Test ID: | PR1223/02 | Sample ID: | SV LDP009 |
| End Date: | 5/09/2014 13:24 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

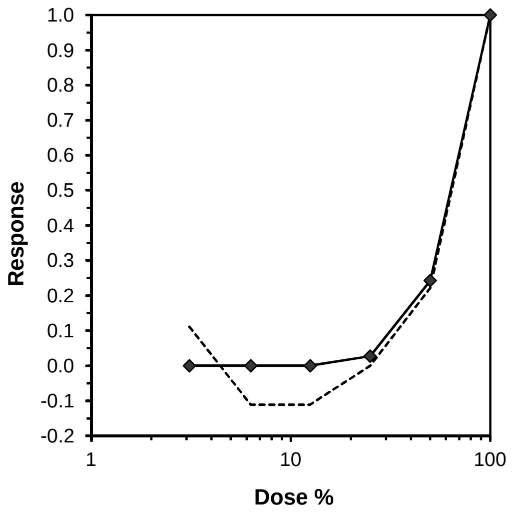
| Conc-% | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| DMW Control | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | 1.0000 |
| 3.1 | 1.0000 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.0000 | 1.0000 | 1.0000 |
| 6.3 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 12.5 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 25 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 50 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | 0.0000 | 1.0000 |
| 100 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| Conc-% | Mean | N-Mean | Resp | Not Resp | Total | N | Fisher's Exact P | 1-Tailed Critical | Number Resp | Total Number |
|---|---|---|---|---|---|---|---|---|---|---|
| DMW Control | 0.9000 | 1.0000 | 1 | 9 | 10 | 10 | | | 1 | 10 |
| 3.1 | 0.8000 | 0.8889 | 2 | 8 | 10 | 10 | 0.5000 | 0.0500 | 2 | 10 |
| 6.3 | 1.0000 | 1.1111 | 0 | 10 | 10 | 10 | 0.5000 | 0.0500 | 0 | 10 |
| 12.5 | 1.0000 | 1.1111 | 0 | 10 | 10 | 10 | 0.5000 | 0.0500 | 0 | 10 |
| 25 | 0.9000 | 1.0000 | 1 | 9 | 10 | 10 | 0.7632 | 0.0500 | 1 | 10 |
| 50 | 0.7000 | 0.7778 | 3 | 7 | 10 | 10 | 0.2910 | 0.0500 | 3 | 10 |
| 100 | 0.0000 | 0.0000 | 10 | 0 | 10 | 10 | | | 10 | 10 |

| Hypothesis Test (1-tail, 0.05) | NOEC | LOEC | ChV | TU |
|---|---|---|---|---|
| Fisher's Exact Test | 50 | 100 | 70.71068 | 2 |
| Treatments vs DMW Control | | | | |

### Trimmed Spearman-Karber

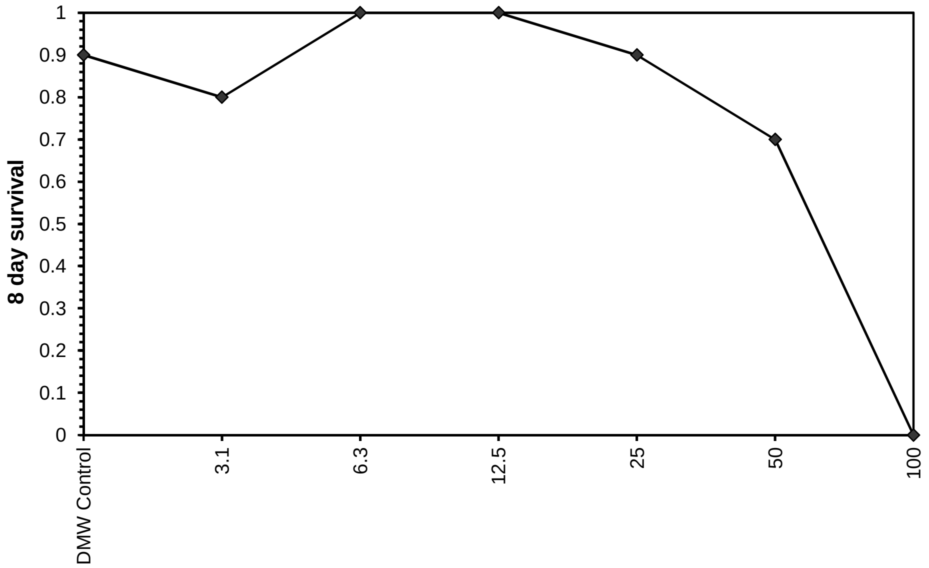
| Trim Level | EC50 | 95% CL | |
|---|---|---|---|
| 0.0% | 58.631 | 47.951 | 71.689 |
| 5.0% | 60.322 | 48.795 | 74.572 |
| 10.0% | 61.426 | 47.972 | 78.653 |
| 20.0% | 63.031 | 42.131 | 94.299 |
| Auto-0.0% | 58.631 | 47.951 | 71.689 |



## Ceriodaphnia Partial Life-Cycle Test-8 day survival

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 28/08/2014 13:30 | Test ID: | PR1223/02 | Sample ID: | SV LDP009 |
| End Date: | 5/09/2014 13:24 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

### Dose-Response Plot



## Ceriodaphnia Partial Life-Cycle Test-8 day survival

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 28/08/2014 13:30 | Test ID: | PR1223/02 | Sample ID: | SV LDP009 |
| End Date: | 5/09/2014 13:24 | Lab ID: | 6808 | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

| | | Auxiliary Data Summary | | | | | |
|---|---|---|---|---|---|---|---|
| **Conc-%** | **Parameter** | **Mean** | **Min** | **Max** | **SD** | **CV%** | **N** |
| DMW Control | No of Young | 15.30 | 4.00 | 27.00 | 6.22 | 16.30 | 10 |
| 3.1 | | 18.10 | 8.00 | 24.00 | 5.47 | 12.92 | 10 |
| 6.3 | | 18.30 | 10.00 | 25.00 | 4.50 | 11.59 | 10 |
| 12.5 | | 13.70 | 3.00 | 26.00 | 8.34 | 21.08 | 10 |
| 25 | | 9.20 | 0.00 | 18.00 | 5.18 | 24.74 | 10 |
| 50 | | 5.60 | 0.00 | 15.00 | 5.40 | 41.49 | 10 |
| 100 | | 0.00 | 0.00 | 0.00 | 0.00 | | 10 |
| DMW Control | % survival | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| 3.1 | | 80.00 | 0.00 | 100.00 | 42.16 | 8.12 | 10 |
| 6.3 | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| 12.5 | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| 25 | | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| 50 | | 70.00 | 0.00 | 100.00 | 48.30 | 9.93 | 10 |
| 100 | | 0.00 | 0.00 | 0.00 | 0.00 | | 10 |
| DMW Control | pH | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| 3.1 | | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| 6.3 | | 8.20 | 8.20 | 8.20 | 0.00 | 0.00 | 1 |
| 12.5 | | 8.30 | 8.30 | 8.30 | 0.00 | 0.00 | 1 |
| 25 | | 8.30 | 8.30 | 8.30 | 0.00 | 0.00 | 1 |
| 50 | | 8.40 | 8.40 | 8.40 | 0.00 | 0.00 | 1 |
| 100 | | 8.40 | 8.40 | 8.40 | 0.00 | 0.00 | 1 |
| DMW Control | DO % | 100.70 | 100.70 | 100.70 | 0.00 | 0.00 | 1 |
| 3.1 | | 100.60 | 100.60 | 100.60 | 0.00 | 0.00 | 1 |
| 6.3 | | 101.10 | 101.10 | 101.10 | 0.00 | 0.00 | 1 |
| 12.5 | | 100.70 | 100.70 | 100.70 | 0.00 | 0.00 | 1 |
| 25 | | 100.80 | 100.80 | 100.80 | 0.00 | 0.00 | 1 |
| 50 | | 101.70 | 101.70 | 101.70 | 0.00 | 0.00 | 1 |
| 100 | | 104.70 | 104.70 | 104.70 | 0.00 | 0.00 | 1 |
| DMW Control | Cond uS/cm | 185.10 | 185.10 | 185.10 | 0.00 | 0.00 | 1 |
| 3.1 | | 222.00 | 222.00 | 222.00 | 0.00 | 0.00 | 1 |
| 6.3 | | 252.00 | 252.00 | 252.00 | 0.00 | 0.00 | 1 |
| 12.5 | | 318.00 | 318.00 | 318.00 | 0.00 | 0.00 | 1 |
| 25 | | 445.00 | 445.00 | 445.00 | 0.00 | 0.00 | 1 |
| 50 | | 691.00 | 691.00 | 691.00 | 0.00 | 0.00 | 1 |
| 100 | | 1180.00 | 1180.00 | 1180.00 | 0.00 | 0.00 | 1 |

## Ceriodaphnia Partial Life-Cycle Test-Reproduction

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 11/09/2014 14:15 | Test ID: | PR1223/21 | Sample ID: | Various |
| End Date: | 19/09/2014 14:00 | Lab ID: | Various | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

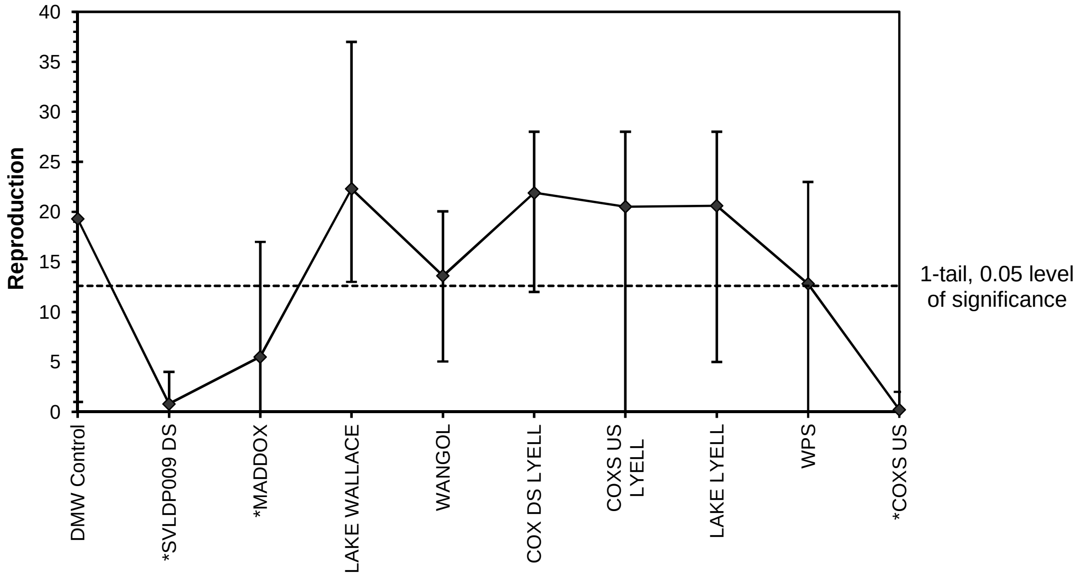
| Conc- | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| DMW Control | 24.000 | 23.000 | 18.000 | 24.000 | 20.000 | 19.000 | 1.000 | 24.000 | 15.000 | 25.000 |
| SVLDP009 DS | 0.000 | 4.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4.000 | 0.000 |
| MADDOX | 4.000 | 7.000 | 17.000 | 0.000 | 4.000 | 2.000 | 4.000 | 2.000 | 12.000 | 3.000 |
| AKE WALLACE | 22.000 | 21.000 | 13.000 | 24.000 | 20.000 | 22.000 | 23.000 | 24.000 | 37.000 | 17.000 |
| WANGOL | 13.000 | 18.000 | 13.000 | 10.000 | 15.000 | 10.000 | 20.000 | 18.000 | 5.000 | |
| COX DS LYELL | 19.000 | 28.000 | 26.000 | 22.000 | 22.000 | 18.000 | 25.000 | 24.000 | 23.000 | 12.000 |
| OXS US LYELL | 25.000 | 28.000 | 24.000 | 20.000 | 23.000 | 27.000 | 22.000 | 14.000 | 0.000 | 22.000 |
| LAKE LYELL | 28.000 | 17.000 | 5.000 | 18.000 | 26.000 | 26.000 | 28.000 | 27.000 | 17.000 | 14.000 |
| WPS | 17.000 | 23.000 | 18.000 | 11.000 | 0.000 | 12.000 | 16.000 | 10.000 | 16.000 | 5.000 |
| COXS US | 0.000 | 2.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| | | | Transform: Untransformed | | | | | | 1-Tailed | |
|---|---|---|---|---|---|---|---|---|---|---|
| Conc- | Mean | N-Mean | Mean | Min | Max | CV% | N | t-Stat | Critical | MSD |
| DMW Control | 19.300 | 1.0000 | 19.300 | 1.000 | 25.000 | 37.367 | 10 | | | |
| *SVLDP009 DS | 0.800 | 0.0415 | 0.800 | 0.000 | 4.000 | 210.819 | 10 | 7.128 | 2.593 | 6.731 |
| *MADDOX | 5.500 | 0.2850 | 5.500 | 0.000 | 17.000 | 94.767 | 10 | 5.317 | 2.593 | 6.731 |
| AKE WALLACE | 22.300 | 1.1554 | 22.300 | 13.000 | 37.000 | 27.728 | 10 | -1.156 | 2.593 | 6.731 |
| WANGOL | 13.556 | 0.7024 | 13.556 | 5.000 | 20.000 | 35.208 | 9 | 2.154 | 2.593 | 6.915 |
| COX DS LYELL | 21.900 | 1.1347 | 21.900 | 12.000 | 28.000 | 21.030 | 10 | -1.002 | 2.593 | 6.731 |
| OXS US LYELL | 20.500 | 1.0622 | 20.500 | 0.000 | 28.000 | 39.978 | 10 | -0.462 | 2.593 | 6.731 |
| LAKE LYELL | 20.600 | 1.0674 | 20.600 | 5.000 | 28.000 | 37.196 | 10 | -0.501 | 2.593 | 6.731 |
| WPS | 12.800 | 0.6632 | 12.800 | 0.000 | 23.000 | 52.447 | 10 | 2.504 | 2.593 | 6.731 |
| *COXS US | 0.200 | 0.0104 | 0.200 | 0.000 | 2.000 | 316.228 | 10 | 7.359 | 2.593 | 6.731 |

| Auxiliary Tests | Statistic | Critical | Skew | Kurt |
|---|---|---|---|---|
| Kolmogorov D Test indicates non-normal distribution (p <= 0.05) | 1.308145 | 0.895 | -0.92016 | 2.801025 |
| Bartlett's Test indicates unequal variances (p = 9.06E-08) | 50.40083 | 21.66599 | | |

| Hypothesis Test (1-tail, 0.05) | MSDu | MSDp | MSB | MSE | F-Prob | df |
|---|---|---|---|---|---|---|
| Bonferroni t Test indicates significant differences<br>Treatments vs DMW Control | 6.730781 | 0.348745 | 759.0183 | 33.68002 | 1.9E-19 | 9, 89 |

**Dose-Response Plot**



Reviewed by:_____

## Ceriodaphnia Partial Life-Cycle Test-Reproduction

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 11/09/2014 14:15 | Test ID: | PR1223/21 | Sample ID: | Various |
| End Date: | 19/09/2014 14:00 | Lab ID: | Various | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

| | | Auxiliary Data Summary | | | | | |
|---|---|---|---|---|---|---|---|
| **Conc-** | **Parameter** | **Mean** | **Min** | **Max** | **SD** | **CV%** | **N** |
| DMW Control | No of Young | 19.30 | 1.00 | 25.00 | 7.21 | 13.91 | 10 |
| SVLDP009 DS | | 0.80 | 0.00 | 4.00 | 1.69 | 162.33 | 10 |
| MADDOX | | 5.50 | 0.00 | 17.00 | 5.21 | 41.51 | 10 |
| AKE WALLACE | | 22.30 | 13.00 | 37.00 | 6.18 | 11.15 | 10 |
| WANGOL | | 13.56 | 5.00 | 20.00 | 4.77 | 16.12 | 9 |
| COX DS LYELL | | 21.90 | 12.00 | 28.00 | 4.61 | 9.80 | 10 |
| OXS US LYELL | | 20.50 | 0.00 | 28.00 | 8.20 | 13.96 | 10 |
| LAKE LYELL | | 20.60 | 5.00 | 28.00 | 7.66 | 13.44 | 10 |
| WPS | | 12.80 | 0.00 | 23.00 | 6.71 | 20.24 | 10 |
| COXS US | | 0.20 | 0.00 | 2.00 | 0.63 | 397.64 | 10 |
| DMW Control | % survival | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| SVLDP009 DS | | 80.00 | 0.00 | 100.00 | 42.16 | 8.12 | 10 |
| MADDOX | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| AKE WALLACE | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| WANGOL | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 9 |
| COX DS LYELL | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| OXS US LYELL | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| LAKE LYELL | | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| WPS | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| COXS US | | 40.00 | 0.00 | 100.00 | 51.64 | 17.97 | 10 |
| DMW Control | pH | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| SVLDP009 DS | | 8.80 | 8.80 | 8.80 | 0.00 | 0.00 | 1 |
| MADDOX | | 8.60 | 8.60 | 8.60 | 0.00 | 0.00 | 1 |
| AKE WALLACE | | 8.50 | 8.50 | 8.50 | 0.00 | 0.00 | 1 |
| WANGOL | | 8.70 | 8.70 | 8.70 | 0.00 | 0.00 | 1 |
| COX DS LYELL | | 8.30 | 8.30 | 8.30 | 0.00 | 0.00 | 1 |
| OXS US LYELL | | 8.70 | 8.70 | 8.70 | 0.00 | 0.00 | 1 |
| LAKE LYELL | | 8.40 | 8.40 | 8.40 | 0.00 | 0.00 | 1 |
| WPS | | 8.40 | 8.40 | 8.40 | 0.00 | 0.00 | 1 |
| COXS US | | 6.60 | 6.60 | 6.60 | 0.00 | 0.00 | 1 |
| DMW Control | DO % | 100.90 | 100.90 | 100.90 | 0.00 | 0.00 | 1 |
| SVLDP009 DS | | 89.00 | 89.00 | 89.00 | 0.00 | 0.00 | 1 |
| MADDOX | | 94.80 | 94.80 | 94.80 | 0.00 | 0.00 | 1 |
| AKE WALLACE | | 99.10 | 99.10 | 99.10 | 0.00 | 0.00 | 1 |
| WANGOL | | 109.00 | 109.00 | 109.00 | 0.00 | 0.00 | 1 |
| COX DS LYELL | | 109.10 | 109.10 | 109.10 | 0.00 | 0.00 | 1 |
| OXS US LYELL | | 104.50 | 104.50 | 104.50 | 0.00 | 0.00 | 1 |
| LAKE LYELL | | 106.40 | 106.40 | 106.40 | 0.00 | 0.00 | 1 |
| WPS | | 90.30 | 90.30 | 90.30 | 0.00 | 0.00 | 1 |
| COXS US | | 102.80 | 102.80 | 102.80 | 0.00 | 0.00 | 1 |
| DMW Control | Cond uS/cm | 187.20 | 187.20 | 187.20 | 0.00 | 0.00 | 1 |
| SVLDP009 DS | | 1089.00 | 1089.00 | 1089.00 | 0.00 | 0.00 | 1 |
| MADDOX | | 1007.00 | 1007.00 | 1007.00 | 0.00 | 0.00 | 1 |
| AKE WALLACE | | 986.00 | 986.00 | 986.00 | 0.00 | 0.00 | 1 |
| WANGOL | | 806.00 | 806.00 | 806.00 | 0.00 | 0.00 | 1 |
| COX DS LYELL | | 506.00 | 506.00 | 506.00 | 0.00 | 0.00 | 1 |
| OXS US LYELL | | 1049.00 | 1049.00 | 1049.00 | 0.00 | 0.00 | 1 |
| LAKE LYELL | | 547.00 | 547.00 | 547.00 | 0.00 | 0.00 | 1 |
| WPS | | 949.00 | 949.00 | 949.00 | 0.00 | 0.00 | 1 |
| COXS US | | 41.50 | 41.50 | 41.50 | 0.00 | 0.00 | 1 |

## Ceriodaphnia Partial Life-Cycle Test-8 day survival

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 11/09/2014 14:15 | Test ID: | PR1223/21 | Sample ID: | Various |
| End Date: | 19/09/2014 14:00 | Lab ID: | Various | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

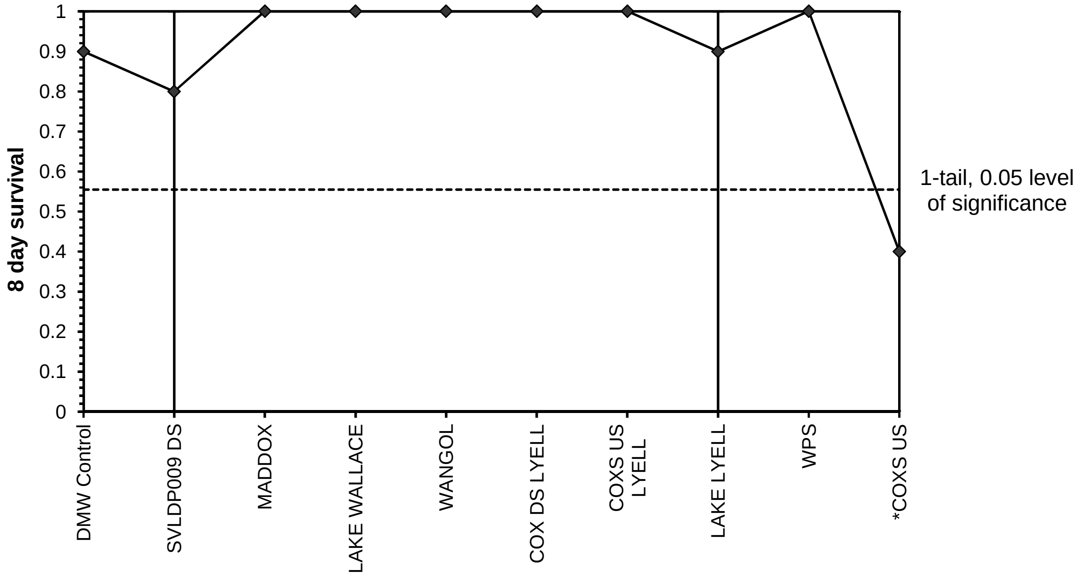
| Conc- | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| DMW Control | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | 1.0000 |
| SVLDP009 DS | 0.0000 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| MADDOX | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| AKE WALLACE | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| WANGOL | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| COX DS LYELL | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| OXS US LYELL | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| LAKE LYELL | 1.0000 | 1.0000 | 0.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| WPS | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| COXS US | 1.0000 | 1.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 |

| | | | Transform: Arcsin Square Root | | | | | | 1-Tailed | |
|---|---|---|---|---|---|---|---|---|---|---|
| Conc- | Mean | N-Mean | Mean | Min | Max | CV% | N | t-Stat | Critical | MSD |
| DMW Control | 0.9000 | 1.0000 | 0.9948 | 0.5236 | 1.0472 | 16.644 | 10 | | | |
| SVLDP009 DS | 0.8000 | 0.8889 | 0.9425 | 0.5236 | 1.0472 | 23.424 | 10 | 0.881 | 2.593 | 0.1541 |
| MADDOX | 1.0000 | 1.1111 | 1.0472 | 1.0472 | 1.0472 | 0.000 | 10 | -0.881 | 2.593 | 0.1541 |
| AKE WALLACE | 1.0000 | 1.1111 | 1.0472 | 1.0472 | 1.0472 | 0.000 | 10 | -0.881 | 2.593 | 0.1541 |
| WANGOL | 1.0000 | 1.1111 | 1.0472 | 1.0472 | 1.0472 | 0.000 | 10 | -0.881 | 2.593 | 0.1541 |
| COX DS LYELL | 1.0000 | 1.1111 | 1.0472 | 1.0472 | 1.0472 | 0.000 | 10 | -0.881 | 2.593 | 0.1541 |
| OXS US LYELL | 1.0000 | 1.1111 | 1.0472 | 1.0472 | 1.0472 | 0.000 | 10 | -0.881 | 2.593 | 0.1541 |
| LAKE LYELL | 0.9000 | 1.0000 | 0.9948 | 0.5236 | 1.0472 | 16.644 | 10 | 0.000 | 2.593 | 0.1541 |
| WPS | 1.0000 | 1.1111 | 1.0472 | 1.0472 | 1.0472 | 0.000 | 10 | -0.881 | 2.593 | 0.1541 |
| *COXS US | 0.4000 | 0.4444 | 0.7330 | 0.5236 | 1.0472 | 36.886 | 10 | 4.404 | 2.593 | 0.1541 |

| Auxiliary Tests | Statistic | Critical | Skew | Kurt |
|---|---|---|---|---|
| Kolmogorov D Test indicates non-normal distribution (p <= 0.05) | 4.03 | 0.895 | -1.39557 | 5.718277 |
| Equality of variance cannot be confirmed | | | | |

| Hypothesis Test (1-tail, 0.05) | MSDu | MSDp | MSB | MSE | F-Prob | df |
|---|---|---|---|---|---|---|
| Bonferroni t Test indicates significant differences | 0.148165 | 0.21065 | 0.097478 | 0.017668 | 5.0E-06 | 9, 90 |
| Treatments vs DMW Control | | | | | | |

### Dose-Response Plot



## Ceriodaphnia Partial Life-Cycle Test-8 day survival

| | | | | | |
|---|---|---|---|---|---|
| Start Date: | 11/09/2014 14:15 | Test ID: | PR1223/21 | Sample ID: | Various |
| End Date: | 19/09/2014 14:00 | Lab ID: | Various | Sample Type: | AQ-Aqueous |
| Sample Date: | | Protocol: | ESA 102 | Test Species: | CD-Ceriodaphnia dubia |
| Comments: | | | | | |

| | | Auxiliary Data Summary | | | | | |
|---|---|---|---|---|---|---|---|
| **Conc-** | **Parameter** | **Mean** | **Min** | **Max** | **SD** | **CV%** | **N** |
| DMW Control | No of Young | 19.30 | 1.00 | 25.00 | 7.21 | 13.91 | 10 |
| SVLDP009 DS | | 0.80 | 0.00 | 4.00 | 1.69 | 162.33 | 10 |
| MADDOX | | 5.50 | 0.00 | 17.00 | 5.21 | 41.51 | 10 |
| AKE WALLACE | | 22.30 | 13.00 | 37.00 | 6.18 | 11.15 | 10 |
| WANGOL | | 12.20 | 0.00 | 20.00 | 6.21 | 20.43 | 10 |
| COX DS LYELL | | 21.90 | 12.00 | 28.00 | 4.61 | 9.80 | 10 |
| OXS US LYELL | | 20.50 | 0.00 | 28.00 | 8.20 | 13.96 | 10 |
| LAKE LYELL | | 20.60 | 5.00 | 28.00 | 7.66 | 13.44 | 10 |
| WPS | | 12.80 | 0.00 | 23.00 | 6.71 | 20.24 | 10 |
| COXS US | | 0.20 | 0.00 | 2.00 | 0.63 | 397.64 | 10 |
| DMW Control | % survival | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| SVLDP009 DS | | 80.00 | 0.00 | 100.00 | 42.16 | 8.12 | 10 |
| MADDOX | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| AKE WALLACE | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| WANGOL | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| COX DS LYELL | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| OXS US LYELL | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| LAKE LYELL | | 90.00 | 0.00 | 100.00 | 31.62 | 6.25 | 10 |
| WPS | | 100.00 | 100.00 | 100.00 | 0.00 | 0.00 | 10 |
| COXS US | | 40.00 | 0.00 | 100.00 | 51.64 | 17.97 | 10 |
| DMW Control | pH | 8.10 | 8.10 | 8.10 | 0.00 | 0.00 | 1 |
| SVLDP009 DS | | 8.80 | 8.80 | 8.80 | 0.00 | 0.00 | 1 |
| MADDOX | | 8.60 | 8.60 | 8.60 | 0.00 | 0.00 | 1 |
| AKE WALLACE | | 8.50 | 8.50 | 8.50 | 0.00 | 0.00 | 1 |
| WANGOL | | 8.70 | 8.70 | 8.70 | 0.00 | 0.00 | 1 |
| COX DS LYELL | | 8.30 | 8.30 | 8.30 | 0.00 | 0.00 | 1 |
| OXS US LYELL | | 8.70 | 8.70 | 8.70 | 0.00 | 0.00 | 1 |
| LAKE LYELL | | 8.40 | 8.40 | 8.40 | 0.00 | 0.00 | 1 |
| WPS | | 8.40 | 8.40 | 8.40 | 0.00 | 0.00 | 1 |
| COXS US | | 6.60 | 6.60 | 6.60 | 0.00 | 0.00 | 1 |
| DMW Control | DO % | 100.90 | 100.90 | 100.90 | 0.00 | 0.00 | 1 |
| SVLDP009 DS | | 89.00 | 89.00 | 89.00 | 0.00 | 0.00 | 1 |
| MADDOX | | 94.80 | 94.80 | 94.80 | 0.00 | 0.00 | 1 |
| AKE WALLACE | | 99.10 | 99.10 | 99.10 | 0.00 | 0.00 | 1 |
| WANGOL | | 109.00 | 109.00 | 109.00 | 0.00 | 0.00 | 1 |
| COX DS LYELL | | 109.10 | 109.10 | 109.10 | 0.00 | 0.00 | 1 |
| OXS US LYELL | | 104.50 | 104.50 | 104.50 | 0.00 | 0.00 | 1 |
| LAKE LYELL | | 106.40 | 106.40 | 106.40 | 0.00 | 0.00 | 1 |
| WPS | | 90.30 | 90.30 | 90.30 | 0.00 | 0.00 | 1 |
| COXS US | | 102.80 | 102.80 | 102.80 | 0.00 | 0.00 | 1 |
| DMW Control | Cond uS/cm | 187.20 | 187.20 | 187.20 | 0.00 | 0.00 | 1 |
| SVLDP009 DS | | 1089.00 | 1089.00 | 1089.00 | 0.00 | 0.00 | 1 |
| MADDOX | | 1007.00 | 1007.00 | 1007.00 | 0.00 | 0.00 | 1 |
| AKE WALLACE | | 986.00 | 986.00 | 986.00 | 0.00 | 0.00 | 1 |
| WANGOL | | 806.00 | 806.00 | 806.00 | 0.00 | 0.00 | 1 |
| COX DS LYELL | | 506.00 | 506.00 | 506.00 | 0.00 | 0.00 | 1 |
| OXS US LYELL | | 1049.00 | 1049.00 | 1049.00 | 0.00 | 0.00 | 1 |
| LAKE LYELL | | 547.00 | 547.00 | 547.00 | 0.00 | 0.00 | 1 |
| WPS | | 949.00 | 949.00 | 949.00 | 0.00 | 0.00 | 1 |
| COXS US | | 41.50 | 41.50 | 41.50 | 0.00 | 0.00 | 1 |

# Appendix C – Water Quality Report

ALS Environmental

# CERTIFICATE OF ANALYSIS

**Work Order** : **ES1418822**

Client : **GHD PTY LTD**
Contact : MR STUART GRAY
Address : PO BOX 5403
NEWCASTLE WEST NSW, AUSTRALIA 2302
E-mail : stuart.c.gray@ghd.com
Telephone : ----
Facsimile : ----
Project : 2217471
Order number : ----
C-O-C number : 161034
Sampler : LH
Site : ----

Quote number : EN/005/14

Page : 1 of 11

Laboratory : Environmental Division Sydney
Contact : Barbara Hanna
Address : 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail : Barbara.Hanna@alsglobal.com
Telephone : +61 2 8784 8555
Facsimile : +61 2 8784 8555
QC Level : NEPM 2013 Schedule B(3) and ALS QCS3 requirement

Date Samples Received : 25-AUG-2014
Issue Date : 01-SEP-2014

No. of samples received : 12
No. of samples analysed : 12

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with
ISO/IEC 17025.

WORLD RECOGNISED
ACCREDITATION

## *Signatories*

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| Ankit Joshi | Inorganic Chemist | Sydney Inorganics |
| Ashesh Patel | Inorganic Chemist | Sydney Inorganics |
| Celine Conceicao | Senior Spectroscopist | Sydney Inorganics |
| Dian Dao | | Sydney Inorganics |
| Shobhna Chandra | Metals Coordinator | Sydney Inorganics |

## General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EA016: Calculated TDS is determined from Electrical conductivity using a conversion factor of 0.65.**
- **ED093F: Sodium Adsorption ratio could not be calculated as Calcium and Magnesium results are below the detection limit for sample ES1418822 #006.**
- **EG020: It has been confirmed by re-digestion and re-analysis that total Strontium concentration is less than dissolved for sample ES1418822 # 001. For all other samples and analytes where dissolved is greater than total, the difference is within experimental variation of the methods.**
- **Ionic Balance out of acceptable limits due to analytes not quantified in this report.**

## *Analytical Results*

| Sub-Matrix: **WATER** (Matrix: **WATER**) | | | *Client sample ID* | **SV LDP009** | **MADOOX** | **AP DS LDP001** | **AP LDP001** | **SV LDP009 DS** |
|---|---|---|---|---|---|---|---|---|
| | | | *Client sampling date / time* | 21-AUG-2014 15:00 | 21-AUG-2014 15:00 | 21-AUG-2014 15:00 | 21-AUG-2014 15:00 | 21-AUG-2014 15:00 |
| *Compound* | *CAS Number* | *LOR* | *Unit* | **ES1418822-001** | **ES1418822-002** | **ES1418822-003** | **ES1418822-004** | **ES1418822-005** |
| **EA005P: pH by PC Titrator** | | | | | | | | |
| **pH Value** | ---- | 0.01 | pH Unit | **8.21** | **8.47** | **8.28** | **8.01** | **8.73** |
| **EA006: Sodium Adsorption Ratio (SAR)** | | | | | | | | |
| **Sodium Adsorption Ratio** | ---- | 0.01 | - | **80.1** | **10.4** | **5.31** | **7.36** | **47.4** |
| **EA010P: Conductivity by PC Titrator** | | | | | | | | |
| **Electrical Conductivity @ 25°C** | ---- | 1 | µS/cm | **1200** | **1030** | **591** | **1050** | **1100** |
| **EA016: Non Marine - Estimated TDS Salinity** | | | | | | | | |
| **Total Dissolved Solids (Calc.)** | ---- | 1 | mg/L | **780** | **670** | **384** | **682** | **715** |
| **EA025: Suspended Solids** | | | | | | | | |
| **Suspended Solids (SS)** | ---- | 5 | mg/L | **19** | **10** | **13** | <5 | **10** |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| **Total Hardness as CaCO3** | ---- | 1 | mg/L | **2** | **76** | **64** | **116** | **7** |
| **ED009: Anions** | | | | | | | | |
| **Bromide** | 24959-67-9 | 0.010 | mg/L | **0.046** | **0.082** | **0.035** | **0.067** | **0.057** |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| **Hydroxide Alkalinity as CaCO3** | DMO-210-001 | 1 | mg/L | <1 | <1 | <1 | <1 | <1 |
| **Carbonate Alkalinity as CaCO3** | 3812-32-6 | 1 | mg/L | <1 | **22** | <1 | <1 | **60** |
| **Bicarbonate Alkalinity as CaCO3** | 71-52-3 | 1 | mg/L | **625** | **392** | **291** | **538** | **512** |
| **Total Alkalinity as CaCO3** | ---- | 1 | mg/L | **625** | **414** | **291** | **538** | **572** |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| **Sulfate as SO4 - Turbidimetric** | 14808-79-8 | 1 | mg/L | **34** | **142** | **17** | **25** | **34** |
| **ED045G: Chloride Discrete analyser** | | | | | | | | |
| **Chloride** | 16887-00-6 | 1 | mg/L | **6** | **15** | **10** | **10** | **6** |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| **Calcium** | 7440-70-2 | 1 | mg/L | **1** | **14** | **11** | **20** | **1** |
| **Magnesium** | 7439-95-4 | 1 | mg/L | <1 | **10** | **9** | **16** | **1** |
| **Sodium** | 7440-23-5 | 1 | mg/L | **291** | **208** | **98** | **182** | **280** |
| **Potassium** | 7440-09-7 | 1 | mg/L | **9** | **10** | **19** | **32** | **10** |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | |
| **Aluminium** | 7429-90-5 | 0.01 | mg/L | **0.01** | **0.02** | **0.02** | <0.01 | **0.03** |
| **Arsenic** | 7440-38-2 | 0.001 | mg/L | **0.024** | **0.014** | <0.001 | <0.001 | **0.021** |
| **Beryllium** | 7440-41-7 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Barium** | 7440-39-3 | 0.001 | mg/L | **0.028** | **0.020** | **0.092** | **0.178** | **0.021** |
| **Cadmium** | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

## Analytical Results

| Sub-Matrix: **WATER** (Matrix: **WATER**) | | | Client sample ID | **SV LDP009** | **MADOOX** | **AP DS LDP001** | **AP LDP001** | **SV LDP009 DS** |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 21-AUG-2014 15:00 | 21-AUG-2014 15:00 | 21-AUG-2014 15:00 | 21-AUG-2014 15:00 | 21-AUG-2014 15:00 |
| Compound | CAS Number | LOR | Unit | **ES1418822-001** | **ES1418822-002** | **ES1418822-003** | **ES1418822-004** | **ES1418822-005** |
| **EG020F: Dissolved Metals by ICP-MS - Continued** | | | | | | | | |
| **Chromium** | 7440-47-3 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Cobalt** | 7440-48-4 | 0.001 | mg/L | <0.001 | **0.001** | <0.001 | <0.001 | <0.001 |
| **Copper** | 7440-50-8 | 0.001 | mg/L | <0.001 | <0.001 | **0.002** | **0.001** | <0.001 |
| **Lead** | 7439-92-1 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | **0.008** | **0.113** | **0.010** | **0.003** | **0.013** |
| **Molybdenum** | 7439-98-7 | 0.001 | mg/L | **0.038** | **0.022** | **0.006** | **0.012** | **0.034** |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | **0.004** | **0.010** | **0.002** | **0.003** | **0.003** |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Strontium** | 7440-24-6 | 0.001 | mg/L | **0.030** | **0.083** | **0.079** | **0.117** | **0.028** |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | **0.007** | **0.012** | **0.012** | **0.016** | **0.005** |
| **Boron** | 7440-42-8 | 0.05 | mg/L | **0.07** | **0.10** | <0.05 | **0.06** | **0.07** |
| **Iron** | 7439-89-6 | 0.05 | mg/L | <0.05 | <0.05 | **0.06** | <0.05 | <0.05 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| **Aluminium** | 7429-90-5 | 0.01 | mg/L | **0.19** | **0.14** | **0.05** | **0.02** | **0.19** |
| **Arsenic** | 7440-38-2 | 0.001 | mg/L | **0.023** | **0.014** | <0.001 | <0.001 | **0.022** |
| **Beryllium** | 7440-41-7 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Barium** | 7440-39-3 | 0.001 | mg/L | **0.027** | **0.023** | **0.089** | **0.194** | **0.024** |
| **Cadmium** | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **Chromium** | 7440-47-3 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Cobalt** | 7440-48-4 | 0.001 | mg/L | <0.001 | **0.002** | <0.001 | <0.001 | **0.002** |
| **Copper** | 7440-50-8 | 0.001 | mg/L | **0.003** | <0.001 | **0.002** | <0.001 | <0.001 |
| **Lead** | 7439-92-1 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | **0.014** | **0.154** | **0.012** | **0.006** | **0.059** |
| **Molybdenum** | 7439-98-7 | 0.001 | mg/L | **0.036** | **0.026** | **0.005** | **0.014** | **0.039** |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | **0.003** | **0.011** | **0.001** | **0.002** | **0.004** |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Strontium** | 7440-24-6 | 0.001 | mg/L | **0.015** | **0.081** | **0.066** | **0.117** | **0.025** |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | **0.017** | **0.014** | **0.014** | **0.010** | **0.009** |
| **Boron** | 7440-42-8 | 0.05 | mg/L | **0.06** | **0.10** | <0.05 | **0.07** | **0.08** |
| **Iron** | 7439-89-6 | 0.05 | mg/L | **0.30** | **0.31** | **0.23** | <0.05 | **0.24** |
| **EG035F: Dissolved Mercury by FIMS** | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

## *Analytical Results*

Sub-Matrix: **WATER** (Matrix: **WATER)**

| *Compound* | *CAS Number* | *LOR* | *Unit* | **SV LDP009** | **MADOOX** | **AP DS LDP001** | **AP LDP001** | **SV LDP009 DS** |
|---|---|---|---|---|---|---|---|---|
| | | | *Client sampling date / time* | 21-AUG-2014 15:00 | 21-AUG-2014 15:00 | 21-AUG-2014 15:00 | 21-AUG-2014 15:00 | 21-AUG-2014 15:00 |
| | | | | **ES1418822-001** | **ES1418822-002** | **ES1418822-003** | **ES1418822-004** | **ES1418822-005** |
| **EG035F: Dissolved Mercury by FIMS - Continued** | | | | | | | | |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EG052F: Dissolved Silica by ICPAES** | | | | | | | | |
| **Silicon as SiO2** | 14464-46-1 | 0.1 | mg/L | **8.6** | **7.8** | **9.7** | **8.6** | **8.5** |
| **EK025SF: Free CN by Segmented Flow Analyser** | | | | | | | | |
| **Free Cyanide** | ---- | 0.004 | mg/L | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| **EK026SF: Total CN by Segmented Flow Analyser** | | | | | | | | |
| **Total Cyanide** | 57-12-5 | 0.004 | mg/L | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | |
| **Fluoride** | 16984-48-8 | 0.1 | mg/L | **1.5** | **1.3** | **0.7** | **1.0** | **1.8** |
| **EK055G: Ammonia as N by Discrete Analyser** | | | | | | | | |
| **Ammonia as N** | 7664-41-7 | 0.01 | mg/L | **0.44** | **0.06** | <0.01 | <0.01 | **0.09** |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| **Nitrite as N** | ---- | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | **0.01** |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| **Nitrate as N** | 14797-55-8 | 0.01 | mg/L | **0.21** | **0.42** | **0.02** | **0.34** | **0.44** |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |
| **Nitrite + Nitrate as N** | ---- | 0.01 | mg/L | **0.21** | **0.42** | **0.02** | **0.34** | **0.45** |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | |
| **Total Kjeldahl Nitrogen as N** | ---- | 0.1 | mg/L | **0.6** | **0.2** | <0.1 | <0.1 | **0.1** |
| **EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser** | | | | | | | | |
| ^ **Total Nitrogen as N** | ---- | 0.1 | mg/L | **0.8** | **0.6** | <0.1 | **0.3** | **0.6** |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | |
| **Total Phosphorus as P** | ---- | 0.01 | mg/L | **0.02** | **0.01** | <0.01 | <0.01 | **0.01** |
| **EN055: Ionic Balance** | | | | | | | | |
| **Total Anions** | ---- | 0.01 | meq/L | **13.4** | **11.6** | **6.45** | **11.6** | **12.3** |
| **Total Cations** | ---- | 0.01 | meq/L | **12.9** | **10.8** | **6.04** | **11.0** | **12.6** |
| **Ionic Balance** | ---- | 0.01 | % | **1.69** | **3.73** | **3.34** | **2.27** | **0.98** |
| **EP002: Dissolved Organic Carbon (DOC)** | | | | | | | | |
| **Dissolved Organic Carbon** | ---- | 1 | mg/L | **55** | **6** | **14** | **17** | **66** |
| **EP020: Oil and Grease (O&G)** | | | | | | | | |
| **Oil & Grease** | ---- | 5 | mg/L | <5 | <5 | <5 | <5 | <5 |

## Analytical Results

| Sub-Matrix: **WATER** (Matrix: **WATER**) | | | Client sample ID | **COXS US** | **WANGCOL** | **WALLACE** | **US LYELL** | **LYELL** |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 21-AUG-2014 15:00 | 21-AUG-2014 15:00 | 22-AUG-2014 15:00 | 22-AUG-2014 15:00 | 22-AUG-2014 15:00 |
| Compound | CAS Number | LOR | Unit | **ES1418822-006** | **ES1418822-007** | **ES1418822-008** | **ES1418822-009** | **ES1418822-010** |
| **EA005P: pH by PC Titrator** | | | | | | | | |
| **pH Value** | ---- | 0.01 | pH Unit | **5.69** | **6.98** | **8.41** | **8.65** | **8.42** |
| **EA006: Sodium Adsorption Ratio (SAR)** | | | | | | | | |
| **Sodium Adsorption Ratio** | ---- | 0.01 | - | ---- | **1.64** | **8.52** | **10.0** | **4.63** |
| **EA010P: Conductivity by PC Titrator** | | | | | | | | |
| **Electrical Conductivity @ 25°C** | ---- | 1 | µS/cm | **39** | **823** | **1010** | **1080** | **557** |
| **EA016: Non Marine - Estimated TDS Salinity** | | | | | | | | |
| **Total Dissolved Solids (Calc.)** | ---- | 1 | mg/L | **25** | **535** | **656** | **702** | **362** |
| **EA025: Suspended Solids** | | | | | | | | |
| **Suspended Solids (SS)** | ---- | 5 | mg/L | **22** | **5** | <5 | <5 | <5 |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| **Total Hardness as CaCO3** | ---- | 1 | mg/L | <1 | **244** | **96** | **82** | **50** |
| **ED009: Anions** | | | | | | | | |
| **Bromide** | 24959-67-9 | 0.010 | mg/L | <0.010 | **0.092** | **0.074** | **0.065** | **0.076** |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| **Hydroxide Alkalinity as CaCO3** | DMO-210-001 | 1 | mg/L | <1 | <1 | <1 | <1 | <1 |
| **Carbonate Alkalinity as CaCO3** | 3812-32-6 | 1 | mg/L | <1 | <1 | **16** | **40** | **2** |
| **Bicarbonate Alkalinity as CaCO3** | 71-52-3 | 1 | mg/L | **1** | **16** | **336** | **348** | **111** |
| **Total Alkalinity as CaCO3** | ---- | 1 | mg/L | **1** | **16** | **352** | **388** | **113** |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| **Sulfate as SO4 - Turbidimetric** | 14808-79-8 | 1 | mg/L | **3** | **341** | **160** | **164** | **117** |
| **ED045G: Chloride Discrete analyser** | | | | | | | | |
| **Chloride** | 16887-00-6 | 1 | mg/L | **8** | **34** | **20** | **18** | **16** |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| **Calcium** | 7440-70-2 | 1 | mg/L | <1 | **45** | **17** | **13** | **10** |
| **Magnesium** | 7439-95-4 | 1 | mg/L | <1 | **32** | **13** | **12** | **6** |
| **Sodium** | 7440-23-5 | 1 | mg/L | **4** | **59** | **192** | **209** | **75** |
| **Potassium** | 7440-09-7 | 1 | mg/L | <1 | **7** | **12** | **13** | **7** |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | |
| **Aluminium** | 7429-90-5 | 0.01 | mg/L | **0.03** | **0.02** | **0.01** | <0.01 | <0.01 |
| **Arsenic** | 7440-38-2 | 0.001 | mg/L | <0.001 | <0.001 | **0.006** | **0.004** | <0.001 |
| **Beryllium** | 7440-41-7 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Barium** | 7440-39-3 | 0.001 | mg/L | **0.016** | **0.014** | **0.026** | **0.025** | **0.026** |
| **Cadmium** | 7440-43-9 | 0.0001 | mg/L | <0.0001 | **0.0001** | <0.0001 | <0.0001 | <0.0001 |

## *Analytical Results*

| Sub-Matrix: **WATER** (Matrix: **WATER**) |  |  | *Client sample ID* | **COXS US** | **WANGCOL** | **WALLACE** | **US LYELL** | **LYELL** |
|---|---|---|---|---|---|---|---|---|
|  |  |  | *Client sampling date / time* | 21-AUG-2014 15:00 | 21-AUG-2014 15:00 | 22-AUG-2014 15:00 | 22-AUG-2014 15:00 | 22-AUG-2014 15:00 |
| *Compound* | *CAS Number* | *LOR* | *Unit* | **ES1418822-006** | **ES1418822-007** | **ES1418822-008** | **ES1418822-009** | **ES1418822-010** |
| **EG020F: Dissolved Metals by ICP-MS - Continued** |  |  |  |  |  |  |  |  |
| **Chromium** | 7440-47-3 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Cobalt** | 7440-48-4 | 0.001 | mg/L | <0.001 | **0.006** | <0.001 | <0.001 | <0.001 |
| **Copper** | 7440-50-8 | 0.001 | mg/L | <0.001 | **0.003** | **0.002** | **0.002** | **0.002** |
| **Lead** | 7439-92-1 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | **0.057** | **0.812** | **0.040** | **0.011** | **0.002** |
| **Molybdenum** | 7439-98-7 | 0.001 | mg/L | <0.001 | <0.001 | **0.015** | **0.016** | **0.005** |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | **0.004** | **0.021** | **0.007** | **0.004** | **0.002** |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Strontium** | 7440-24-6 | 0.001 | mg/L | **0.009** | **0.188** | **0.117** | **0.139** | **0.120** |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | **0.011** | **0.037** | **0.047** | **0.005** | <0.005 |
| **Boron** | 7440-42-8 | 0.05 | mg/L | <0.05 | **0.14** | **0.12** | **0.18** | **0.09** |
| **Iron** | 7439-89-6 | 0.05 | mg/L | **0.09** | **0.05** | <0.05 | <0.05 | <0.05 |
| **EG020T: Total Metals by ICP-MS** |  |  |  |  |  |  |  |  |
| **Aluminium** | 7429-90-5 | 0.01 | mg/L | **0.05** | **0.11** | **0.07** | **0.06** | **0.02** |
| **Arsenic** | 7440-38-2 | 0.001 | mg/L | <0.001 | <0.001 | **0.006** | **0.004** | <0.001 |
| **Beryllium** | 7440-41-7 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Barium** | 7440-39-3 | 0.001 | mg/L | **0.016** | **0.011** | **0.025** | **0.025** | **0.023** |
| **Cadmium** | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **Chromium** | 7440-47-3 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Cobalt** | 7440-48-4 | 0.001 | mg/L | <0.001 | **0.005** | <0.001 | <0.001 | <0.001 |
| **Copper** | 7440-50-8 | 0.001 | mg/L | **0.002** | <0.001 | <0.001 | **0.001** | **0.001** |
| **Lead** | 7439-92-1 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | **0.058** | **0.859** | **0.059** | **0.031** | **0.006** |
| **Molybdenum** | 7439-98-7 | 0.001 | mg/L | <0.001 | <0.001 | **0.017** | **0.018** | **0.005** |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | <0.001 | **0.020** | **0.006** | **0.004** | **0.002** |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Strontium** | 7440-24-6 | 0.001 | mg/L | **0.007** | **0.180** | **0.116** | **0.131** | **0.106** |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | **0.009** | **0.027** | <0.005 | <0.005 | <0.005 |
| **Boron** | 7440-42-8 | 0.05 | mg/L | <0.05 | **0.16** | **0.12** | **0.19** | **0.11** |
| **Iron** | 7439-89-6 | 0.05 | mg/L | **0.61** | **0.30** | **0.10** | **0.05** | <0.05 |
| **EG035F: Dissolved Mercury by FIMS** |  |  |  |  |  |  |  |  |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

## Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)

| | | | *Client sample ID* | **COXS US** | **WANGCOL** | **WALLACE** | **US LYELL** | **LYELL** |
|---|---|---|---|---|---|---|---|---|
| | | | *Client sampling date / time* | 21-AUG-2014 15:00 | 21-AUG-2014 15:00 | 22-AUG-2014 15:00 | 22-AUG-2014 15:00 | 22-AUG-2014 15:00 |
| *Compound* | *CAS Number* | *LOR* | *Unit* | **ES1418822-006** | **ES1418822-007** | **ES1418822-008** | **ES1418822-009** | **ES1418822-010** |
| **EG035F: Dissolved Mercury by FIMS - Continued** | | | | | | | | |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EG052F: Dissolved Silica by ICPAES** | | | | | | | | |
| **Silicon as SiO2** | 14464-46-1 | 0.1 | mg/L | **9.4** | **7.5** | **3.9** | **1.0** | **0.2** |
| **EK025SF: Free CN by Segmented Flow Analyser** | | | | | | | | |
| **Free Cyanide** | ---- | 0.004 | mg/L | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| **EK026SF: Total CN by Segmented Flow Analyser** | | | | | | | | |
| **Total Cyanide** | 57-12-5 | 0.004 | mg/L | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | |
| **Fluoride** | 16984-48-8 | 0.1 | mg/L | <0.1 | **0.2** | **1.1** | **1.1** | **0.6** |
| **EK055G: Ammonia as N by Discrete Analyser** | | | | | | | | |
| **Ammonia as N** | 7664-41-7 | 0.01 | mg/L | <0.01 | **0.02** | **0.03** | <0.01 | <0.01 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| **Nitrite as N** | ---- | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| **Nitrate as N** | 14797-55-8 | 0.01 | mg/L | **0.24** | <0.01 | **0.13** | <0.01 | **0.14** |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |
| **Nitrite + Nitrate as N** | ---- | 0.01 | mg/L | **0.24** | <0.01 | **0.13** | <0.01 | **0.14** |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | |
| **Total Kjeldahl Nitrogen as N** | ---- | 0.1 | mg/L | <0.1 | <0.1 | **0.3** | **0.2** | **0.3** |
| **EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser** | | | | | | | | |
| ^ **Total Nitrogen as N** | ---- | 0.1 | mg/L | **0.2** | <0.1 | **0.4** | **0.2** | **0.4** |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | |
| **Total Phosphorus as P** | ---- | 0.01 | mg/L | <0.01 | <0.01 | **0.01** | **0.02** | **0.01** |
| **EN055: Ionic Balance** | | | | | | | | |
| **Total Anions** | ---- | 0.01 | meq/L | **0.31** | **8.38** | **10.9** | **11.7** | **5.15** |
| **Total Cations** | ---- | 0.01 | meq/L | **0.17** | **7.62** | **10.6** | **11.1** | **4.43** |
| **Ionic Balance** | ---- | 0.01 | % | ---- | **4.71** | **1.68** | **2.75** | **7.46** |
| **EP002: Dissolved Organic Carbon (DOC)** | | | | | | | | |
| **Dissolved Organic Carbon** | ---- | 1 | mg/L | **48** | **7** | **6** | **42** | **20** |
| **EP020: Oil and Grease (O&G)** | | | | | | | | |
| **Oil & Grease** | ---- | 5 | mg/L | <5 | <5 | <5 | <5 | <5 |

## *Analytical Results*

| Sub-Matrix: **WATER** (Matrix: **WATER**) | | | *Client sample ID* | **DS LYELL** | **WPS** | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | *Client sampling date / time* | 22-AUG-2014 15:00 | 22-AUG-2014 15:00 | ---- | ---- | ---- |
| *Compound* | *CAS Number* | *LOR* | *Unit* | **ES1418822-011** | **ES1418822-012** | **----** | **----** | **----** |
| **EA005P: pH by PC Titrator** | | | | | | | | |
| **pH Value** | ---- | 0.01 | pH Unit | **8.28** | **8.40** | ---- | ---- | ---- |
| **EA006: Sodium Adsorption Ratio (SAR)** | | | | | | | | |
| **Sodium Adsorption Ratio** | ---- | 0.01 | - | **3.93** | **8.74** | ---- | ---- | ---- |
| **EA010P: Conductivity by PC Titrator** | | | | | | | | |
| **Electrical Conductivity @ 25°C** | ---- | 1 | µS/cm | **516** | **973** | ---- | ---- | ---- |
| **EA016: Non Marine - Estimated TDS Salinity** | | | | | | | | |
| **Total Dissolved Solids (Calc.)** | ---- | 1 | mg/L | **335** | **632** | ---- | ---- | ---- |
| **EA025: Suspended Solids** | | | | | | | | |
| **Suspended Solids (SS)** | ---- | 5 | mg/L | <5 | <5 | ---- | ---- | ---- |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| **Total Hardness as CaCO3** | ---- | 1 | mg/L | **65** | **101** | ---- | ---- | ---- |
| **ED009: Anions** | | | | | | | | |
| **Bromide** | 24959-67-9 | 0.010 | mg/L | **0.063** | **0.082** | ---- | ---- | ---- |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| **Hydroxide Alkalinity as CaCO3** | DMO-210-001 | 1 | mg/L | <1 | <1 | ---- | ---- | ---- |
| **Carbonate Alkalinity as CaCO3** | 3812-32-6 | 1 | mg/L | <1 | **16** | ---- | ---- | ---- |
| **Bicarbonate Alkalinity as CaCO3** | 71-52-3 | 1 | mg/L | **128** | **359** | ---- | ---- | ---- |
| **Total Alkalinity as CaCO3** | ---- | 1 | mg/L | **128** | **375** | ---- | ---- | ---- |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| **Sulfate as SO4 - Turbidimetric** | 14808-79-8 | 1 | mg/L | **107** | **126** | ---- | ---- | ---- |
| **ED045G: Chloride Discrete analyser** | | | | | | | | |
| **Chloride** | 16887-00-6 | 1 | mg/L | **16** | **16** | ---- | ---- | ---- |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| **Calcium** | 7440-70-2 | 1 | mg/L | **13** | **19** | ---- | ---- | ---- |
| **Magnesium** | 7439-95-4 | 1 | mg/L | **8** | **13** | ---- | ---- | ---- |
| **Sodium** | 7440-23-5 | 1 | mg/L | **73** | **202** | ---- | ---- | ---- |
| **Potassium** | 7440-09-7 | 1 | mg/L | **8** | **11** | ---- | ---- | ---- |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | |
| **Aluminium** | 7429-90-5 | 0.01 | mg/L | <0.01 | **0.02** | ---- | ---- | ---- |
| **Arsenic** | 7440-38-2 | 0.001 | mg/L | <0.001 | **0.010** | ---- | ---- | ---- |
| **Beryllium** | 7440-41-7 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| **Barium** | 7440-39-3 | 0.001 | mg/L | **0.023** | **0.023** | ---- | ---- | ---- |
| **Cadmium** | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | ---- | ---- | ---- |

## *Analytical Results*

Sub-Matrix: **WATER** (Matrix: **WATER**)

| | | | *Client sample ID* | **DS LYELL** | **WPS** | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | *Client sampling date / time* | 22-AUG-2014 15:00 | 22-AUG-2014 15:00 | ---- | ---- | ---- |
| *Compound* | *CAS Number* | *LOR* | *Unit* | **ES1418822-011** | **ES1418822-012** | **----** | **----** | **----** |
| **EG020F: Dissolved Metals by ICP-MS - Continued** | | | | | | | | |
| **Chromium** | 7440-47-3 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| **Cobalt** | 7440-48-4 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| **Copper** | 7440-50-8 | 0.001 | mg/L | **0.001** | **0.002** | ---- | ---- | ---- |
| **Lead** | 7439-92-1 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | **0.008** | **0.077** | ---- | ---- | ---- |
| **Molybdenum** | 7439-98-7 | 0.001 | mg/L | **0.004** | **0.018** | ---- | ---- | ---- |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | **0.002** | **0.007** | ---- | ---- | ---- |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | ---- | ---- | ---- |
| **Strontium** | 7440-24-6 | 0.001 | mg/L | **0.109** | **0.088** | ---- | ---- | ---- |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | <0.01 | <0.01 | ---- | ---- | ---- |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | **0.005** | **0.016** | ---- | ---- | ---- |
| **Boron** | 7440-42-8 | 0.05 | mg/L | **0.08** | **0.08** | ---- | ---- | ---- |
| **Iron** | 7439-89-6 | 0.05 | mg/L | <0.05 | <0.05 | ---- | ---- | ---- |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| **Aluminium** | 7429-90-5 | 0.01 | mg/L | **0.04** | **0.10** | ---- | ---- | ---- |
| **Arsenic** | 7440-38-2 | 0.001 | mg/L | <0.001 | **0.010** | ---- | ---- | ---- |
| **Beryllium** | 7440-41-7 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| **Barium** | 7440-39-3 | 0.001 | mg/L | **0.020** | **0.022** | ---- | ---- | ---- |
| **Cadmium** | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | ---- | ---- | ---- |
| **Chromium** | 7440-47-3 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| **Cobalt** | 7440-48-4 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| **Copper** | 7440-50-8 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| **Lead** | 7439-92-1 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | **0.013** | **0.090** | ---- | ---- | ---- |
| **Molybdenum** | 7439-98-7 | 0.001 | mg/L | **0.005** | **0.021** | ---- | ---- | ---- |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | **0.002** | **0.007** | ---- | ---- | ---- |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | ---- | ---- | ---- |
| **Strontium** | 7440-24-6 | 0.001 | mg/L | **0.097** | **0.087** | ---- | ---- | ---- |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | <0.01 | <0.01 | ---- | ---- | ---- |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | <0.005 | **0.008** | ---- | ---- | ---- |
| **Boron** | 7440-42-8 | 0.05 | mg/L | **0.09** | **0.09** | ---- | ---- | ---- |
| **Iron** | 7439-89-6 | 0.05 | mg/L | **0.10** | **0.20** | ---- | ---- | ---- |
| **EG035F: Dissolved Mercury by FIMS** | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | <0.0001 | <0.0001 | ---- | ---- | ---- |

## Analytical Results

| Sub-Matrix: **WATER** (Matrix: **WATER**) |  |  | *Client sample ID* | **DS LYELL** | **WPS** | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
|  |  |  | *Client sampling date / time* | 22-AUG-2014 15:00 | 22-AUG-2014 15:00 | ---- | ---- | ---- |
| *Compound* | *CAS Number* | *LOR* | *Unit* | **ES1418822-011** | **ES1418822-012** | **----** | **----** | **----** |
| **EG035F: Dissolved Mercury by FIMS - Continued** |  |  |  |  |  |  |  |  |
| **EG035T: Total Recoverable Mercury by FIMS** |  |  |  |  |  |  |  |  |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | <0.0001 | <0.0001 | ---- | ---- | ---- |
| **EG052F: Dissolved Silica by ICPAES** |  |  |  |  |  |  |  |  |
| **Silicon as SiO2** | 14464-46-1 | 0.1 | mg/L | **1.8** | **7.8** | ---- | ---- | ---- |
| **EK025SF: Free CN by Segmented Flow Analyser** |  |  |  |  |  |  |  |  |
| **Free Cyanide** | ---- | 0.004 | mg/L | <0.004 | <0.004 | ---- | ---- | ---- |
| **EK026SF: Total CN by Segmented Flow Analyser** |  |  |  |  |  |  |  |  |
| **Total Cyanide** | 57-12-5 | 0.004 | mg/L | <0.004 | <0.004 | ---- | ---- | ---- |
| **EK040P: Fluoride by PC Titrator** |  |  |  |  |  |  |  |  |
| **Fluoride** | 16984-48-8 | 0.1 | mg/L | **0.6** | **1.1** | ---- | ---- | ---- |
| **EK055G: Ammonia as N by Discrete Analyser** |  |  |  |  |  |  |  |  |
| **Ammonia as N** | 7664-41-7 | 0.01 | mg/L | <0.01 | **0.04** | ---- | ---- | ---- |
| **EK057G: Nitrite as N by Discrete Analyser** |  |  |  |  |  |  |  |  |
| **Nitrite as N** | ---- | 0.01 | mg/L | <0.01 | <0.01 | ---- | ---- | ---- |
| **EK058G: Nitrate as N by Discrete Analyser** |  |  |  |  |  |  |  |  |
| **Nitrate as N** | 14797-55-8 | 0.01 | mg/L | **0.04** | **0.32** | ---- | ---- | ---- |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** |  |  |  |  |  |  |  |  |
| **Nitrite + Nitrate as N** | ---- | 0.01 | mg/L | **0.04** | **0.32** | ---- | ---- | ---- |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** |  |  |  |  |  |  |  |  |
| **Total Kjeldahl Nitrogen as N** | ---- | 0.1 | mg/L | **0.2** | **0.2** | ---- | ---- | ---- |
| **EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser** |  |  |  |  |  |  |  |  |
| ^ **Total Nitrogen as N** | ---- | 0.1 | mg/L | **0.2** | **0.5** | ---- | ---- | ---- |
| **EK067G: Total Phosphorus as P by Discrete Analyser** |  |  |  |  |  |  |  |  |
| **Total Phosphorus as P** | ---- | 0.01 | mg/L | **0.02** | **0.02** | ---- | ---- | ---- |
| **EN055: Ionic Balance** |  |  |  |  |  |  |  |  |
| **Total Anions** | ---- | 0.01 | meq/L | **5.24** | **10.6** | ---- | ---- | ---- |
| **Total Cations** | ---- | 0.01 | meq/L | **4.69** | **11.1** | ---- | ---- | ---- |
| **Ionic Balance** | ---- | 0.01 | % | **5.57** | **2.35** | ---- | ---- | ---- |
| **EP002: Dissolved Organic Carbon (DOC)** |  |  |  |  |  |  |  |  |
| **Dissolved Organic Carbon** | ---- | 1 | mg/L | **24** | **5** | ---- | ---- | ---- |
| **EP020: Oil and Grease (O&G)** |  |  |  |  |  |  |  |  |
| **Oil & Grease** | ---- | 5 | mg/L | <5 | <5 | ---- | ---- | ---- |

# Appendix D – Catchment Runoff Results

Table D-1 Dilution of SV LDP009 Discharges for Water Strategy WS1

| Location | Dilution (% of daily flow) | | |
|---|---|---|---|
| | 10th percentile | 50th percentile | 90th percentile |
| A | 96.78 | 88.96 | 44.36 |
| B | 94.11 | 85.49 | 31.82 |
| C | 96.41 | 96.40 | 32.11 |
| D | 92.43 | 81.97 | 21.90 |
| E | 91.15 | 78.75 | 20.51 |
| F | 89.15 | 71.02 | 32.15 |
| G | 89.01 | 69.35 | 21.90 |
| H | 88.61 | 64.48 | 9.40 |
| I | 88.52 | 61.92 | 7.16 |
| J | 88.43 | 58.82 | 5.71 |
| K | 83.06 | 43.59 | 4.49 |
| L | 77.52 | 37.99 | 3.83 |
| M | 63.43 | 26.59 | 3.06 |
| N | 55.30 | 21.48 | 2.64 |
| O | 53.91 | 20.77 | 2.55 |

Table D-2 Dilution of SV LDP009 Discharges for Water Strategy WS2a

| Location | Dilution (% of daily flow) | | |
|---|---|---|---|
| | 10th percentile | 50th percentile | 90th percentile |
| A | 97.96 | 92.78 | 55.99 |
| B | 96.23 | 90.39 | 42.68 |
| C | 97.72 | 97.72 | 43.01 |
| D | 95.12 | 87.88 | 30.92 |
| E | 94.26 | 85.53 | 29.17 |
| F | 92.91 | 79.63 | 43.06 |
| G | 92.82 | 78.31 | 30.92 |
| H | 92.54 | 74.34 | 14.21 |
| I | 92.49 | 72.18 | 10.95 |
| J | 92.42 | 69.51 | 8.80 |
| K | 88.67 | 55.22 | 6.98 |
| L | 84.63 | 49.44 | 5.98 |
| M | 73.46 | 36.63 | 4.80 |
| N | 66.37 | 30.38 | 4.15 |
| O | 65.11 | 29.50 | 4.02 |

Table D-3 Dilution of SV LDP009 Discharges for Water Strategy WS2b

| Location | Dilution (% of daily flow) | | |
|---|---|---|---|
| | 10th percentile | 50th percentile | 90th percentile |
| A | 98.58 | 94.90 | 64.79 |
| B | 97.36 | 93.15 | 51.86 |
| C | 98.41 | 98.41 | 52.19 |
| D | 96.58 | 91.30 | 39.30 |
| E | 95.96 | 89.53 | 37.34 |
| F | 94.99 | 84.98 | 52.24 |
| G | 94.92 | 83.93 | 39.30 |
| H | 94.72 | 80.73 | 19.33 |
| I | 94.68 | 78.97 | 15.11 |
| J | 94.64 | 76.73 | 12.26 |
| K | 91.88 | 64.08 | 9.79 |
| L | 88.84 | 58.58 | 8.43 |
| M | 80.02 | 45.54 | 6.80 |
| N | 74.06 | 38.70 | 5.90 |
| O | 72.97 | 37.71 | 5.71 |

Table D 4 Dilution of Total Discharges (AP LDP001 and SV LDP009) for all Water Strategies

| Location | Dilution (% of daily flow) | | |
|---|---|---|---|
| | 10th percentile | 50th percentile | 90th percentile |
| A | 98.64 | 95.11 | 65.81 |
| B | 97.48 | 93.43 | 52.98 |
| C | 98.48 | 98.48 | 53.31 |
| D | 96.72 | 91.65 | 40.38 |
| E | 96.13 | 89.95 | 38.40 |
| F | 95.20 | 85.54 | 53.36 |
| G | 95.13 | 84.53 | 40.38 |
| H | 94.95 | 81.42 | 20.04 |
| I | 94.90 | 79.70 | 15.70 |
| J | 94.86 | 77.53 | 12.75 |
| K | 92.21 | 65.11 | 10.20 |
| L | 89.28 | 59.67 | 8.78 |
| M | 80.73 | 46.66 | 7.09 |
| N | 74.92 | 39.78 | 6.15 |
| O | 73.85 | 38.77 | 5.95 |

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Document Status

| Rev No. | Author | Reviewer | | Approved for Issue | | |
|---|---|---|---|---|---|---|
| | | Name | Signature | Name | Signature | Date |
| 0 | J Woodworth / T Davies | S Gray | | S Gray | | 29/09/14 |
| | | | | | | |
| | | | | | | |

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## Kangaroo Creek Dam Photo Monitoring: 30 December 2009 - 8 June 2012 Springvale Mine's LW401

Kangaroo Creek Dam photo monitoring conducted in the period 2009 -2012 shows that the dam has contained water on **22 out of 24 monitoring occasions** (conducted monthly or bi-monthly). No or very small pools of water was observed in the dam on 17 March 2010 (Figure 3) and 19 April 2010 (Figure 4).

The Kangaroo Creek Dam overlies Angus Place Colliery's LW970 (already mined), and lies upstream from Kangaroo Creek Swamp and downstream of Kangaroo Creek Swamp South. For the locations of Kangaroo Creek Swamp and Kangaroo Creek Swamp South refer to Figure 2.2 of the Angus Place EIS and Figure 2.7 of the Springvale EIS.

Kangaroo Creek Swamp South was undermined by Springvale L LW401 in 1996. An aerial assessment of the Newnes Plateau Shrub Swamps by Blue Mountains City Council as 'Caring for Country Save Our Swamps 2010 Project'[1] has noted the overall condition of the Kangaroo Creek Swamp South as 'Good', which is the highest category in the assessment report. This overall category for the swamp was based on assessments of key impacts divided into seven categories as follows:

- **Pine wildings infestation** - Kangaroo Creek Swamp South was assessed to have minor impact in this category
- **Blackberry infestation** - Kangaroo Creek Swamp South was assessed to have no impact (good condition) in this category
- **Channelisation** - Kangaroo Creek Swamp South was assessed to have no impact (good condition) in this category
- **Dessication -** Kangaroo Creek Swamp South was assessed to have no impact (good condition) in this category
- **Swamp Crossing -** Kangaroo Creek Swamp South was assessed to have no impact (good condition) in this category
- **Access Track -** Kangaroo Creek Swamp South was assessed to have no impact (good condition) in this category
- **Erosion -** Kangaroo Creek Swamp South was assessed to have no impact (good condition) in this category

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[1] Michael Hensen, Newnes Plateau Shrub Swamp Aerial Assessment Project Report 2010, Blue Mountains City Council

Figure 1 Kangaroo Creek Dam 30 December 2009

Figure 2 Kangaroo Creek Dam 16 February 2010

Figure 3 Kangaroo Creek Dam 17 March 2010

Figure 4 Kangaroo Creek Dam 19 April 2010

Figure 5 Kangaroo Creek Dam 22 June 2010

Figure 6 Kangaroo Creek Dam 28 July2010

Figure 7 Kangaroo Creek Dam 23 August 2010

Figure 8 Kangaroo Creek Dam 29 September 2010

Figure 9 Kangaroo Creek Dam 25 October 2010

Figure 10 Kangaroo Creek Dam 1 December 2010

Figure 11 Kangaroo Creek Dam 20 December 2010

Figure 12 Kangaroo Creek Dam 20 January 2011

Figure 13 Kangaroo Creek Dam 21 February 2011

Figure 14 Kangaroo Creek Dam 23 March 2011

Figure 15 Kangaroo Creek Dam 4 April 2011

Figure 16 Kangaroo Creek Dam 4 May 2011

Figure 17 Kangaroo Creek Dam 6 June 2011

Figure 18 Kangaroo Creek Dam 5 July 2011

Figure 19 Kangaroo Creek Dam 9 August 2011

Figure 20 Kangaroo Creek Dam 17 October 2011

Figure 21 Kangaroo Creek Dam 13 December 2011

Figure 22 Kangaroo Creek Dam 7 February 2012

Figure 23 Kangaroo Creek Dam 19 April 2012

Figure 24 Kangaroo Creek Dam 8 June 2012

# Kangaroo Creek Waterhole Photo Monitoring: 1 October 2009 - 7 August 2014

## Angus Place Colliery's LW940

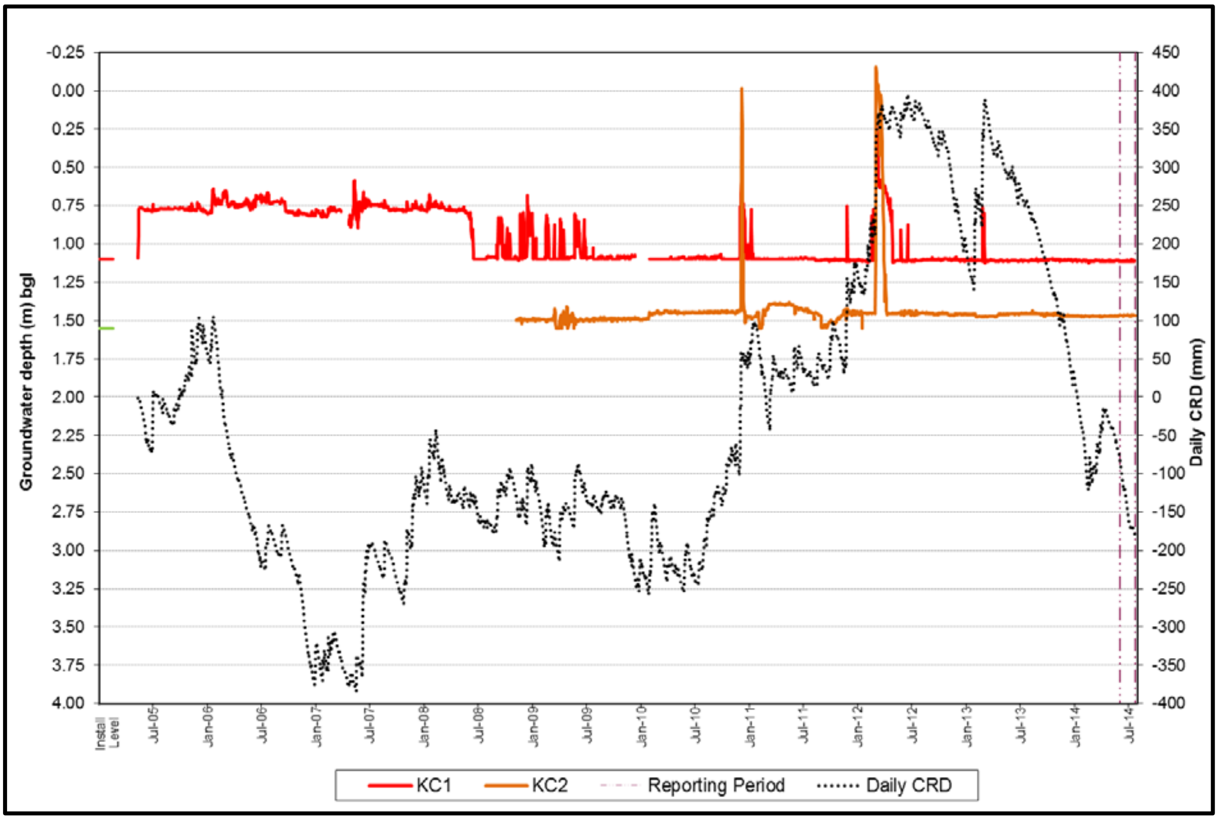

Figure 1 – Kangaroo Creek Piezometer Monitoring Data and Cumulative Rainfall Deviation

Figure 1 shows Kangaroo Creek Swamp Piezometer Monitoring Data (KC1 and KC2) and Cumulative Rainfall Deviation over the period between 2006 and 2014. It shows hydrographs of the swamp piezometers installed at Kangaroo Creek Swamp (refer Figure 10.1 of both Angus Place and Springvale EISs for the location of the swamp), together with the cumulative rainfall deviation (CRD), which is indicated by the black trendline. The KC1 piezometer is located downstream of Kangaroo Creek Swamp and the KC2 piezometer is located upstream of the swamp.

Figure 1 shows that there is a very strong correlation between the trendline of standing water level beneath the swamp and the cumulative rainfall deviation trendline for the KC2 piezometer over the eight years of monitoring at this location. This data indicated that the swamp is periodically waterlogged at this location (standing water levels respond to rainfall). The data also indicates that there have been no significant impacts to swamp hydrology in response to longwall mining at KC2. Groundwater levels at KC1 appear to have been affected by the longwall mining of Angus Place Colliery's LW940, which was below the lower reaches of the swamp, as there was a sudden reduction in groundwater levels in June 2008, unrelated to rainfall. The CRD trend also helps to understand changes in presence and flows of surface water. Since March 2013, there has been rainfall deficit in excess of 550 mm (a significant proportion of the annual average Newnes Plateau rainfall of 1092 mm). The rainfall deficit in the past 18 months is greater than any period since the end of 2005 (including the drought of 2006-2007). This helps to explain the lack of surface water present in recent monitoring periods e.g. February, June and August 2014 (and photos taken in May 2014 for the purpose of community submissions to the Angus Place and Springvale Mine Extension Project EISs). The photo used in the EIS (Photograph 2.16 in Angus Place EIS and Photograph 2.13 Springvale EIS) was taken on 16 July 2013 and can be seen to be consistent with monitoring photos in prior and subsequent periods. In the five years of photographic monitoring since the measured reduction in groundwater levels at KC1 piezometer, there have only been **three monitoring events out of 41 monthly or bi-monthly monitoring events** where water has not been present in the waterhole (February 2014, June 2014 and August 2014) and these events, as noted above and Figure 1 shows, relate to deficit in rainfall in the period. On these occasions groundwater seeps from upstream can still be seen to be present (refer Figures 38, 40 and 41).

Figure 1 Kangaroo Creek Swamp Waterhole 1 October 2009

Figure 2 Kangaroo Creek Swamp Waterhole 25 November 2009

Figure 3 Kangaroo Creek Swamp Waterhole 30 December 2009

Figure 4 Kangaroo Creek Swamp Waterhole 20 January 2010

Figure 5 Kangaroo Creek Swamp Waterhole 18 February 2010

Figure 6 Kangaroo Creek Swamp Waterhole 17 March 2010

Figure 7 Kangaroo Creek Swamp Waterhole 19 April 2010

Figure 8 Kangaroo Creek Swamp Waterhole 5 May 2010

Figure 9 Kangaroo Creek Swamp Waterhole  22 June 2010

Figure 10 Kangaroo Creek Swamp Waterhole 28 July 2010

Figure 11 Kangaroo Creek Swamp Waterhole 23 August 2010

Figure 12 Kangaroo Creek Swamp Waterhole 29 September 2010

Figure 13 Kangaroo Creek Swamp Waterhole 25 October 2010

Figure 14 Kangaroo Creek Swamp Waterhole 1 December 2010

Figure 15 Kangaroo Creek Swamp Waterhole 20 December 2010

Figure 16 Kangaroo Creek Swamp Waterhole 20 January 2011

Figure 17 Kangaroo Creek Swamp Waterhole 21 February 2011

Figure 18 Kangaroo Creek Swamp Waterhole 23 March 2011

Figure 19 Kangaroo Creek Swamp Waterhole 4 April 2011

Figure 20  Kangaroo Creek Swamp Waterhole 4 May 2011

Figure 21 Kangaroo Creek Swamp Waterhole 6 June 2011

Figure 22 Kangaroo Creek Swamp Waterhole 5 July 2011

Figure 23 Kangaroo Creek Swamp Waterhole 9 August 2011

Figure 24 Kangaroo Creek Swamp Waterhole 17 October 2011

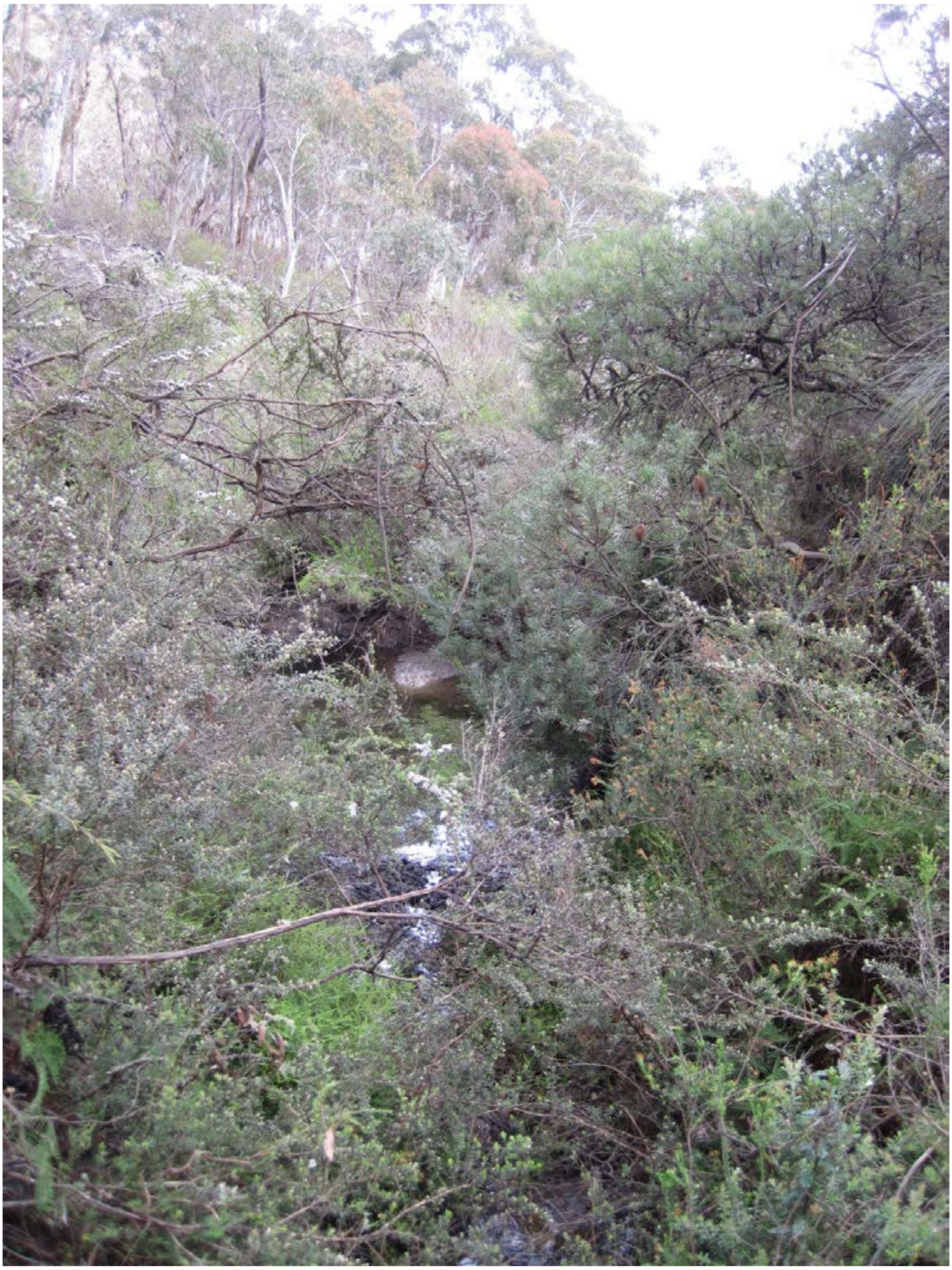

Figure 25 Kangaroo Creek Swamp Waterhole 13 December 2011

Figure 26 Kangaroo Creek Swamp Waterhole 7 February 2012

Figure 27 Kangaroo Creek Swamp Waterhole 19 April 2012

Figure28  Kangaroo Creek Swamp Waterhole 8 June 2012

Figure 29 Kangaroo Creek Swamp Waterhole 13 August 2012

Figure 30 Kangaroo Creek Swamp Waterhole 13 August 2012

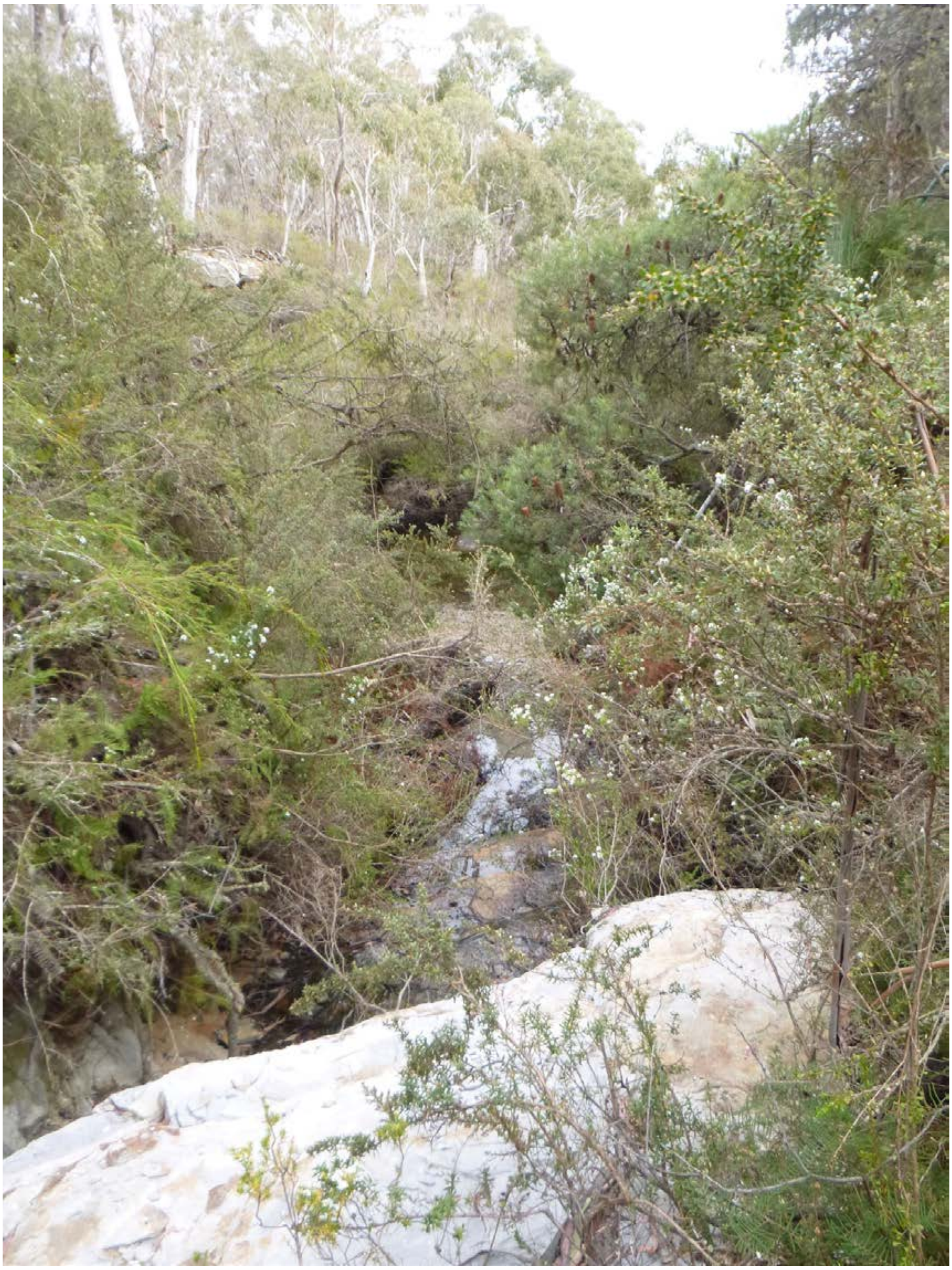

Figure 31 Kangaroo Creek Swamp Waterhole 30 October 2012

Figure 32 Kangaroo Creek Swamp Waterhole 11 December 2012

Figure 33 Kangaroo Creek Swamp Waterhole 9 April 2013

Figure 34 Kangaroo Creek Swamp Waterhole 6 June 2013

Figure 35 Kangaroo Creek Swamp Waterhole 13 August 2013

Figure 36 Kangaroo Creek Swamp Waterhole 13 October 2013

Figure 37 Kangaroo Creek Swamp Waterhole 6 December 2013

Figure 38 Kangaroo Creek Swamp Waterhole 25 February 2014

Figure 39 Kangaroo Creek Swamp Waterhole 7 April 2014

Figure 40 Kangaroo Creek Swamp Waterhole 11 June 2014

Figure 41 Kangaroo Creek Swamp Waterhole 7 August 2014

# Kangaroo Creek Downstream Photo Monitoring: 30 August 2012 – 18 September 2013

# Angus Place Colliery’s LW910

LW910 at Angus Place Colliery has not been mined as yet. For its location relative to Kangaroo Creek and Kangaroo Creek Swamp refer to Figure 2.2 in the Angus Place EIS.

Figure 1 Kangaroo Creek Downstream – Site 1 (Over LW910) 30 August 2012

Figure 2 Kangaroo Creek Downstream – Site 3 (Over LW910) 30 August 2012

Figure 3 Kangaroo Creek Downstream – Site 3 (Over LW910) 30 August 2012

Figure 4 Kangaroo Creek Downstream – Site 1 (Over LW910) 18 September 2013

Figure 5 Kangaroo Creek Downstream – Site 3 (Over LW910) 18 September 2013

Figure 6 Kangaroo Creek Downstream – Site 3 (Over LW910) 18 September 2013

RPS

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Our Ref: S188G/005b
Date: 12 September 2014

Nagindar Singh
Springvale Coal Pty Ltd
Locked Bag 1002
WALLERAWANG
NSW 2845

Dear Nagindar,

**RE: SPRINGVALE MINE EXTENSION PROJECT - RESPONSE TO SUBMISSIONS (Query on Total Predicted Discharge to the Coxs River)**

## 1. Introduction

We have prepared letter this based on email correspondence between Springvale Coal Pty Ltd (Springvale) and RPS Aquaterra Pty Ltd (RPS) (BELL/SINGH, 28 August 2014) seeking assistance to address a query received via email from the NSW Environmental Protection Authority (EPA) on the proposed total discharge to the Coxs River associated with the Springvale Mine Extension Project (KIRSCH/CLIFT, 27 June 2014).

## 2. Proposed Response

*Query 1. …I raised at yesterday's meeting what I saw as a discrepancy in what the project estimates will be the mine water discharge volumes (ML/day) from both Angus Place and Springvale combined for each year 2013-2032….*

Table 5.2 of the Surface Water Impact Assessment (RPS, 2014a) presents the predicted discharge from each Licensed Discharge Point (LDP) at Springvale Mine for the period 2013 to 2032. These discharges were determined from the site water balance prepared for Springvale Mine in GoldSIM by GHD Pty Ltd. Further details of the site water balance are presented in Appendix D of RPS (2014a).

There are two model scenarios presented in Table 5.2, one assuming the current capacity of the Springvale Delta Water Transfer Scheme (SDWTS) is maintained at 30ML/d and the second being with the capacity of the SDWTS increased to 50ML/d, when the combined mine water make at Angus Place Colliery and Springvale Mine exceeds 30ML/d. A third scenario, not presented explicitly in Table 5.2, is the predicted discharges in the circumstance that the SDWTS is not available to Angus Place Colliery and Angus Place Colliery and Springvale Mine discharge separately to Coxs River.

With the recent closure of Wallerawang Power Station, there is currently no direct demand for water from the SDWTS and flows are currently being discharged via Springvale LDP009. This is consistent with historical practice when responsibility for the SDWTS bypass was administered through Energy Australia LDP020.

The modelled discharges from the site water balance are presented below, as per Table 5.2 of the Surface Water Impact Assessment, together with totalled discharge to the Coxs River. It is noted that Springvale LDP004 and LDP005 are discharge locations on the Newnes Plateau that flow to the Wolgan

**Table: Predicted Discharge (ML/d) to the Coxs River (adapted from Table 5.2 of RPS (2014a)).**

| **Year** | **Discharge (ML/d) with SDWTS at 30ML/d** | | | **Discharge (ML/d) with SDWTS at 50ML/d** | | | **No SDWTS available to Angus Place Colliery** | | |
|---|---|---|---|---|---|---|---|---|---|
| | LDP001 | LDP009 | Total to Coxs River | LDP001 | LDP009 | Total to Coxs River | LDP001 | LDP009[1] | Total to Coxs River |
| 2013 | 1.77 | 20.88 | 22.65 | 1.77 | 20.88 | 22.65 | 1.77 | 12.47 | 14.24 |
| 2014 | 1.77 | 19.36 | 21.14 | 1.77 | 19.36 | 21.14 | 1.77 | 10.95 | 12.72 |
| 2015 | 1.77 | 23.69 | 25.47 | 1.77 | 23.69 | 25.47 | 1.77 | 12.05 | 13.82 |
| 2016 | 1.78 | 27.36 | 29.14 | 1.78 | 27.36 | 29.14 | 1.78 | 12.79 | 14.57 |
| 2017 | 1.77 | 28.87 | 30.65 | 1.77 | 28.87 | 30.65 | 1.77 | 14.08 | 15.86 |
| 2018 | 1.77 | 27.77 | 29.54 | 1.77 | 27.77 | 29.54 | 1.77 | 14.05 | 15.82 |
| 2019 | 1.77 | 29.55 | 31.33 | 1.77 | 30.18 | 31.95 | 1.77 | 15.15 | 16.92 |
| 2020 | 1.78 | 30.06 | 31.84 | 1.78 | 35.97 | 37.75 | 1.78 | 16.02 | 17.80 |
| 2021 | 1.77 | 29.98 | 31.75 | 1.77 | 37.93 | 39.70 | 1.77 | 16.51 | 18.28 |
| 2022 | 1.77 | 29.98 | 31.75 | 1.77 | 41.65 | 43.42 | 1.77 | 16.89 | **18.66** |
| 2023 | 1.77 | 29.98 | 31.75 | 1.77 | 42.73 | 44.50 | 1.77 | 16.19 | 17.97 |
| 2024 | 1.78 | 30.06 | **31.84** | 1.78 | 43.26 | **45.03** | 1.78 | 15.62 | 17.40 |
| 2025 | 0.52 | 28.48 | 29.00 | 0.52 | 30.68 | 31.20 | 0.52 | 2.51 | 3.03 |
| 2026 | 0.24 | 28.28 | 28.52 | 0.24 | 28.28 | 28.52 | 0.24 | 0.00 | 0.24 |
| 2027 | 0.20 | 26.86 | 27.06 | 0.20 | 26.86 | 27.06 | 0.20 | 0.00 | 0.20 |
| 2028 | 0.16 | 26.27 | 26.42 | 0.16 | 26.27 | 26.42 | 0.16 | 0.00 | 0.16 |
| 2029 | 0.11 | 26.90 | 27.02 | 0.11 | 26.90 | 27.02 | 0.11 | 0.00 | 0.11 |
| 2030 | 0.07 | 28.63 | 28.70 | 0.07 | 28.63 | 28.70 | 0.07 | 0.00 | 0.07 |
| 2031 | 0.03 | 24.43 | 24.46 | 0.03 | 24.43 | 24.46 | 0.03 | 0.00 | 0.03 |
| 2032 | 0.00 | 25.66 | 25.66 | 0.00 | 25.69 | 25.69 | 0.00 | 0.00 | 0.00 |

1. Calculated based on Springvale's contribution to SDWTS, as presented in Table 5.2 of the Surface Water Impact Assessment for the model scenario where the capacity of the SDWTS was 30ML/d.

River.  As indicated in RPS (2014a) these LDPs are not proposed to be used during the Mine Extension Project at Springvale Mine. Furthermore, Springvale Mine has proposed in the Environmental Impact Statement for the Project that these LDPs be relinquished post-approval when infrastructure required to re-direct emergency discharge water from the SDWTS back underground to the Angus Place Colliery's 900 Water Storage Area has been installed.

It is noted that the data presented in the Table above is the same as that presented in Table 5.2 but expressed to two decimal places.  It is noted that Springvale LDP002 comprises discharge of treated effluent via spray irrigation and was not incorporated in Table 5.2 of the Surface Water Impact Assessment due to the flow rate being negligible at <0.1ML/d.

It is also noted that discharge from Angus Place Colliery is different to that from Springvale Mine due to differences in groundwater inflow to the underground workings.  As presented in the Groundwater Impact Assessment (RPS, 2014b), the extension of Springvale Mine is hydrogeologically up-gradient compared to Angus Place.  The regional hydraulic gradient is to the northeast toward the Wolgan Valley.

From the above table, the predicted total discharge to the Coxs River ranges from 21.14ML/d in 2014 to a peak of 31.84ML/d in 2024 with SDWTS at 30ML/d.  When the SDWTS is upgraded to a capacity of 50ML/d, discharge to the Coxs River ranges from 21.14ML/d in 2014 to 45.03ML/d in 2024.  It is noted that this latter scenario represents Angus Place discharge predominantly being transferred to SDWTS and Springvale discharging through its LDP009 since there is now no direct demand at Wallerawang Power Station.  In the circumstance that the SDWTS is not available to Angus Place Colliery, discharge to the Coxs River of only mine water make at Springvale LDP009 and Pit Top via LDP001 ranges between 12.72ML/d in 2014 and 18.66ML/d in 2022.  Following cessation of mining at Springvale Mine, discharge to the Coxs River reduces to <1ML/d.

A regional water quality impact assessment has been prepared by RPS (2014c) as part of the Response to Submissions and that water quality model presents the impact to flow and salinity of each of these scenarios.

It is highlighted that the model predictions presented above were obtained from the detailed site water balance prepared in GoldSIM and therefore take into account both above-ground and underground water management infrastructure, including storages.

## 3. References

RPS, 2014a. *Springvale Mine Extension Project – Surface Water Impact Assessment*. Reference No. S188E/057c, dated 9 February 2014.

RPS, 2014b. *Springvale Mine Extension Project – Groundwater Impact Assessment*. Reference No. S188B/006d, dated 9 February 2014.

RPS, 2014c. *Regional Water Quality Impact Assessment*. Reference No. S187E/012b, dated 10 September 2014.

## 4. Closing

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

Yours sincerely
RPS Water

*Justin*

Dr Justin Bell
Principal Environmental Engineer

cc:
enc:

Centennial Coal

# Response to the Independent Expert Scientific Committee on Coal Seam Gas and Coal Mining Knowledge Report

## Temperate Highland Peat Swamps on Sandstone: ecological characteristics, sensitivities to change, and monitoring and reporting techniques

September 2014

# Introduction

The following is a response by Centennial Coal to the Independent Expert Scientific Committee on Coal Seam Gas and Coal Mining Knowledge Report: Temperate Highland Peat Swamps on Sandstone: evaluation of mitigation and remediation techniques (the IESC Report). In general the IESC Report:

- does not consider all of the relevant publicly available information in developing arguments about the effects of longwall mining on Temperate Highland Peat Swamps on Sandstone communities (THPSS).
- Where publicly available data has been used in the preparation of this report, certain data has been excluded where it does not support the position argued in the IESC report.
- Certain reference sources cited in the IESC report contain material which is not based on data and is biased against coal mining.

These general observations are further described in this report. For ease of reference, the structure of this report is based on the structure of the IESC report, and has been appended to the Response to Submissions to add a summary of relevant information from publicly available sources. In some areas this extends to a rebuttal of the data analysis or arguments presented in the report.

Centennial acknowledged in Chapter 2 and Chapter 8 of the Springvale Mine Extension Project Environmental Impact Statement (SVMEP EIS) and the Angus Place Colliery Mine Extension Project Environmental Impact Statement (APMEP EIS) that longwall mining has caused impacts to certain THPSS, however, as identified in these documents, this has not been the case in all instances. Chapter 2 of both the SVMEP EIS and the APMEP EIS acknowledged that subsidence impacts to swamp hydrology have been noted at two swamps (Kangaroo Creek Swamp and East Wolgan Swamp). Where impacts to certain THPSS on the Newnes Plateau have occurred, Centennial has conducted extensive research to understand the causes of the impacts. Centennial has used the findings of the research to avoid and mitigate both past and future impacts of longwall mining and related activities to THPSS on the Newnes Plateau.

Extensive research and investigation, lead primarily by work commissioned by the then DEWHA (the Goldney 2010 Report), has shown that impacts to THPSS on the Newnes Plateau have been caused primarily by:

- Licenced discharge of mine water through THPSS
- Changes to swamp hydrology caused by cracking of rock substrate beneath THPSS as a result of mine subsidence

The Goldney 2010 Report found that *the principal cause of impacts* to East Wolgan Swamp and Narrow Swamp was mine water discharge. This finding has been reinforced by research conducted by the University of Queensland. Neither these reports, nor Centennial's response to the findings, have been referenced in the IESC Report. The finding of major impacts caused by mine water discharge is not acknowledged in the IESC Report. As a result of the finding, Centennial has not discharged mine water through THPSS on the Newnes Plateau since 2010 and is committed to managing mine water through the Water Transfer Scheme (WTS), which transfers mine water off the Newnes Plateau.

Following completion of the DEWHA investigation and the Goldney 2010 Report, in November 2011, Centennial (through its Joint Venture) and the Minister for the Environment entered into an Enforceable Undertaking under section 486DA of the Environment Protection and Biodiversity

Conservation Act 1999. Under this Enforceable Undertaking, the Joint Venture entered into a research agreement with the Australian National University to undertake a comprehensive research program into THPSS[1].

With the conclusion of these investigations, in 2011, Centennial made applications to the Minister for the Environment to extract coal from Springvale Mine longwall 415 to 417 (EPBC2011/5949) and from the Angus Place Colliery longwall 900W and 910. In 2012, the Minister for the Environment conditionally approved these applications. The primary condition of approval was the need to demonstrate that sub-critical longwall panel design would not result in anomalous subsidence impacts to THPSS.

To demonstrate this, changes to the mine design were are based on reduced mining void widths and increased chain pillar widths. The changes have been made in the context of cover depths in proposed future mining areas in the vicinity of THPSS and are designed to a criterion of sub-critical panel geometry. Subsidence modelling indicates that the design changes will result is very significant reductions to total subsidence and differential subsidence movements. These changes were made specifically to reduce the environmental impacts of longwall mining under the Newnes Plateau, and demonstrate Centennial's commitment to sustainable mining practices.

This mine design approach for all future longwall mining described in the SVMEP EIS and the APMEP EIS in the vicinity of THPSS is consistent with that approved for longwall mining beneath THPSS by DotE under EPBC2011/5949.

All documentation supporting this research, investigations, outcomes is available on the Centennial Coal website, www.centennialcoal.com.au.

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[1] In should be noted that in this report, a reference to the federally listed endangered ecological community Temperate Highland Peat Swamps on Sandstone, includes a reference to the State listed endangered ecological communities incorporating the Newnes Plateau Shrub Swamps and Newnes Plateau Hanging Swamps. The extent to which these communities have been described under these listings is discussed further in response to the IESC Report on ecological characteristics of THPSS.

# Overview and Summary

## Mining and Subsidence

In 2008 and 2009, monitoring at Angus Place and Springvale Collieries detected impacts attributable to mining-related activities at two THPSS. Centennial Coal launched an extensive investigative program to determine the factors causing these impacts. Specific investigations were targeted to determine the hydrogeological characteristics of THPSS. The purpose of these investigations was to ascertain the coincident characteristics which lead to THPSS formation and to understand the sensitivity of those characteristics to mine subsidence behaviour.

These investigations include:

- Aurecon Report Ref:7049-010 Newnes Plateau Shrub Swamp Management Plan Investigation of Irregular Surface Movement in East Wolgan Swamp (2009)
- Determining Whether or not a Significant Impact has Occurred on Temperate Highland Peat Swamps on Sandstone within the Angus Place Colliery Lease on the Newnes Plateau, Goldney et at, 2010 (a report prepared for the then Department of Environment, Water, Heritage and the Arts)
- Aurecon Report Ref: 208354, Geotechnical Investigation Report East Wolgan Swamp Investigation, 2011
- Geophysical Survey Ground Penetrating Radar and Resistivity Investigation of East Wolgan Swamp on the Newnes Plateau, Speer (2011)
- DgS Report No SPV-003/6 Further Discussion on the Potential Impacts to Sunnyside East and Carne West Temperate Highland Peat Swamps on Sandstone due to the Proposed LW416 to 1418, Ditton 2013The Geology of the Shrub Swamps within Angus Place/Springvale Collieries, McHugh 2013
- Assessment of Flora Impacts Associated with Subsidence, Fletcher et at, 2013
- EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau – Supplementary Data Volume 1 to 3 and Appendices, Corbett et all, 2013
- Monitoring Surface Condition of Upland Swamps Subject to Mining Subsidence with very high resolution imagery, Fletcher et al, 2014
- DgS Report No SPV-003/7B Subsurface Fracture Zone Assessment above the Proposed Springvale and Angus Place Mine Extension Project Area Longwalls, Ditton, 2014
- Hydrogeological Characterisation of Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau, Corbett et al, 2014
- Case Studies of Groundwater Response to Mine Subsidence in the Western Coalfields of NSW, Corbett et al, 2014
- Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps, Brownstein et al, 2014

The results of these investigations, described further in the SVMEP EIS, the APMEP EIS, the respective Response to Submission Reports and this report, have allowed Centennial Coal to understand the multiple co-incident factors that led to historical mining-related impacts and implement management practices to ensure mining impacts will be avoided in the future or can be appropriately mitigated.

Since the investigations were conducted, Centennial Coal has been proactive in avoiding or minimising potential subsidence impacts to the geodiversity and biodiversity of the mining area using a comprehensive multi-disciplinary risk-based approach to mine planning and mine design in conjunction with a rigorous monitoring program.

The monitoring techniques employed are wide-ranging and complementary and the combined results provide insights into the role those factors such as geology, hydrogeology and topography play in THPSS formation and the effects of mine subsidence on these.

The extensive monitoring and investigation process employed by Centennial Coal, which utilised multiple lines of evidence to support the management decisions, created the foundations for an adaptive management outcome. Mine design changes (in the form of reduced longwall void width and increased chain pillar width) were implemented in 2011 and are planned in all Mine Extension Project (MEP) areas where THPSS are present.

Based on the results of the investigation and changes implemented in response to the investigation, the Federal DotE gave approval to mine beneath THPSS under EPBC2011/5949 in October 2013.

## Monitoring

There is no evidence to support the statement of limited onsite monitoring data to determine the effect of longwall mining subsidence on upland peat swamps on the Newnes Plateau. There are 36 swamp piezometers installed in Newnes Plateau shrub swamps over the Angus Place and Springvale MLs. They were installed over the period 2005-2011 (Corbett et al 2014).

Groundwater aquifer monitoring commenced at Springvale Mine in 2002. The are currently 28 open hole aquifer monitoring piezometers and 26 multi-level vibrating wire piezometers at Springvale and Angus Place.

The results of these monitoring points are described further in the SVMEP EIS, the APMEP EIS (specifically Chapters 2 and 8), the respective Response to Submission Reports and this report.

The peer reviewed THPSS Monitoring and Management Plan (THPSS MMP) which has been approved by the Federal Department of the Environment (DotE) is aligned with **Before-After/Control-Impact (BACI)** design.

## Mitigation

The primary mechanism to mitigate potential impacts to THPSS is mine design. The mine design for the SVMEP and APMEP is described in detail in the respective Environmental Impact Statements (specifically, Chapter 8).

Major design changes have been made to the Springvale and Angus Place mine plan in order to reduce subsidence from longwall mining. These changes are based on the following dimensional changes:

- Void width reduced from 315m to 261m
- Pillar width increased from 45m to 58m

The changes have been made in good faith and at significant cost to the business at a time when there was no guarantee of approval for ongoing mining activities. No subsidence effects to swamp hydrology or flora communities have been identified in areas where sub-critical mine design have been used in the past (refer to Chapter 2 and Chapter 8 of the respective EIS).

The mine design approach for all future longwall mining in the Springvale and Angus Place MEP areas is consistent with that approved for longwall mining beneath THPSS by DotE under EPBC2011/5949.

Future mine dewatering systems have been designed to ensure that discharge of mine water to Newnes Plateau Shrub Swamps is avoided. No mine water discharges into Newnes Plateau THPSS have occurred since April 2010.

## Remediation

To date, there has been no requirement or need to undertake hard engineering mitigation on a THPSS on the Newnes Plateau. Regardless, there are examples from other regions where hard engineering mitigation has been successful.

A specific example of where PUR grouting has been shown to successfully repair a rock substrate can be seen at Helensburgh Coal Pty Ltd (HCPL) in the NSW Southern Coalfields. Experience at HCPL has shown that grouting using PUR can be used to successfully fill cracks ranging from small sub millimetre sized cracks to open fractures greater than 100 mm.

A trial was conducted at HCPL on the WRS4 rock bar in the Waratah Rivulet and was followed by a remediation report (Waratah Rivulet Remediation Trial Activities – Completion Report (2007)). The main findings of the remediation report were:

· PUR is non-toxic.

· PUR injection can be conducted in an environmentally acceptable fashion.

· PUR injection is suitable for sealing cracking in rocks from less than 1mm to greater than 100 mm.

· Pre and post permeability testing showed that permeability was reduced by several orders of magnitude following PUR injection.

· The PUR injection process was transferrable to other areas where cracking of rock had occurred.

The HCPL PUR grouting programs are used to seal cracking in outcropping rock bars. However, it is considered that this technology is transferrable and can be used to seal cracks in swamp bases as a swamp base is analogous to a rock bar, albeit one covered with peat and sand.

The use of cementitious grouts has also been used to successfully remediate subsidence induced cracking which led to water loss in watercourses in the Southern Coalfield. Injection grouting with cementitious grouts was successfully used for rock bar rehabilitation in the Georges River.

Where alluvial material overlies sandstone, injection grouting though drill rods has also been used successfully to seal void under the alluvial material (soil / peat). This technique was also used in the

Georges River, where 1-2m of loose sediment was grouted through using purpose designed grouting pipes.

# 2 Overview of Temperate Highland Peat Swamps on Sandstone

## 2.1 Location

### THPSS Communities in the Blue Mountains / Newnes Plateau

Centennial Coal has acknowledged the importance of the THPSS in the landscape. Research conducted over the last 5 years (2009 to 2014) by the University of Queensland has worked towards quantifying the nature and extent of the community across the Newnes Plateau. Further work undertaken through the Enforceable Undertaking has been targeted towards:

- The nature and extent of THPSS
- THPSS water balances
- Functionality of swamps
- Environmental history and origins
- Ecology/biodiversity of major structural species
- Contribution to the landscape
- Condition status/mapping
- Monitoring of selected reference sites
- Thresholds for recovery

The University of Queensland is currently conducting research on communities identified as temperate treeless palustrine swamps in a 268 square kilometre area which includes the Newnes Plateau. Based on publicly available combined mapping from the temperate zone of New South Wales and manual interpretation of the numerous vegetation classifications used, a region containing more than 1000 shrub swamp communities per degree of latitude/longitude was identified which contained the communities mapped as Newnes Plateau shrub swamps. A report based on the research will be published and finalised in 2014.

## 2.2 Geology

### Newnes Plateau Geology / Hydrogeology Related to THPSS Formation

Centennnial Coal has conducted detailed studies into the geology and hydrogeology of the Newnes Plateau, as outlined in the following excerpts from Corbett et al (2014).

Detailed analysis of the lithology was undertaken and the data was incorporated into the Minex geological database to allow three-dimensional modelling of correlatable stratigraphic units (i.e. stratigraphic units that are present on a regional scale). The analysis of the near surface stratigraphy also involved the use of geophysical data from 84 exploration boreholes (i.e. a total of 101 exploration boreholes).

A key finding of the study (McHugh, 2013) was the identification and detailing of the stratigraphyof the Burralow Formation, which overlies the Banks Wall Sandstone. Most previous studies of the Angus Place Colliery and Springvale Mine areas do not typically include the presence of the Burralow Formation, and instead refer to the Banks Wall Sandstone as the uppermost outcropping unit.
At a maximum thickness of approximately 110m, the Burralow Formation above Angus Place and Springvale is thicker than previously proposed in the general Lithgow region.

The Burralow Formation consists of medium- to coarse-grained sandstones interbedded with frequent sequences of fine-grained, clay-rich sandstones, siltstones, shales and claystones.

From the 101 bores, the Burralow Formation was determined to contain multiple fine-grained lithological units, which can be several metres thick: their presence differentiates the Burralow Formation from the underlying Banks Wall Sandstone. Correlation of the finer-grained units within the Burralow Formation identified at least seven units, as described in Palaris (2013). Several of the claystone horizons, together with clay-rich, fine-to-medium grained sandstones and shales, were found to be acting as aquitards, or semi-permeable layers. These aquitards retard the vertical movement of groundwater into underlying strata. Instead, much of the groundwater present within the Burralow Formation is redirected laterally down-dip to discharge points in nearby valleys (valley wall seepage), which creates a permanent water source for the formation and maintenance of the NPHS. In the case of NPSS, precipitation is supplemented by moisture from groundwater sources to form several discharge horizons along the course of the host creek in which a shrub swamp is located.

This is presented in Figure 3, whereby the brown contours show the outcropping Burralow Formation units where groundwater seepage would occur. Valley wall seepage, together with direct in-gully input of groundwater via aquitards, permits continuity of hydration for the THPSS during periods of drought. The presence of the Burralow Formation is essential to the formation and persistence of both hanging and shrub swamps (McHugh, 2013). Figure 3 presents a three-dimensional representation of the topography over the eastern area of the Springvale Mining lease. Steep changes in topography occur at the downstream of the THPSS often in the form of water falls.

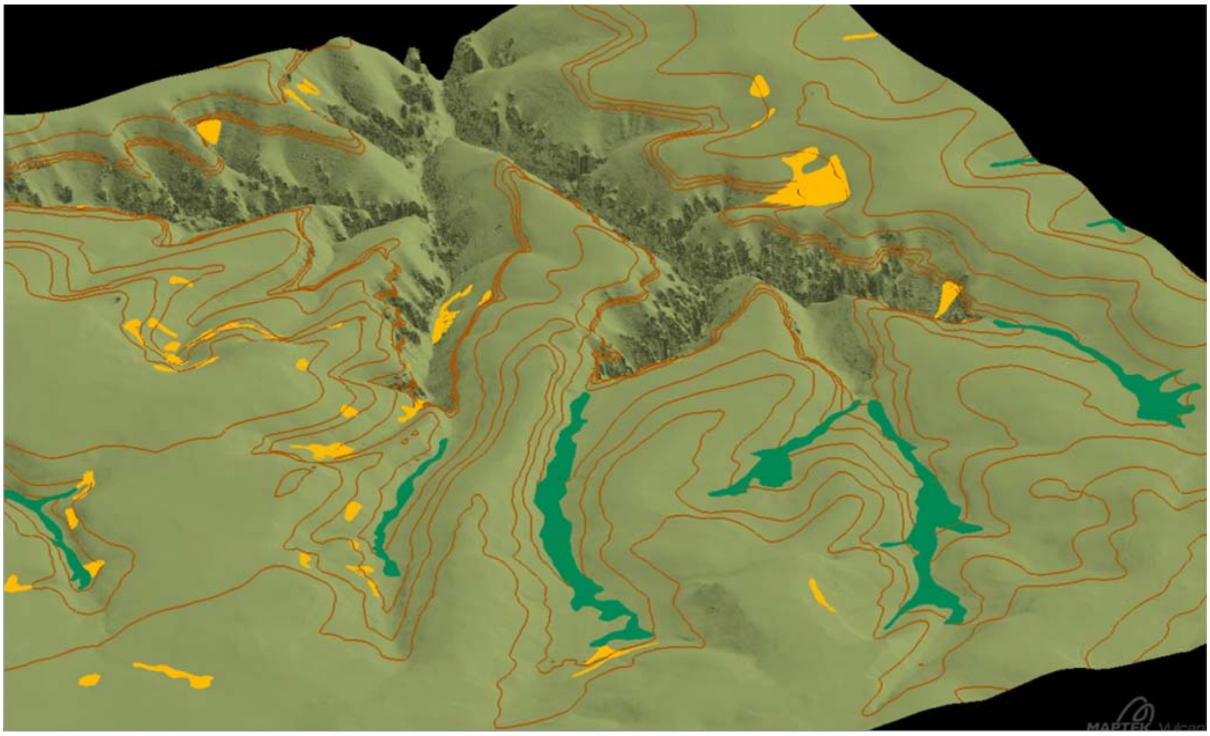


**Figure 3 View of shrub swamps in headwaters of Carne Creek from 3-D geology model**

Figure 4 presents the interpreted extent of the Burralow Formation in both lateral (spatial) and vertical (thickness) extent in relation to the Angus Place and Springvale Mining Leases. Figure 4 also shows the location of swamps in relation to the Burralow Formation and it can be concluded that the majority of the major swamp formations are located in this Formation. The extensive ridge system in the Springvale lease, where the Burralow Formation is at its thickest, provides both a substantial precipitation recharge zone plus an array of aquitards to promote groundwater retention in the streams which flow from this watershed area.

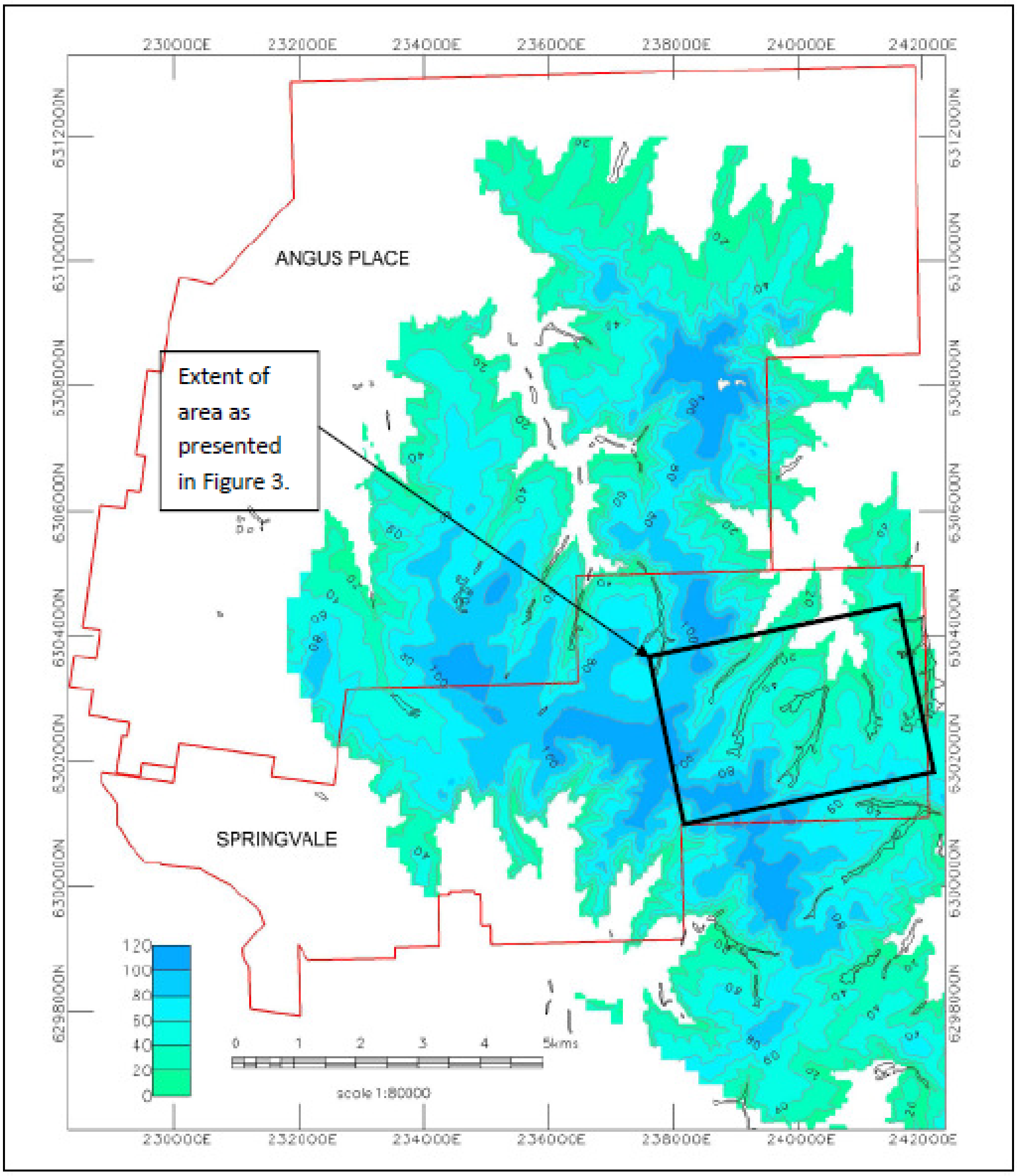


Figure 4 Isopach drawing of the Burralow Formation in the Angus Place and Springvale Mining Lease Areas together with shrub swamp locations (black outline)

## Peer review comments on Chapter 2

### Existing damage to upland swamps

Investigations of the Drillhole and Flat Rock Swamps identified that impacts had developed at these swamps prior to mine subsidence and that they were also affected by physical disturbances. Tomkins and Humphreys (2006) were engaged by the Sydney Catchment Authority to assess the erosion in swamps on the Woronora Plateau, including Flat Rock and Drill Hole Swamps, and concluded that:- “Human disturbance in the catchment, particularly direct physical disturbance such as at Drillhole Swamp has been found to be an important trigger of erosion of swamps. The impact of mine subsidence, however is less clear. Both Swamp 18 and Flat Rock Swamp featured scour pools and gully erosion well before any direct effects of mining were observed. It may be likely that dewatering of swamps due to mining increases the sensitivity of swamps to other influences such as wildfires.”;

and that “The impacts of mining on erosion of Swamp 18 and Flat Rock Swamp is less clear as both swamps were already in the process of erosion prior to the commencement of known mining and ground subsidence.”

The findings were supported by the Southern Coalfields Inquiry (DP&I, 2008) which stated that:- “Most impacted swamps that the Panel was made aware of were valley infill swamps (e.g. Flatrock Swamp and Swamps 18 and 19). However, at all sites inspected by the Panel, there had been a range of other environmental factors in play, including evidence of pre-existing scour pools, previous initiation of erosion, concurrent drought, and subsequent heavy rainfall and/or severe bushfires. The sequence of events was not clear in relation to the swamp impacts (drying, erosion and scouring, water table drop, burning, vegetation succession, etc).”; and that in relation to Drill Hole Swamp: “gully erosion was not directly caused by mining subsidence, per se. Significant site disturbance took place as a result of site clearing, soil disturbance and erosion associated with the drilling of a stratigraphic drillhole in 1976 for the Reynolds Inquiry. Tomkins and Humphreys conclude that the cause of the gully erosion was this site disturbance, coupled with an extreme rainfall event.”

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

# 3 Peat swamp conceptualisation

## *3.1.1 Headwater swamps*

### 3.1.1.1 Geology/substrate

See 2.2 (Geology) above

### 3.1.1.2 Water regime

See 3.3 Swamp Hydrology (below)

### 3.1.1.3 Groundwater connection

See 3.3 Swamp Hydrology (below)

### 3.1.1.5 Threats to swamps from longwall mining

Mine water discharge from Springvale and Angus Place impacted on Headwater Swamps on the Newnes Plateau as documented by Goldney et al (2010) and UQ (2014).

## *3.1.3 Hanging swamps*

### 3.1.3.1 Geology/substrate

See 2.2 (Geology) above

### 3.1.3.2 Water regime

See 3.3 Swamp Hydrology (below)

### 3.1.3.3 Groundwater connection

See 3.3 Swamp Hydrology (below)

### 3.1.3.5 Threats to swamps from longwall mining

Despite the statement CoA (2014) "Hanging swamps are expected to be more vulnerable to subsidence impacts than headwater and valley infill swamps, due to their location in steep topography where natural stresses are highest", there are no documented cases of impacts to Newnes Plateau Hanging Swamps in the history of mining at Angus Place and Springvale since 1979.

## 3.2 Swamp stratigraphy

Baumgartl (2013) wrote the following regarding swamp hydrology "The EWS like most of the other shrub swamps within the Newnes plateau are situated at or associated with a drainage face from the lowest aquitard units of the Burralow formation at locations where these units are intersected by a valley or exposed as outcrop through regressive erosion along a valley upstream. The drainage originates from groundwater within the Burralow formation, which drains from the interstitial space of aquitards or high permeable aquifers above aquitards. Drainage from these units is not specifically localised, but is diffuse along this aquitard-unit exposed to the land surface. The drainage from these units occurs along some length of the valley either at the valley floor or from the sides of the valley. The flows concentrate in a relatively narrow valley, but are in principle identical to the type of drainage as can be found at the hanging swamps on steep slopes at higher stratigraphic locations. From a brief visual assessment of the local environment at three swamps (East Wolgan, Kangaroo Creek and Carne West) typical swamp vegetation communities could be identified at locations above the valley floor and at some distance from the direct swamp influence, which are unmapped. The expression of water seeping from outcrops of aquifer/aquitard units seems to be not uncommon at the steeper flanks of the valleys.

Constant drainage along those drainage faces allowed the establishment of a specific swamp vegetation community. In the EWS, this vegetation can be found along the central parts of the valley, but also upslope along a contributory valley (and higher in topographic elevation compared to the valley) at the central part of EWS. The soil profile in this region of the swamp is well drained to below 1.2m for most of the time of the year 2012 and piezometer measurements have shown that this reflects the general trend of the pre-mining groundwater baseline. Drained conditions of the swamp can be also assumed from the comparably high slope of the EWS-valley. While at the downstream parts of EWS the soil moisture within the first 0.2m of the soil is higher, the soil upstream can be considerably drier once any major rainfall, which contributed to soil moisture, has drained downstream or within the soil profile. The existence of swamp vegetation, which usually is dependent on extended periods of water logged conditions, also at those drier regions of the swamp may be enabled through deep rooting of the typical species into (or close to) the aquifer. As has been shown, the distance to the aquifer from the surface at the upstream location of the swamp is much higher than downstream as the topographical elevation is markedly higher upstream, but at the same time the strike direction of Burralow formation is quite similar to the orientation of the

EWS valley, i.e. there are only small changes in elevation of the formation over the length of the swamp.

From the soil profile description it can be deduced that plants are developing roots to a depth of at least 1.1m, i.e. they may be able to reach depths (even beyond the depth of 1.1m) of the soil, which are permanently moist as they lie in the vicinity of units feeding groundwater, whereby the origin of the water may be from valley side seepages, subsurface flow in the valley and deeper draining rainfall. This would allow this water dependent vegetation to sustain periods of dry conditions within the soil profile.

The soil profile description at the central slump location showed a top soil horizon, which was enriched in organic matter, but may not suffice the classification of peat. The topsoil within the existing swamp vegetation upstream of the slump location is overlain by a layer of organic matter. Due to the elevated position of the investigated vegetation outside of the central part of the valley, this organic horizon will always be drained and not water logged.”

### *3.2.1 Swamp sedimentation*

As part of the investigation into impacts at East Wolgan Swamp, an investigation of the soil profile present was undertaken as follows:

#### *Soil profile description*

An open cut at the central slump location was used to assess the soil profile as a representative for the type of soils, which can be expected.
Table 1 summarises the profile description and Fig. 4 shows the soil profile at the southern end of the slump.

Soil Profile:

Fig 4: Soil profile at central slump

Tab. 1 Soil profile description in central slump area

| Depth | Horizon | comments |
|---|---|---|
| 0-40 | A-horizon/peat | densely rooted |
| 40-60 | (bleached) sand | |
| 60-65 | Wet organic matter enriched layer | densely rooted |
| 65-90 | (brown) sand | |
| 90-95 | organic matter enriched layer | densely rooted |
| 95-110 | Sand enriched with organic matter | |

The soil profile at the slump shows well developed root layers and relatively dense root distribution up to the max. investigated depth of 1.1m. The rooting depth may be potentially deeper.

### *3.2.2 Erosion*

Major incisions have been recorded in pre-mining surveys of swamps including Sunnyside East Swamp (McTaggart 2013). Major incisions were recorded prior to a bushfire in 2010 which burnt through the middle reaches of the swamp, however records indicate that the bushfire did cause additional incisions to be caused to Sunnyside East Swamp in the period between 2010 and 2013.

Incisions which pre-dated mining were also identified by Goldney et al (2010) at Junction Swamp, Kangaroo Creek North, Kangaroo Creek (Mid), Narrow Swamp South and Sunnyside East (Burnt) Swamp.

## 3.3 Swamp hydrology

In the case of Newnes Plateau Shrub Swamps, baseline data from the piezometers indicates that swamp hydrology is variable along individual swamps, and standing water levels are typically influenced by rainfall in the upper reaches and by groundwater in the lower reaches. This demonstrates the increasing groundwater contributions from the multiple outcrops of the Burralow Formation aquitards.

The data from the swamp monitoring has shown that the hydrology of an individual swamp can be ‘periodically waterlogged’ or ‘permanently waterlogged’ or can vary along its length from ‘periodically waterlogged’ to ‘permanently waterlogged’, with transitional behaviour between (Corbett et al 2014).

Monitoring of piezometers in Sunnyside, Sunnyside East, Tri-Star and Carne West swamps indicates that variable hydrology (between periodically waterlogged in the upper reaches and permanently waterlogged in the lower reaches) occurs for swamps to the East of the Newnes Plateau in swamps previously identified as entirely permanently waterlogged.

## 3.4 Groundwater interaction

Hydrogeological models for Newnes Plateau swamps have been developed through detailed investigation and research since 2010 (detailed in McHugh (2013) and Corbett et al (2014)). These models are described in detail in the SVMEP EIS, the APMEP EIS (specifically Chapters 2 and 8), the respective Response to Submission Reports.

A key finding of the study (McHugh, 2013) was the identification and detailing of the stratigraphy of the Burralow Formation, which overlies the Banks Wall Sandstone. Most previous studies of the Angus Place Colliery and Springvale Mine areas do not typically include the presence of the Burralow Formation, and instead refer to the Banks Wall Sandstone as the uppermost outcropping unit.

Several of the claystone horizons, together with clay-rich, fine-to-medium grained sandstones and shales, were found to be acting as aquitards, or semi-permeable layers. These aquitards retard the vertical movement of groundwater into underlying strata. Instead, much of the groundwater present within the Burralow Formation is redirected laterally down-dip to discharge points in nearby valleys (valley wall seepage), which creates a permanent water source for the formation and maintenance of the Newnes Plateau Hanging Swamps (NPHS).

In the case of Newnes Plateau Shrub Swamps (NPSS), precipitation is supplemented by moisture from groundwater sources to form several discharge horizons along the course of the host creek in which a shrub swamp is located. Valley wall seepage, together with direct in-gully input of groundwater via aquitards, permits continuity of hydration for the THPSS during periods of drought. The presence of the Burralow Formation is essential to the formation and persistence of both hanging and shrub swamps (McHugh, 2013).

### 4.2 Sensitivity to mine waste water discharge

Goldney et al (2010) concluded the following with regard to East Wolgan Swamp: 'Site 10 (East Wolgan Samples a and b): There has been a significant and catastrophic impact on this swamp, where ecological and geomorphic thresholds have been exceeded.
Shrub components had disappeared, a significant thickness of peat had been washed away and a heavy deposit of patchy sand of unknown origin was deposited over what remains of the swamp bed. We attributed this swamp's destruction principally to mine water discharge. However, we are unable to determine the role of longwall mining as a contributing factor since mine water discharge impacts have very likely masked the longwall mining impacts. We have determined that these impacts were very likely significant."

The findings of the Goldney et al (2010) report are supported by further research by University of Queensland. An extract from ACARP Project - C20046 Report (Monitoring surface condition of upland swamps subject to mining subsidence with very high-resolution imagery) is included below:

"Imagery collected by the small-UAS clearly show spatially discrete impacts on the vegetation within a shrub swamp associated with mine discharge flow channel (Fig. 21a,d), including slumping and scouring of peat and underlying sand (Fig. 21b) and trampling as a result of subsidence monitoring (Fig 21e). Mine water discharge rates were as high as 240l.sec-1 which, combined with a continuous slope of 1.53 degrees along the length of the shrub swamp (25m decline over 960m), resulted in a channel up to 28m wide. Vegetation outside the flow path of the mine associated water is still intact present (Fig. 22). As imagery was collected in mid-June (late autumn) condition is difficult to assess from imagery.

To allow classification of shrub swamp impacts a 15cm GSD orthophoto product was segmented using multi-resolution segmentation algorithm (eCognition Developer v8.7 scale 30, shape 20, compactness 30) resulting in recognizable features in the image. The segments were converted to polygon features and exported to ArcGIS (v10.1, ESRI, CA, U.S.A.). Manual interpretation was then applied to each segment to assign a class of shrub vegetation, bare ground/dead vegetation or other. Dead vegetation was characterized by high reflectance while bare peat in eroded areas was dark in colour. Shrub vegetation was defined by a combination of colour, surface elevation and texture. The imagery detected both live vegetation and areas of bare ground allowing the spatial extent of disturbance to be classified in two categories (Fig. 22). Waypoints (Fig. 22; e.g., 14 and 15) could be separated in two categories even if they had similar estimates of bare ground (10-25 percent), high estimates of leaf litter (55-80%), and differed only in low percentage cover estimates of vegetation. For example, waypoint 14 had cover from a common shrub swamp species Leptospermum obovatum (7%), while waypoint 15 had small low growing species, including Baumea rubiginosa (6%) and Centella asiatica (5%). In contrast to ground surveys, the classification process utilized surrounding information to quantify natural breaks in shrub swamp habitat and disturbed areas over a broad geographic area. The utility of small UAS can bridge the gap between data collected from the ground (local) and information captured using remote sensing tools (regional), to provide broad landform assessments covering key conservation concerns in protected and threatened ecosystems (Kerr and Ostrovsky, 2003; Turner et al., 2003).

The primary cause for vegetation loss appears to be the flow path of mine discharge water through the studied shrub swamp community. This conclusion is supported by the presence of shrub swamp species surrounding impacted areas caused by discharge events which ended in March 2010. The extensive areas of dead vegetation and bare ground remaining more than three years later demonstrates a sustained and extensive degradation of this community. UAS

imagery combined with field survey demonstrates the capacity for assessment of impacts at an actionable scale by applying ground derived knowledge to spatial extents.
Manual delimitation of extent and context of spatially discrete impacts to vegetation is not necessarily quantitative but provides coverage of entire shrub swamp communities at a known date without impact to the community.

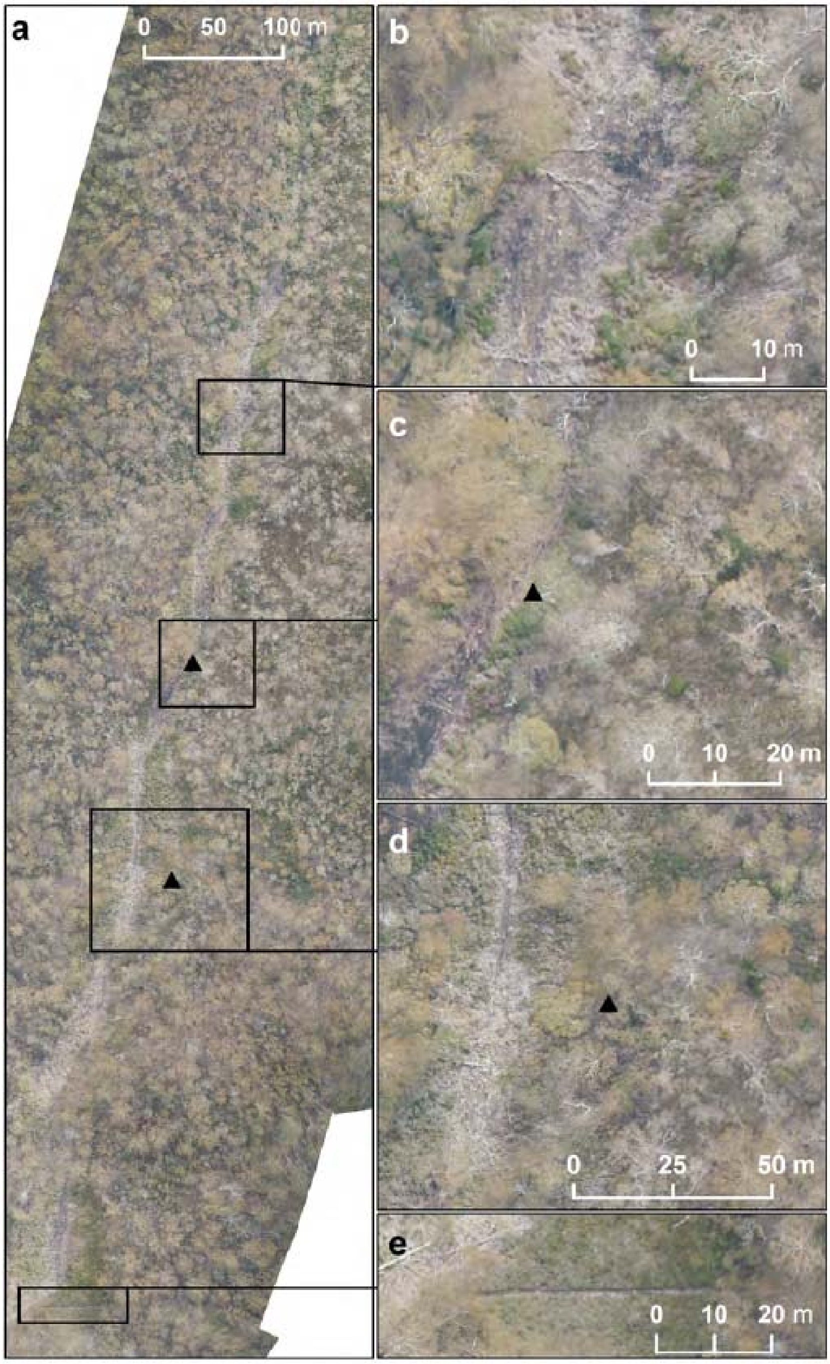


Figure 21: (a) UAS orthophoto mosaic of a shrub swamp collected in June 2013 showing outline of community as described in VISmap 2231 by New South Wales Office of Environment and Heritage. (b). Detail of slump towards downstream end of swamp caused by preferential flow of mine discharge water to below ground strata. (c) Detail image of location of monitoring plot EW01. (d) Detail image of location of EW02 monitoring plot. (e) Upstream end of shrub

swamp community showing trampling impact of subsidence monitoring line.

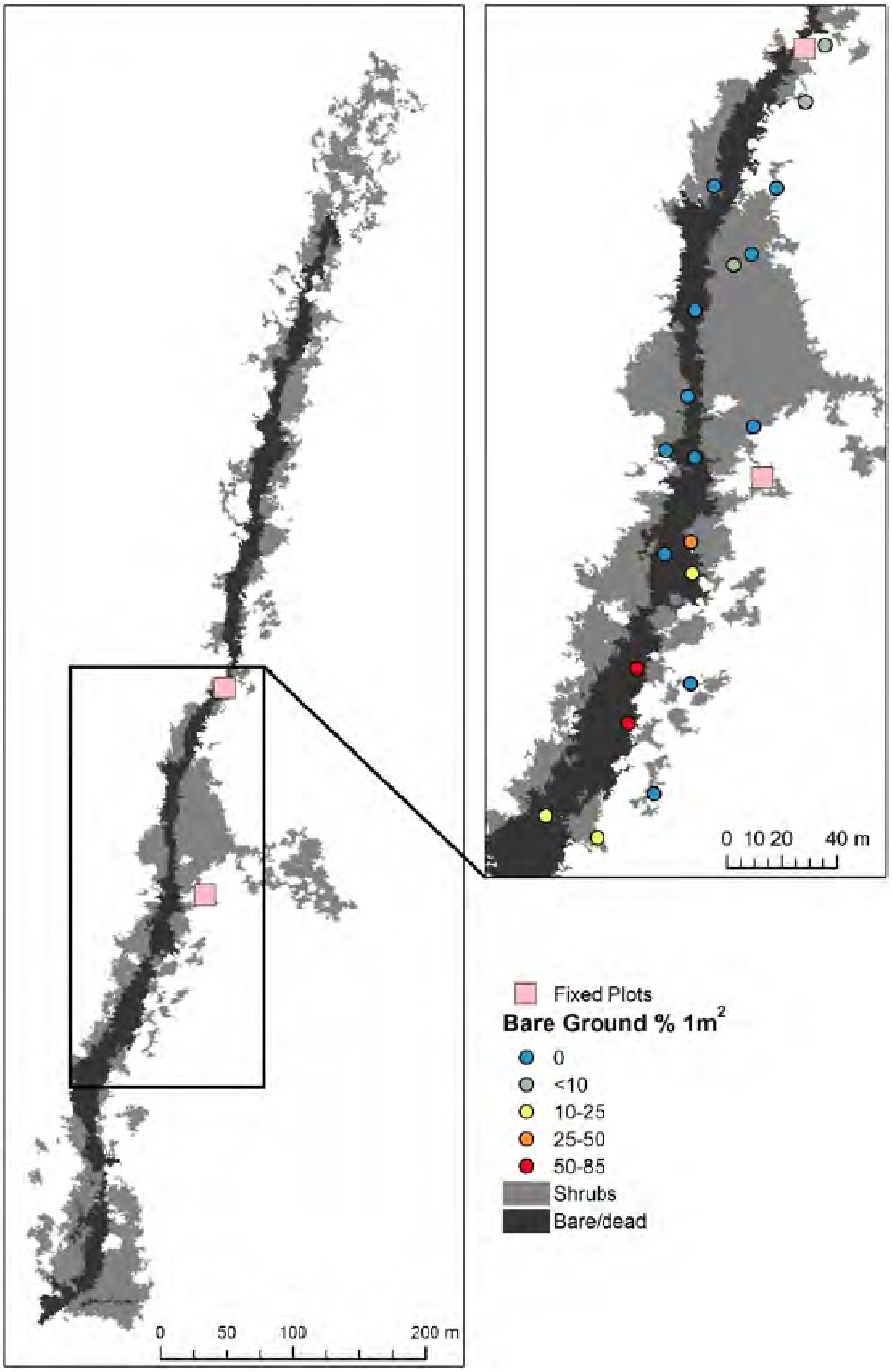


Figure 22: (main) Thematic map of a shrub swamp describing shrub vegetation and dead or bare ground. (inset) Area of mini-plot vegetation assessment ranked by proportion of bare ground identified in 1m2 plot.”

Springvale Coal Pty Ltd (2013) reported the following in terms of investigations into the role of mine water discharge in impacts to East Wolgan Swamp. "Figures 1.20 to 1.25 were taken in areas of East Wolgan Swamp affected by mine water discharge. These photos show the following trends:

- surface erosion and remnants of topsoil secured from erosion by dead root biomass (hummocky surface)
- erosion channels caused by mine water flows
- sediment deposition caused by mine water flows
- healthy swamp vegetation outside of mine water flow path
- limited regrowth of sedges and weeds within flow path

Aurecon (2009) reported *"The photographic monitoring has shown that the discharge from LDP004 has had some visible impact on vegetation within the East Wolgan Swamp. Significant surface flows through the swamp have been continuous, and groundwater levels have been raised for extended periods. The most obvious disturbance to the swamp vegetation from the discharge is where the creek channel is not well defined, and discharge flows have spread out over the swamp vegetation in a broad area across the width of the swamp and resulted in slumping of the peat deposit and dieback of some species over limited areas, most probably due to water logging and the force of the elevated volumes flowing through the swamp. Three primary sites have been identified where this has occurred. In these areas the swamp flora have been disturbed, silt has been deposited due to the slowing of the flow velocity, and the vegetation condition is relatively poor, after being inundated for extended periods. At these sites, it appears that the vegetation associated with the swamp was protecting the peat substrate from disturbance. As the vegetation has been affected by water logging and water flows, the peat structure/complex has also been disturbed. The bare peat material has not been able to retain its integrity most probably due to its low shear strength (in the absence of root matter holding it together) and the force of the water flow. This disturbance is probably a recent phenomenon, as the flow rates from the prolonged emergency discharge down the East Wolgan watercourse from LDP004 in 2008 were significantly greater than previous discharges."*

Figure 1.20 East Wolgan Swamp in Area Affected by Mine Water Discharge. Note surface erosion and remnants of topsoil secured from erosion by (dead) root biomass (hummocky surface)

Figure 1.21 - Looking Across East Wolgan Swamp from the Flow Path of Mine Water Discharge Towards Swamp Unaffected by Mine Water Discharge - Note Limited Regrowth of Sedges and Weeds

Figure 1.22 - East Wolgan Swamp in Area Affected by Mine Water Discharge – Note Limited Regrowth of Sedges Outside of Erosion Channels

Figure 1.23 - East Wolgan Swamp Between Slumping Locations – Note Erosion Channels and Sediment Deposition Caused by Mine Water Discharge

Figure 1.24 Photo of East Wolgan Swamp at WE2 Piezometer location showing vegetation damage along flow path of mine water discharge – not evident outside of flow path

Figure 1.25 Photo of East Wolgan Swamp downstream of WE2 Piezometer location showing vegetation damage along flow path of mine water discharge – not evident outside of flow path.

## Surface Water Flow and Quality

Figure 1.26 shows mine water discharge to East Wolgan and Narrow Swamps via Licenced Discharge Points 4, 5 and 6. The first licenced discharge occurred on 16/4/1997. In February 2006 the Water Transfer Scheme was commissioned and mine water was pumped to Delta Electricity's Wallerawang Power Station. Due to issues with infrastructure and management of the system, licenced emergency discharges to Narrow and East Wolgan Swamps via Licenced Discharge Points 4, 5 and 6 were required to ensure the safety of mine workers when the system was not available. These issues have been resolved over the life of the WTS and there have been no discharges since 10/4/2010.

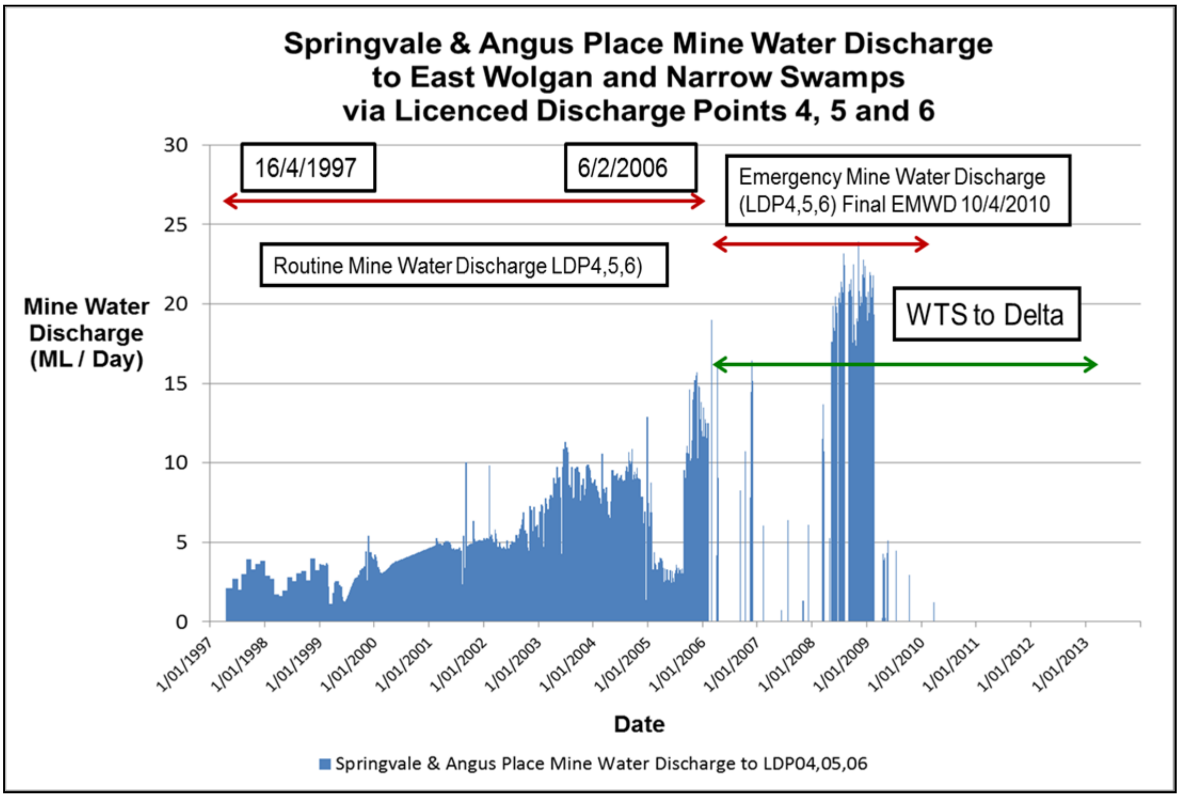


Figure 1.26 Mine Water Discharge to East Wolgan and Narrow Swamps via Licenced Discharge Points 4, 5 and 6 – first discharge 16/4/1997, no discharges since 10/4/2010

Figure 1.27 shows soil moisture monitoring data from WE2 piezometer location, showing significant differences between results during and after mine water discharges. The wetting / drying cycles of Narrow and East Wolgan Swamps due to mine water discharge are evident in the data.

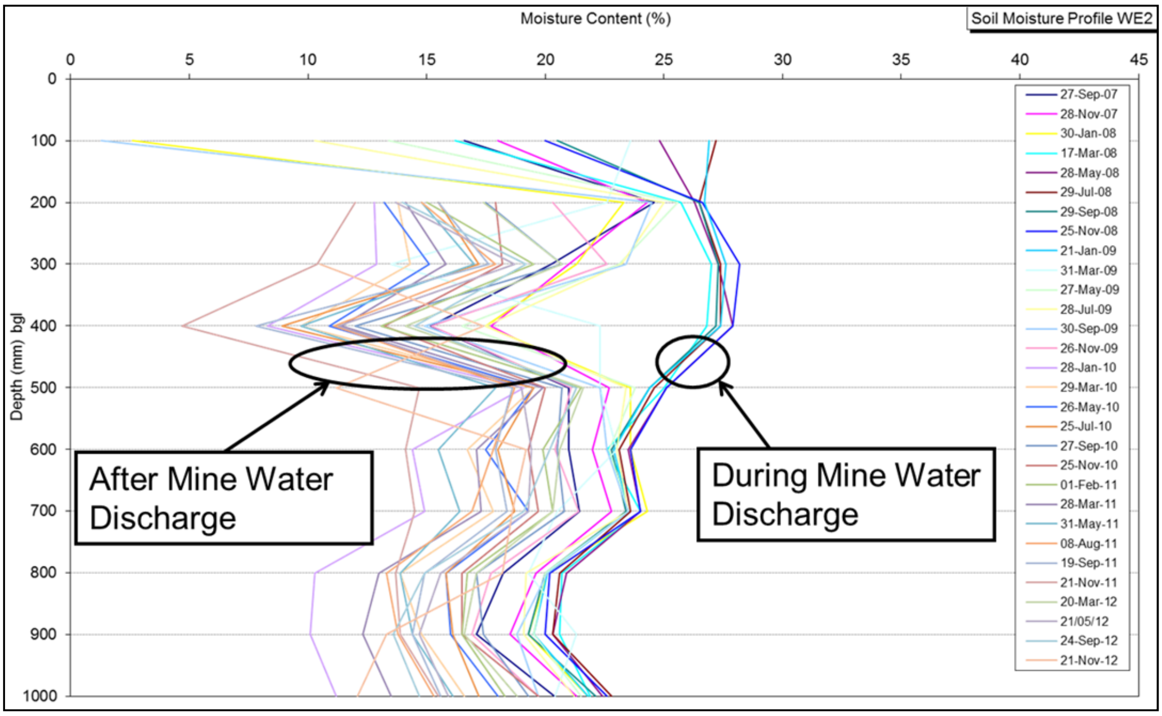


Figure 1.27 Soil Moisture Monitoring Data from WE2 Piezometer Location in East Wolgan – Showing Differences Between Results During and After Mine Water Discharge

Figure 1.28 shows electrical conductivity (EC) water quality data from Newnes Plateau swamp sampling sites, showing significant differences between measured EC at Narrow and East Wolgan Swamps (which were impacted by mine water discharge) compared to Carne West Swamp, which is unaffected by mine water discharge. Elevated EC values are still being recorded at Narrow and East Wolgan Swamps three years after cessation of mine water discharge, but the trend is back towards normal levels. Some change in soil water chemistry at these sites may have occurred as a result of mine water discharge. Further investigation through soil sampling and testing is currently underway to quantify these effects.

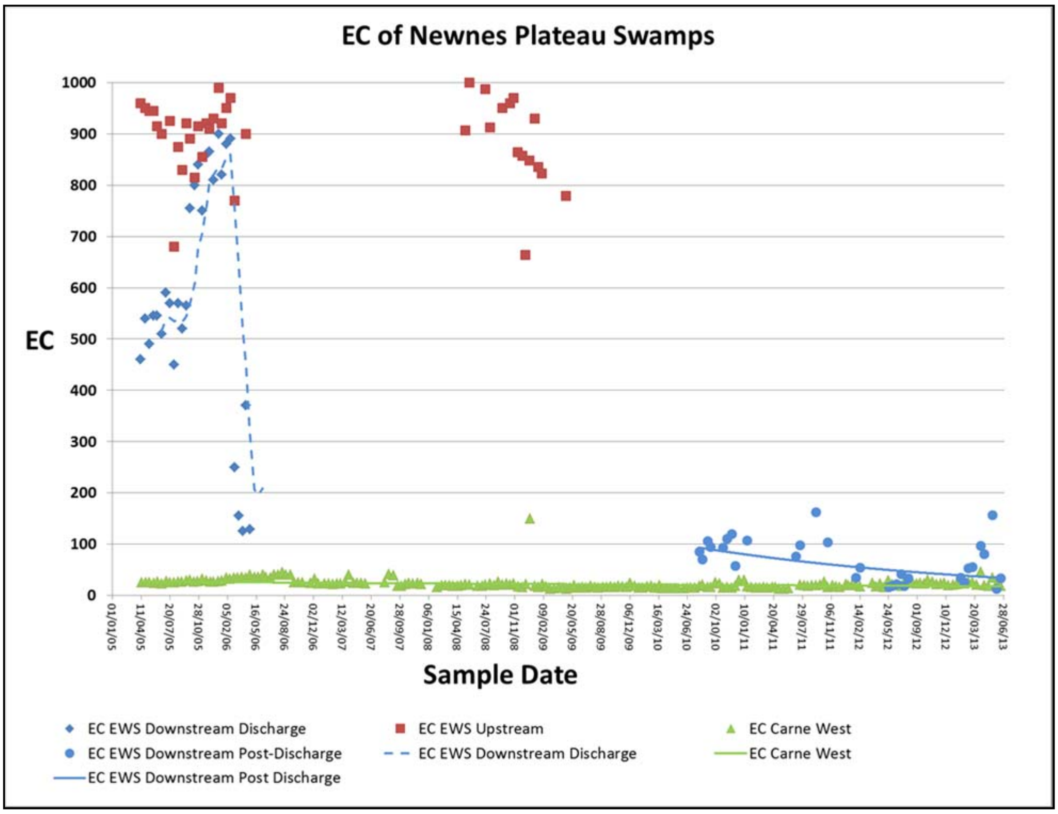
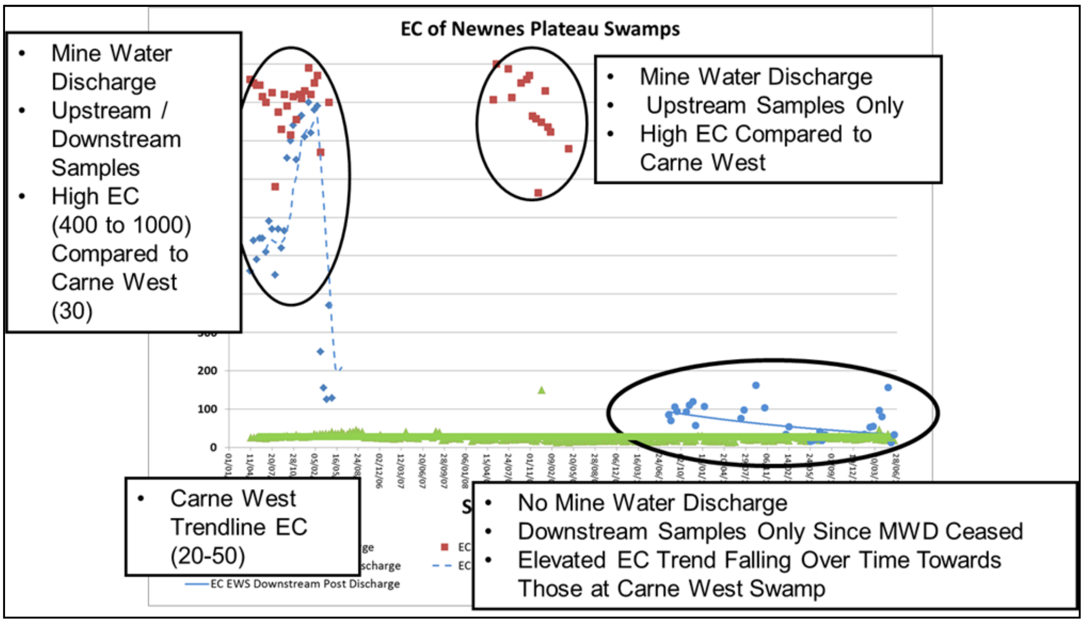


Figure 1.28 Electrical Conductivity (EC) Water Quality Data from Newnes Plateau Swamp Sampling Sites – showing significant differences between measured EC at swamps impacted by mine water discharge compared to typical Newnes Plateau swamp (Carne West). NB Elevated EC values are still being recorded at swamps impacted by mine water discharge three years after cessation of mine water discharge, but the trend is back towards normal levels.



- Mine Water Discharge
- Upstream / Downstream Samples
- High EC (400 to 1000) Compared to Carne West (30)

- Mine Water Discharge
- Upstream Samples Only
- High EC Compared to Carne West

- Carne West Trendline EC (20-50)

- No Mine Water Discharge
- Downstream Samples Only Since MWD Ceased
- Elevated EC Trend Falling Over Time Towards Those at Carne West Swamp

Figure 1.28(a) As per Figure 1.28 with Explanation of Interpretation of Data

Figure 1.29 Water Quality Data (pH) from Newnes Plateau swamp sampling sites, showing significant differences between measured pH at Narrow and East Wolgan Swamps (which were impacted by mine water discharge) compared to Carne West Swamp, which is unaffected by mine water discharge. Elevated pH values are still being recorded at Narrow and East Wolgan Swamps three years after cessation of mine water discharge, but the trend is back towards normal levels. Some change in soil water chemistry at these sites may have occurred as a result of mine water discharge. Further investigation through soil sampling and testing is currently underway to quantify these effects.

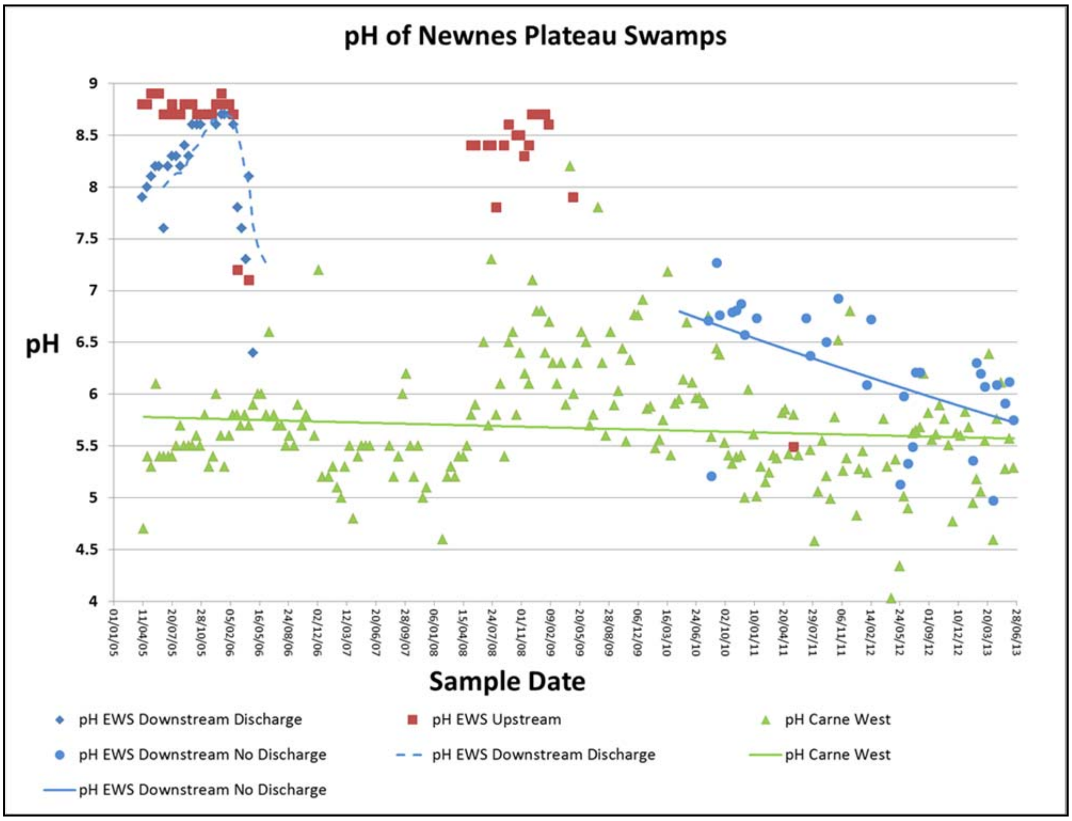


Figure 1.29 Water Quality Data (pH) from Newnes Plateau Swamp Sampling Sites – showing significant differences between measured pH at swamps impacted by mine water discharge compared to typical Newnes Plateau swamp (Carne West). NB Elevated pH values are still being recorded at swamps impacted by mine water discharge three years after cessation of mine water discharge, but the trend is back towards normal levels.

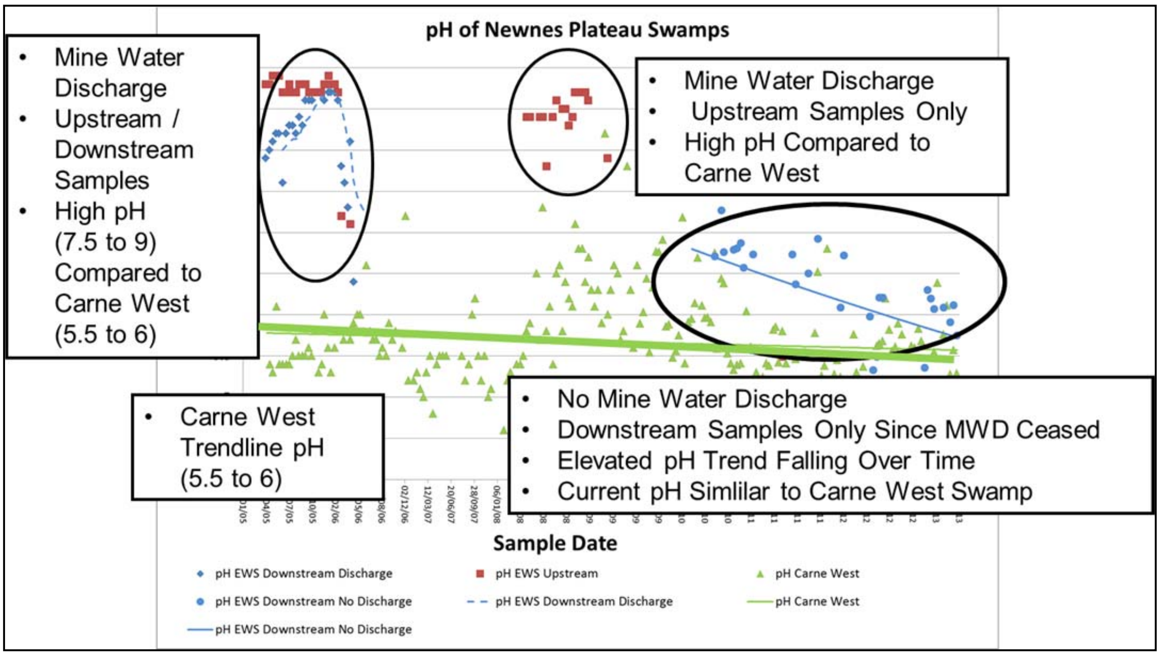


Figure 1.29(a) As per Figure 1.29 with Explanation of Interpretation of Data

Baumgartl (2013) wrote the following regarding East Wolgan Swamp: "*At locations where linear erosion and sheet erosion occurred, vegetation has died back. It is currently unknown whether vegetation initially died as a result of water saturated conditions and lack of oxygen for plant growth or altered chemical conditions impacting on plant health. As a result topsoil could have been eroded due to the loss of a surface near stabilizing root mat. Alternatively, high flow rates may have eroded the topsoil and caused the vegetation to die subsequently*."

Investigations into soil water chemistry were undertaken at East Wolgan Swamp, with soil samples taken at multiple horizons within the peat. These samples were tested to determine if any contaminants from mine water discharge remain in the peat and soils of the swamp.

Figure 1.56(a) is a table showing soil testing results from Southern slumping location in East Wolgan Swamp. A "control" sample was taken from outside of the path of mine water flows and appears to have relatively normal EC and pH values for a Newnes Plateau Shrub Swamp. The samples taken at various depths within the soil profile exposed within the Southern Slumping Location (in the path of the mine water flows) show relatively normal EC values for a Newnes Plateau Shrub Swamp. The pH values, however, are significantly higher than those typical for a Newnes Plateau Shrub Swamp i.e. the pH in the soil profile from within the slump is slightly alkaline at the top and alkaline towards the depth where expected range for an organic rich humous containing horizon is acidic. The reason for elevated pH levels in the soils adjacent to the Southern Slumping Location may be related to mine water discharge.

| Samples | pH | EC [µS/cm] |
|---|---|---|
| EW SS E | 5.2 | 37 |
| EW SS 0-10 | 7.37 | 67.4 |
| EW SS 40-50 | 8.9 | 31.8 |
| EW SS 60-70 | 8.83 | 51.5 |
| EW SS 100-110 | 8.57 | 32.9 |

Figure 1.56(a) – Table Shows Soil Testing Results from Southern Slumping Location in East Wolgan Swamp – note that EW SS E sample was taken from outside of the path of mine water flows and appears to have relatively normal EC and pH values for a Newnes Plateau Shrub Swamp. The samples taken at various depths within the soil profile exposed within the Southern Slumping Location (in the path of the mine water flows) show relatively normal EC values, but the pH values are significantly higher than those typical for a Newnes Plateau Shrub Swamp i.e. the pH in the soil profile from within the slump is slightly alkaline at the top and alkaline towards the depth where expected range for an organic rich humus containing horizon is acidic."

# 6 Evaluation of monitoring techniques

# 7 Ecological monitoring and reporting approach

# 8 Recommended monitoring methods

Monitoring programs have been established in accordance with NSW State and Federal requirements in order to determine if mining related impacts from longwall mining activities on the Newnes Plateau.

The Springvale THPSS Monitoring and Management Plan was approved by DotE in October 2013 following peer review by two independent reviewers. It is based on BACI design within statistically calculated triggers for the following parameters:

- Subsidence
- Flora
- Groundwater Level and Quality
- Surface Water Quality

Time series analysis processes have been built into the development of trigger values, to identify short and long term mining related impacts, should any occur. The Springvale THPSS Monitoring and Management Plan is appended to this review report.

# 9 Knowledge gaps

In order to further improve understanding of the impacts of longwall mining on Newnes Plateau THPSS, Centennial implemented research programs in conjunction with the University of Queensland with the following key outcomes:

- Development of a statistically robust ecological change methodology for flora monitoring of THPSS and an associated Monitoring Methodology handbook. This handbook outlines the datasets, analyses and reporting required to conduct a statistically rigorous and sensitive flora monitoring program to detect change in Newnes Plateau Shrub Swamps and Hanging Swamps, at an individual swamp community scale, due to underground mining. It contains the following improvements, relative to current monitoring programs in use: 1) sufficient replication at the swamp scale such that analysis of key indicators of community composition and health can be assessed in a statistically rigorous manner, 2) clearly defined and ecologically meaningful trigger values and 3) a clear framework outlining required. The Monitoring Methodology handbook - Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps is appended to this review report.

- The University of Queensland is currently conducting research on communities identified as temperate treeless palustrine swamps in a 268 square kilometre area which includes the Newnes Plateau. Based on publicly available combined mapping from the temperate zone of New South Wales and manual interpretation of the numerous vegetation classifications used, a region containing more than 1000 shrub swamp communities per degree of latitude/longitude was identified which contained the communities mapped as Newnes Plateau shrub swamps. A report based on the research will be published and finalised in 2014.

## References

A number of relevant publicly available references were not used in the preparation of these reports. These include:

Forster, I., (2009) Aurecon Report Ref: 7049-010 Newnes Plateau Shrub Swamp Management Plan Investigation of Irregular Surface Movement in East Wolgan Swamp

Goldney, D., Mactaggart B., and Merrick, N. (2010) Determining Whether Or Not A Significant Impact Has Occurred On Temperate Highland Peat Swamps On Sandstone Within The Angus Place Colliery Lease On The Newnes Plateau

McHugh, E., (2013) The Geology of the Shrub Swamps within Angus Place/Springvale Collieries

Fletcher, A., Brownstein, G., Blick, R., Johns, C., Erskine, P. (2013) Assessment of Flora Impacts Associated with Subsidence

Springvale Coal Pty Ltd (2013) EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau – Supplementary Data Volume 1 – 3 and Appendices

Fletcher, A. and Erskine, P. (2014) Monitoring surface condition of upland swamps subject to mining subsidence with very high-resolution imagery (ACARP Project - C20046)

DgS Report No. SPV-003/7b (2014) Subsurface Fracture Zone Assessment above the Proposed Springvale and Angus Place Mine Extension Project Area Longwalls

Corbett, P., White, E., Kirsch, B., (2014) Hydrogeological Characterisation of Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau

Corbett, P., White, E., Kirsch, B., (2014) Case Studies of Groundwater Response to Mine Subsidence in the Western Coalfields of NSW

Brownstein, G., Johns, C., Blick, R., Fletcher, A., Erskine, P., (2014) Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps

Centennial Coal

# Response to the Independent Expert Scientific Committee on Coal Seam Gas and Coal Mining Knowledge Report

## Temperate Highland Peat Swamps on Sandstone: evaluation of mitigation and remediation techniques

September 2014

# Introduction

The following is a response by Centennial Coal to the Independent Expert Scientific Committee on Coal Seam Gas and Coal Mining Knowledge Report: Temperate Highland Peat Swamps on Sandstone: evaluation of mitigation and remediation techniques (the IESC Report). In general the IESC Report:

- does not consider all of the relevant publicly available information in developing arguments about the effects of longwall mining on Temperate Highland Peat Swamps on Sandstone communities (THPSS).
- Where publicly available data has been used in the preparation of this report, certain data has been excluded where it does not support the position argued in the IESC report.
- Certain reference sources cited in the IESC report contain material which is not based on data and is biased against coal mining.

These general observations are further described in this report. For ease of reference, the structure of this report is based on the structure of the IESC report, and has been appended to the Response to Submissions to add a summary of relevant information from publicly available sources. In some areas this extends to a rebuttal of the data analysis or arguments presented in the report.

Centennial acknowledged in Chapter 2 and Chapter 8 of the Springvale Mine Extension Project Environmental Impact Statement (SVMEP EIS) and the Angus Place Colliery Mine Extension Project Environmental Impact Statement (APMEP EIS) that longwall mining has caused impacts to certain THPSS, however, as identified in these documents, this has not been the case in all instances. Chapter 2 of both the SVMEP EIS and the APMEP EIS acknowledged that subsidence impacts to swamp hydrology have been noted at two swamps (Kangaroo Creek Swamp and East Wolgan Swamp). Where impacts to certain THPSS on the Newnes Plateau have occurred, Centennial has conducted extensive research to understand the causes of the impacts. Centennial has used the findings of the research to avoid and mitigate both past and future impacts of longwall mining and related activities to THPSS on the Newnes Plateau.

Extensive research and investigation, lead primarily by work commissioned by the then DEWHA (the Goldney 2010 Report), has shown that impacts to THPSS on the Newnes Plateau have been caused primarily by:

- Licenced discharge of mine water through THPSS
- Changes to swamp hydrology caused by cracking of rock substrate beneath THPSS as a result of mine subsidence

The Goldney 2010 Report found that *the principal cause of impacts* to East Wolgan Swamp and Narrow Swamp was mine water discharge. This finding has been reinforced by research conducted by the University of Queensland. Neither these reports, nor Centennial's response to the findings, have been referenced in the IESC Report. The finding of major impacts caused by mine water discharge is not acknowledged in the IESC Report. As a result of the finding, Centennial has not discharged mine water through THPSS on the Newnes Plateau since 2010 and is committed to managing mine water through the Water Transfer Scheme (WTS), which transfers mine water off the Newnes Plateau.

Following completion of the DEWHA investigation and the Goldney 2010 Report, in November 2011, Centennial (through its Joint Venture) and the Minister for the Environment entered into an Enforceable Undertaking under section 486DA of the Environment Protection and Biodiversity Conservation Act 1999. Under this Enforceable Undertaking, the Joint Venture entered into a research agreement with the Australian National University to undertake a comprehensive research program into THPSS[1].

With the conclusion of these investigations, in 2011, Centennial made applications to the Minister for the Environment to extract coal from Springvale Mine longwall 415 to 417 (EPBC2011/5949) and from the Angus Place Colliery longwall 900W and 910. In 2012, the Minister for the Environment conditionally approved these applications. The primary condition of approval was the need to demonstrate that sub-critical longwall panel design would not result in anomalous subsidence impacts to THPSS.

To demonstrate this, changes to the mine design were are based on reduced mining void widths and increased chain pillar widths. The changes have been made in the context of cover depths in proposed future mining areas in the vicinity of THPSS and are designed to a criterion of sub-critical panel geometry. Subsidence modelling indicates that the design changes will result is very significant reductions to total subsidence and differential subsidence movements. These changes were made specifically to reduce the environmental impacts of longwall mining under the Newnes Plateau, and demonstrate Centennial's commitment to sustainable mining practices.

This mine design approach for all future longwall mining described in the SVMEP EIS and the APMEP EIS in the vicinity of THPSS is consistent with that approved for longwall mining beneath THPSS by DotE under EPBC2011/5949.

All documentation supporting this research, investigations, outcomes is available on the Centennial Coal website, www.centennialcoal.com.au.

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[1] In should be noted that in this report, a reference to the federally listed endangered ecological community Temperate Highland Peat Swamps on Sandstone, includes a reference to the State listed endangered ecological communities incorporating the Newnes Plateau Shrub Swamps and Newnes Plateau Hanging Swamps. The extent to which these communities have been described under these listings is discussed further in response to the IESC Report on ecological characteristics of THPSS.

# Overview and Summary

## Mining and Subsidence

In 2008 and 2009, monitoring at Angus Place and Springvale Collieries detected impacts attributable to mining-related activities at two THPSS. Centennial Coal launched an extensive investigative program to determine the factors causing these impacts. Specific investigations were targeted to determine the hydrogeological characteristics of THPSS. The purpose of these investigations was to ascertain the coincident characteristics which lead to THPSS formation and to understand the sensitivity of those characteristics to mine subsidence behaviour.

These investigations include:

- Aurecon Report Ref:7049-010 Newnes Plateau Shrub Swamp Management Plan Investigation of Irregular Surface Movement in East Wolgan Swamp (2009)
- Determining Whether or not a Significant Impact has Occurred on Temperate Highland Peat Swamps on Sandstone within the Angus Place Colliery Lease on the Newnes Plateau, Goldney et at, 2010 (a report prepared for the then Department of Environment, Water, Heritage and the Arts)
- Aurecon Report Ref: 208354, Geotechnical Investigation Report East Wolgan Swamp Investigation, 2011
- Geophysical Survey Ground Penetrating Radar and Resistivity Investigation of East Wolgan Swamp on the Newnes Plateau, Speer (2011)
- DgS Report No SPV-003/6 Further Discussion on the Potential Impacts to Sunnyside East and Carne West Temperate Highland Peat Swamps on Sandstone due to the Proposed LW416 to 1418, Ditton 2013The Geology of the Shrub Swamps within Angus Place/Springvale Collieries, McHugh 2013
- Assessment of Flora Impacts Associated with Subsidence, Fletcher et at, 2013
- EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau – Supplementary Data Volume 1 to 3 and Appendices, Corbett et all, 2013
- Monitoring Surface Condition of Upland Swamps Subject to Mining Subsidence with very high resolution imagery, Fletcher et al, 2014
- DgS Report No SPV-003/7B Subsurface Fracture Zone Assessment above the Proposed Springvale and Angus Place Mine Extension Project Area Longwalls, Ditton, 2014
- Hydrogeological Characterisation of Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau, Corbett et al, 2014
- Case Studies of Groundwater Response to Mine Subsidence in the Western Coalfields of NSW, Corbett et al, 2014
- Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps, Brownstein et al, 2014

The results of these investigations, described further in the SVMEP EIS, the APMEP EIS, the respective Response to Submission Reports and this report, have allowed Centennial Coal to understand the multiple co-incident factors that led to historical mining-related impacts and implement management practices to ensure mining impacts will be avoided in the future or can be appropriately mitigated.

Since the investigations were conducted, Centennial Coal has been proactive in avoiding or minimising potential subsidence impacts to the geodiversity and biodiversity of the mining area using a comprehensive multi-disciplinary risk-based approach to mine planning and mine design in conjunction with a rigorous monitoring program.

The monitoring techniques employed are wide-ranging and complementary and the combined results provide insights into the role those factors such as geology, hydrogeology and topography play in THPSS formation and the effects of mine subsidence on these.

The extensive monitoring and investigation process employed by Centennial Coal, which utilised multiple lines of evidence to support the management decisions, created the foundations for an adaptive management outcome. Mine design changes (in the form of reduced longwall void width and increased chain pillar width) were implemented in 2011 and are planned in all Mine Extension Project (MEP) areas where THPSS are present.

Based on the results of the investigation and changes implemented in response to the investigation, the Federal DotE gave approval to mine beneath THPSS under EPBC2011/5949 in October 2013.

## Monitoring

There is no evidence to support the statement of limited onsite monitoring data to determine the effect of longwall mining subsidence on upland peat swamps on the Newnes Plateau. There are 36 swamp piezometers installed in Newnes Plateau shrub swamps over the Angus Place and Springvale MLs. They were installed over the period 2005-2011 (Corbett et al 2014).

Groundwater aquifer monitoring commenced at Springvale Mine in 2002. The are currently 28 open hole aquifer monitoring piezometers and 26 multi-level vibrating wire piezometers at Springvale and Angus Place.

The results of these monitoring points are described further in the SVMEP EIS, the APMEP EIS (specifically Chapters 2 and 8), the respective Response to Submission Reports and this report.

The peer reviewed THPSS Monitoring and Management Plan (THPSS MMP) which has been approved by the Federal Department of the Environment (DotE) is aligned with **Before-After/Control-Impact (BACI)** design.

## Mitigation

The primary mechanism to mitigate potential impacts to THPSS is mine design. The mine design for the SVMEP and APMEP is described in detail in the respective Environmental Impact Statements (specifically, Chapter 8).

Major design changes have been made to the Springvale and Angus Place mine plan in order to reduce subsidence from longwall mining. These changes are based on the following dimensional changes:

- Void width reduced from 315m to 261m
- Pillar width increased from 45m to 58m

The changes have been made in good faith and at significant cost to the business at a time when there was no guarantee of approval for ongoing mining activities. No subsidence effects to swamp hydrology or flora communities have been identified in areas where sub-critical mine design have been used in the past (refer to Chapter 2 and Chapter 8 of the respective EIS).

The mine design approach for all future longwall mining in the Springvale and Angus Place MEP areas is consistent with that approved for longwall mining beneath THPSS by DotE under EPBC2011/5949.

Future mine dewatering systems have been designed to ensure that discharge of mine water to Newnes Plateau Shrub Swamps is avoided. No mine water discharges into Newnes Plateau THPSS have occurred since April 2010.

## Remediation

To date, there has been no requirement or need to undertake hard engineering mitigation on a THPSS on the Newnes Plateau. Regardless, there are examples from other regions where hard engineering mitigation has been successful.

A specific example of where PUR grouting has been shown to successfully repair a rock substrate can be seen at Helensburgh Coal Pty Ltd (HCPL) in the NSW Southern Coalfields. Experience at HCPL has shown that grouting using PUR can be used to successfully fill cracks ranging from small sub millimetre sized cracks to open fractures greater than 100 mm.

A trial was conducted at HCPL on the WRS4 rock bar in the Waratah Rivulet and was followed by a remediation report (Waratah Rivulet Remediation Trial Activities – Completion Report (2007)). The main findings of the remediation report were:

- PUR is non-toxic.
- PUR injection can be conducted in an environmentally acceptable fashion.
- PUR injection is suitable for sealing cracking in rocks from less than 1mm to greater than 100 mm.
- Pre and post permeability testing showed that permeability was reduced by several orders of magnitude following PUR injection.
- The PUR injection process was transferrable to other areas where cracking of rock had occurred.

The HCPL PUR grouting programs are used to seal cracking in outcropping rock bars. However, it is considered that this technology is transferrable and can be used to seal cracks in swamp bases as a swamp base is analogous to a rock bar, albeit one covered with peat and sand.

The use of cementitious grouts has also been used to successfully remediate subsidence induced cracking which led to water loss in watercourses in the Southern Coalfield. Injection grouting with cementitious grouts was successfully used for rock bar rehabilitation in the Georges River.

Where alluvial material overlies sandstone, injection grouting though drill rods has also been used successfully to seal void under the alluvial material (soil / peat). This technique was also used in the Georges River, where 1-2m of loose sediment was grouted through using purpose designed grouting pipes.

# Upland Peat Swamps

## 2.1 Importance of the THPSS community

Centennial Coal has acknowledged the importance of the THPSS in the landscape. Research conducted over the last 5 years (2009 to 2014) by the University of Queensland has worked towards quantifying the nature and extent of the community across the Newnes Plateau. Further work undertaken through the Enforceable Undertaking has been targeted towards:

- The nature and extent of THPSS
- THPSS water balances
- Functionality of swamps
- Environmental history and origins
- Ecology/biodiversity of major structural species
- Contribution to the landscape
- Condition status/mapping
- Monitoring of selected reference sites
- Thresholds for recovery

The University of Queensland is currently conducting research on communities identified as temperate treeless palustrine swamps in a 268 square kilometre area which includes the Newnes Plateau. Based on publicly available combined mapping from the temperate zone of New South Wales and manual interpretation of the numerous vegetation classifications used, a region containing more than 1000 shrub swamp communities per degree of latitude/longitude was identified which contained the communities mapped as Newnes Plateau shrub swamps. A report based on the research will be published and finalised in 2014.

## 2.3 Formation and characteristics of upland peat swamps

Monitoring of piezometers in Sunnyside, Sunnyside East, Tri-Star and Carne West swamps indicates that variable hydrology (between periodically waterlogged in the upper reaches and permanently waterlogged in the lower reaches) occurs for swamps to the East of the Newnes Plateau in swamps previously identified as entirely permanently waterlogged.

Major incisions have been recorded in pre-mining surveys of swamps including Sunnyside East Swamp (McTaggart 2013). Major incisions were recorded prior to a bushfire in 2010 which burnt through the middle reaches of the swamp, however records indicate that the bushfire did cause additional incisions to be caused to Sunnyside East Swamp in the period between 2010 and 2013.

Incisions which pre-dated mining were also identified by Goldney et al (2010) at Junction Swamp, Kangaroo Creek North, Kangaroo Creek (Mid), Narrow Swamp South and Sunnyside East (Burnt) Swamp.

## 2.4 Representative swamp conceptual models

Hydrogeological models for Newnes Plateau swamps have been developed through detailed investigation and research since 2010 (detailed in McHugh (2013) and Corbett et al (2014)). These models are described in detail in the SVMEP EIS, the APMEP EIS (specifically Chapters 2 and 8), the respective Response to Submission Reports.

A key finding of the study (McHugh, 2013) was the identification and detailing of the stratigraphy of the Burralow Formation, which overlies the Banks Wall Sandstone. Most previous studies of the Angus Place Colliery and Springvale Mine areas do not typically include the presence of the Burralow Formation, and instead refer to the Banks Wall Sandstone as the uppermost outcropping unit.

Several of the claystone horizons, together with clay-rich, fine-to-medium grained sandstones and shales, were found to be acting as aquitards, or semi-permeable layers. These aquitards retard the vertical movement of groundwater into underlying strata. Instead, much of the groundwater present within the Burralow Formation is redirected laterally down-dip to discharge points in nearby valleys (valley wall seepage), which creates a permanent water source for the formation and maintenance of the Newnes Plateau Hanging Swamps (NPHS).

In the case of Newnes Plateau Shrub Swamps (NPSS), precipitation is supplemented by moisture from groundwater sources to form several discharge horizons along the course of the host creek in which a shrub swamp is located. Valley wall seepage, together with direct in-gully input of groundwater via aquitards, permits continuity of hydration for the THPSS during periods of drought. The presence of the Burralow Formation is essential to the formation and persistence of both hanging and shrub swamps (McHugh, 2013).

## 2.5 Chapter synthesis and knowledge gaps

In the case of Newnes Plateau Shrub Swamps, baseline data from the piezometers indicates that swamp hydrology is variable along individual swamps, and standing water levels are typically influenced by rainfall in the upper reaches and by groundwater in the lower reaches. This demonstrates the increasing groundwater contributions from the multiple outcrops of the Burralow Formation aquitards.

The data from the swamp monitoring has shown that the hydrology of an individual swamp can be ‘periodically waterlogged’ or ‘permanently waterlogged’ or can vary along its length from ‘periodically waterlogged’ to ‘permanently waterlogged’, with transitional behaviour between (Corbett et al 2014).

# Impacts of longwall mining and subsidence

## 3.3 Historical context

Since 2002, Centennial has conducted extensive research on the effects to groundwater systems and ecosystem resilience of longwall mining under the Newnes Plateau. An extensive groundwater monitoring network (comprising 36 swamp piezometers, 36 open hole aquifer piezometers and 26 multi-level vibrating wire piezometers) has been installed and monitored in current and future mining areas. The geology of the overlying strata has been modelled using data from 501 boreholes on the Newnes Plateau. Hydrogeological characterisation of THPSS on the Newnes Plateau has been conducted for the swamps in the Angus Place and Springvale Mine Extension Project areas.

The COSFLOW groundwater model used by CSIRO, and referenced as Appendix K: CSIRO Numerical Modelling Report to the SVMEP EIS and the APMEP EIS, is arguably the most representative model currently in use (Merrick (2014), Kay (2014)). NSW Office of Water reviewed the EIS' and stated in part: "In general, the impact assessment on aquifers has been carried out to a high standard, including preparation of a large and complex groundwater model by CSIRO. The most sensitive receptors in the area are the protected Temperate Highland Peat Swamps on Sandstone, for which longwall mining has been declared a key threatening process under the Threatened Species Conservation Act 1995. A great deal of attention has been paid in the EIS to demonstrate that the proposed extensions will not significantly harm overlying swamps and no specific shortcomings have been found in this assessment."

The COSFLOW model is able to predict groundwater behaviour as measured by changes in piezometric head in response to mine subsidence, which appear to occur as changes to phreatic surfaces within aquifers, instead of as a "height of complete dewatering". The COSFLOW model uses a "ramp function" to simulate the reduction in changes to permeability higher in the overburden. This ramp function is based on measured A, B and C zone data which is correlated to measured changes in permeability (from actual packer test results). As such this model is more representative of what actually occurs than other groundwater models.

In addition to using a groundwater model for the Angus Place and Springvale MEP's, an empirical model has also been used to characterise changes to groundwater systems caused by longwall mining throughout the overburden lithology. The height of continuous fracturing (HoCF) has been assessed for all longwalls in the proposed MEP areas using the DgS and Hydrosimulations Geology Pi-Term model. A presentation on the new methodology was co-authored by Steve Ditton and Noel Merrick and presented at the Australian Earth Sciences Convention (AESC) in July 2014. The new methodology recognises the key fracture height driving parameters of panel width (W), cover depth (H), mining thickness (T), and local geology factors (t'), which represents the effective thickness of strata at height of A-Zone to estimate the A-Zone and B-Zone horizons above a given longwall panel. This model is superior to the existing models as it does recognise geology from a geotechnical perspective. The Pi-Term empirical model is based on an extensive database of 34 Case Studies from all NSW and Qld Coalfields.

It has also been calibrated against local data from a number of multi-level extensometers, multi-level vibrating wire piezometers and groundwater level monitoring bores. Microseismic data from overburden monitoring at Longwall 413 also appears to support the modelled height of the A-Zone. The effective delineation of A, B and C Subsidence Zones is critical to understanding effects to groundwater in the overburden.

The process by which the Pi-Term empirical model was calibrated to the geological and hydrogeological conditions and then used to model subsidence zones in future mining areas at Angus Place and Springvale was through:
- Measuring subsidence zones using extensometers
- Measuring groundwater effects within different subsidence zones using vibrating wire piezometers AND water level monitoring piezometers (changes in storage though minor bed separation may change pressures without measurable changes in water level)
- Modelling of subsidence zones using the Pi-Term Model (calibrated to site measured data)
- Use of historical piezometric response within the measured subsidence zones to approximate future groundwater response in the overburden (modelled subsidence zones) throughout the mine extension areas.

It is certainly the case that significant claystone aquitards are present in the overburden lithology and that these have a significant effect on groundwater behaviour in response to longwall mining. The Mt York Claystone (analogous to the Bald Hill Claystone in the Southern Coalfield) is a major claystone unit (average 22m thick and laterally continuous across the historical and proposed mining areas) which lies approximately 200m above the Lithgow Seam. Measurement with multi-level vibrating wire piezometers in 26 different boreholes over up to a 12 year period indicates that desaturation of the AQ3 aquifer which underlies the Mt York Claystone is very significant, compared to a relatively minor response in the AQ4 aquifer which overlies the Mt York Claystone (this is also modelled in the COSFLOW groundwater model).

In addition, there are a number of claystone units (up to 4m in thickness) located in the Burralow Formation, which lies immediately below the surface. These units appear to have a significant influence on retarding downward movement of groundwater flows and causing lateral movement of groundwater into the adjacent valleys, where it represents a significant source of water to the THPSS (GDE's) which lie in those valleys. These do not appear to be significantly affected by longwall mining, as measured in five water level monitoring bores installed in 2005 and subsequently undermined by longwall panels, without measurable response to water levels. This measured lack of change to groundwater levels has been measured at a number of other bores also.

In a Peer Review of Mine Subsidence Induced Height of Fracturing Issues for Angus Place and Springvale Collieries, Kay (2014) wrote: “MSEC has reviewed the above referenced CSIRO and DgS Reports and found that they provide detailed information on the existing environment, the groundwater systems, the overburden and the presence of layers of low permeability for this Western Coalfields area. The selection and use of both numerical and empirical models which have been calibrated to site data over many years and used for the Angus Place and Springvale Mine Extension Projects, are believed to represent the current “industry best practice”.

MSEC has reviewed these reports and, in our opinion, we consider the assessments of the HoCF for the proposed longwalls at Angus Place and Springvale Collieries that are included in these reports are reasonable for this particular geological region.

It is noted that these reports have provided geologically adjusted and calibrated predictions and assessments of the likely HoCF over the proposed longwalls at Angus Place and Springvale Collieries, which, in our opinion, appear to be appropriate for this geological region and, hence, should provide a satisfactory estimate for the impact assessments on the groundwater systems from the proposed mining for this particular geological region. The selection and use of both numerical and empirical models (calibrated to site data over many years) which has been used in the Angus Place and Springvale Mine Extension Projects, represents current industry best practice and provides a satisfactory estimate of the effects to groundwater systems of the proposed mining."

Based on the research undertaken and described above, a site specific hydrogeological model has been developed that is considered by a number of experts in the field as best practice. The level of detail, as well as the calibration with a significant geological and hydrological data set, is unprecedented for longwall mining operations in the Western Coalfield and is superior to the modelling summations made in the IESC Report.

## 3.4 Impact mechanisms

The IESC Report: THPSS: Evaluation of Mitigation and Remediation Techniques (pp 36) cites the Tametta (2013) model. Rather than the two zones in the Tammetta conceptual model, it is generally accepted in literature (e.g. Forster, 1995[2]) that there is a sequence of deformational zones illustrated in Figure 1(b) and usually described as:

- the caved zone;
- the fractured zone, consisting of:
    - a lower zone of connective-cracking; and
    - an upper zone of disconnected-cracking;
- the constrained zone; and
- the surface zone.

Ditton and Merrick (2014) describe four zones with different terminology but essentially the same conceptualisation (Figure 1(a)):

- the A-Zone or "Continuous Cracking" zone - equivalent to the caved zone plus the connective-cracking part of the fractured zone;
- the B-Zone or "Lower Dilated" zone - equivalent to the disconnected-cracking part of the fractured zone, or the lower part of the constrained zone;
- the C-Zone or " Upper Dilated" zone - equivalent to the upper part of the constrained zone; and
- the D-Zone or "Surface Cracking" zone - equivalent to the surface zone.

It will be shown in a later section of this report that the "Collapsed Zone" of the Tammetta model corresponds with the A-Zone plus the B-Zone. As the B-Zone has disconnected

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[2] Forster, I.R., 1995. Impact of underground mining on the hydrogeological regime, Central Coast NSW. In: Sloan, S W and Allman, M.A. (Ed.), Engineering Geology of the Newcastle-Gosford Region, pp156-168.

fractures, it is not appropriate to ascribe complete collapse to this zone. Nor is it appropriate to infer unsaturated conditions for the entire zone. Unsaturated conditions would occur in the A-Zone, but need not necessarily occur throughout the entire A-Zone.

The rocks in the A-Zone would have a substantially higher vertical permeability than the undisturbed host rocks. This will encourage groundwater to move out of rock storage downwards towards the goaf. In the B-Zone, where disconnected-cracking occurs, the vertical movement of groundwater should not be significantly greater than under natural conditions, but horizontal permeability would be expected to be enhanced through dilation of bedding planes.

Depending on the width of the longwall panels and the depth of mining, and the presence of low permeability lithologies, there would be a constrained zone in the overburden that acts as a bridge. Rock layers are likely to sag without breaking, and bedding planes are also likely to dilate. As a result, some increase in horizontal permeability can be expected.

In the surface zone, near-surface fracturing can occur due to horizontal tension at the edges of a subsidence trough. Fracturing would be shallow (<20 m), often transitory, and any loss of water into the cracks would not continue downwards towards the goaf. The IESC Report: THPSS: Evaluation of Mitigation and Remediation Techniques (pp 36) agrees that "surface waters lost to the subsurface re-emerge downstream via lateral faults". As "lateral faults" is a strange concept, are dilated bedding planes or opened joints intended as the mechanism?

The strata movements and deformation that accompany subsidence will alter the hydraulic and storage characteristics of aquifers and aquitards. As there would be an overall increase in rock permeability, groundwater levels will be reduced either due to actual drainage of water into the goaf or by a flattening of the hydraulic gradient without drainage of water (in accordance with Darcy’s Law).

The literature review cited in IESC Report: THPSS: Evaluation of Mitigation and Remediation Techniques (pp 37) is inadequate because it ignores the substantial field of discrete fracture networks (e.g. Xu and Dowd, 2010)[3]. The review considers only continuous (infinite) fractures characterised by aperture and roughness, and the impression is given that very large effective permeabilities would result from fracturing by application of an unmodified cubic law.

The argument is flawed for a couple of reasons. First, the application of the cubic law is an assumption that ignores the most important feature of a fracture - its continuity. Crimping or closure or truncation of a fracture would terminate the flow path and reduce the flow rate to zero, unless the discrete fracture intersects another fracture. Nullification of flow could be achieved with equation 3.2 by use of a large *f* factor (for roughness). However, the chart in Figure 3.8 is restricted to a unit value for *f*, a most unlikely condition. Second, the application of an unmodified cubic law leads to hydraulic conductivities that this author has found to be 4-6 orders of magnitude greater than required to match observed mine inflows, using an equivalent porous medium approach to modelling. This suggests that the admittedly high

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[3] C. Xu and P. Dowd. A new computer code for discrete fracture network modelling. Computers & Geosciences, 36(3):292-301, Mar. 2010.

permeabilities in individual fractures are modified by weighted averaging with the deformed rock mass in the fractured zone, or the fractures lack sufficient continuity to transmit large volumes of water.

A better model of fracture flow should be based on stochastic representations of discrete fracture networks, such as offered by discrete fracture ellipses in the FracSim3D code of Wu and Dowd (2010).

Without proper consideration of fracture continuity, and fracture density in the case of surficial cracking, the claim is not substantiated that "a few small cracks through the swamp substrate can lead to substantial vertical drainage". For observed field fracture densities, the cracks themselves would have very small water storage capacity compared to the volume of water held within the bulk of the swamp sediments. A weighted average of the void water and matrix water is appropriate to assess whether the loss of water through surficial fractures might be significant. The fracture density would have to be much higher than generally observed for the loss of water to be significant.

## Case Studies: Sunnyside West Swamp Heath and West Wolgan Swamp

The Sunnyside West Swamp Heath is located upstream of the Sunnyside Swamp over Springvale Colliery, and West Wolgan Swamp is located over Angus Place Colliery. While these swamps have been classified as different botanical types, both are located at higher elevations, where the groundwater table beneath the low flanking ridges is situated well below the base of the swamps. As a result, these swamps are not fed by the main aquifer in this area, but rely to a large extent on rainfall to contribute to the groundwater. The swamps have probably formed in these areas due to the presence of a perched water table on a high-level aquitard.

Sunnyside West Swamp Heath is located over the pillar between LW412 and 413 at 10 cut-through at Springvale Colliery (Figure 9). West Wolgan Swamp is located over LW 940 and LW 950 at 17 cut-through at Angus Place Colliery (Figure 10). Both swamps are periodically waterlogged swamps in which the groundwater level varies significantly with rainfall.

Groundwater monitoring commenced at West Wolgan Swamp in two piezometers (WW1 and WW2) in May 2005, while monitoring in one piezometer (SW1) at the Sunnyside West Swamp Heath commenced in July 2007. Monitoring data are shown in Figure 11. West Wolgan Swamp was undermined by LW 940 in November 2007, while LW 950 passed the site in July 2009. At the Sunnyside West Swamp Heath, LW 912 passed beneath the swamp in January 2009 and LW 413 passed the site in July 2010. Groundwater monitoring results are presented in Figure 11, and discussed in detail in the following section.

These two swamps are discussed together as they display almost identical hydrogeological behaviour (even though they are separated by about 4 km), and the data from the piezometers in one swamp can be compared with data from the piezometers in the alternate swamp, to check for mining-related impacts. There is no flow monitoring at either of these swamps as they are both periodically waterlogged and flow from the downstream ends of these swamps occurs very rarely.

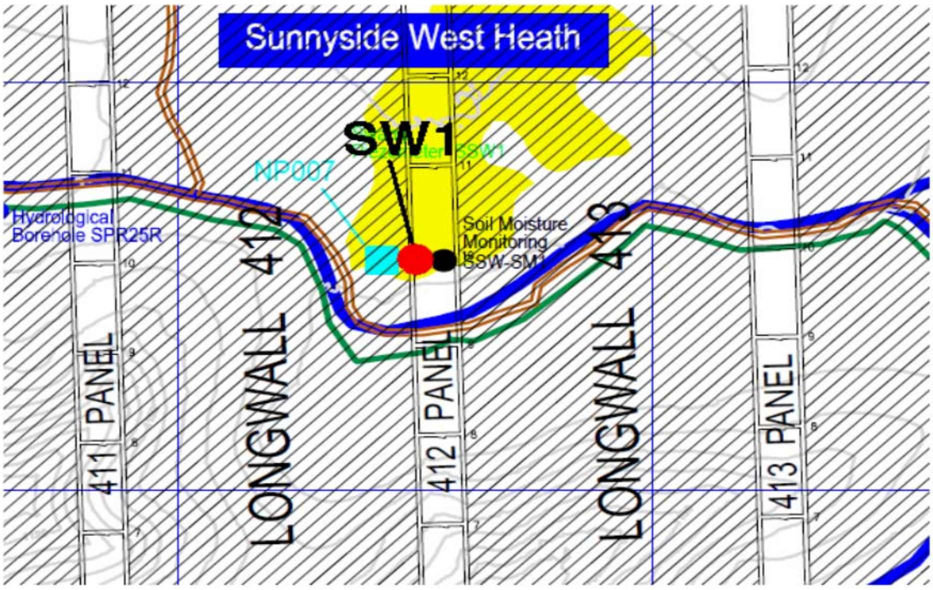


Figure 9 - Sunnyside West Swamp Heath - location of piezometer

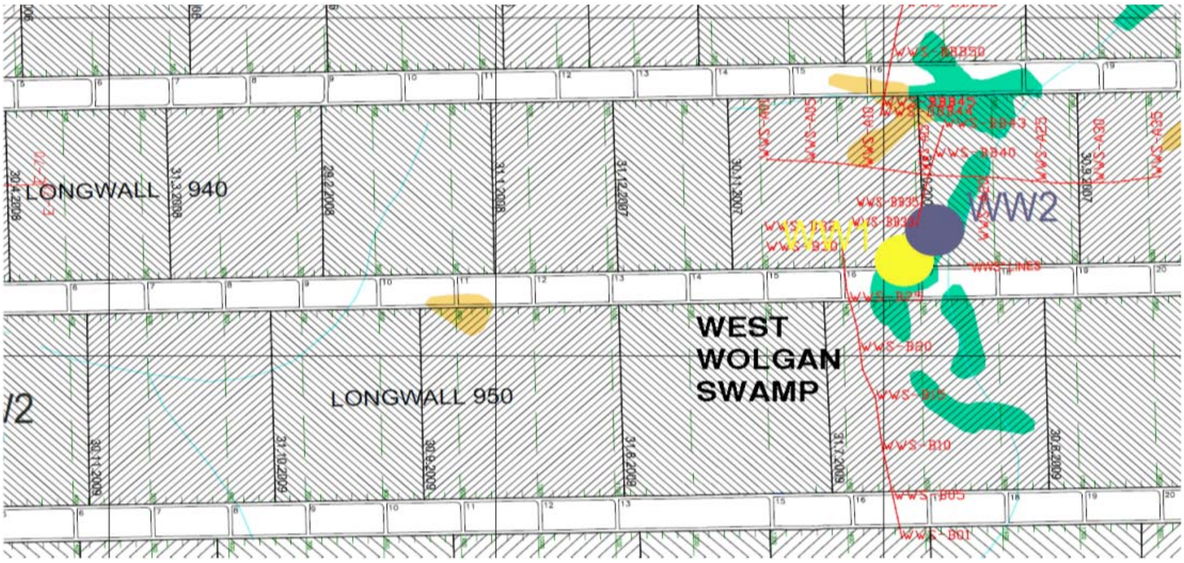


Figure 10 - West Wolgan Swamp - location of piezometers

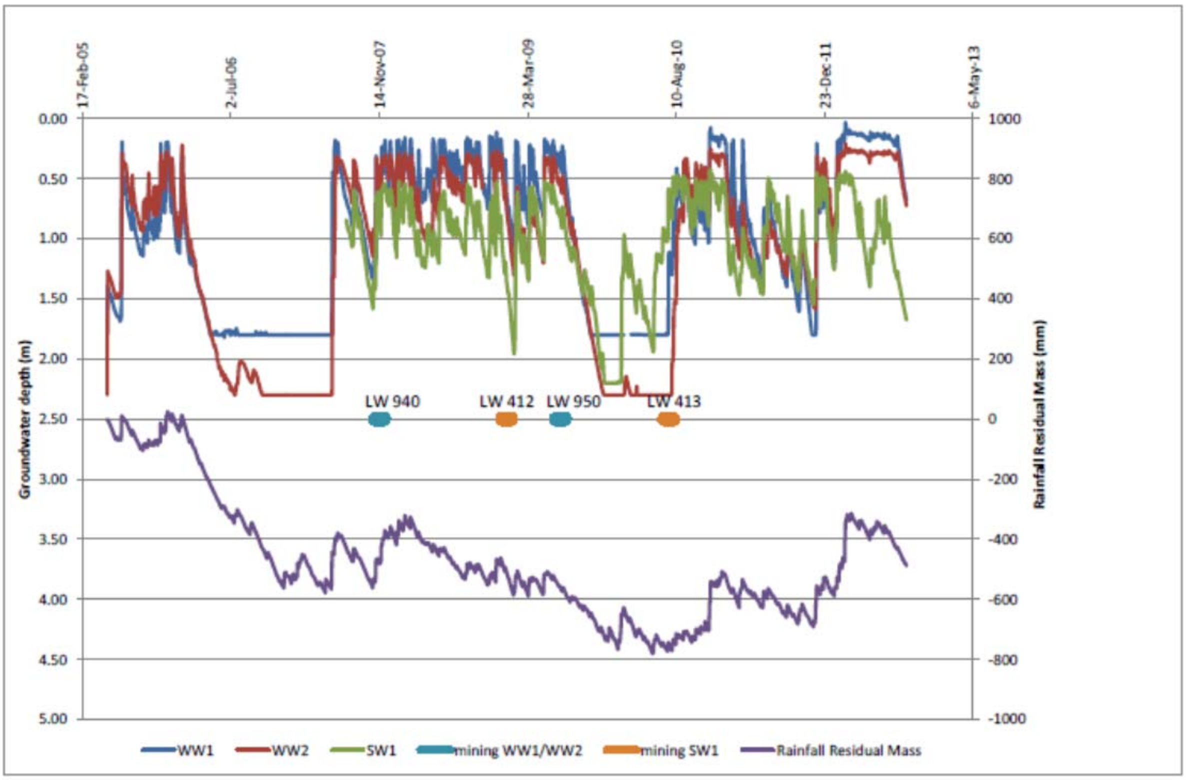


**Figure 11 – West Wolgan Swamp and Sunnyside West Swamp Heath – groundwater levels**

**Monitoring results and analysis**

The monitoring results for WW1 and WW2 (Figure 11) in the West Wolgan Swamp show groundwater level movements which are typical of a periodically waterlogged swamp, where the groundwater level rises rapidly, then declines more gradually following rainfall events. The low groundwater level in both WW1 and WW2 in 2006/2007 (pre-mining) was due to the severe drought conditions at the time. This drought period is also evident on the rainfall residual mass plot shown in Figure 11. Above average rainfall in the latter half of 2007 raised the groundwater to pre-drought levels prior to the swamp being undermined by LW 940 in November 2007.

Following the undermining, the monitoring shows no change in the groundwater level behaviour in WW1 and WW2 to that observed prior to mining, with the same pattern of rapid rise followed by gradual decline after rainfall events. It is also clearly evident from Figure 11 that the post-mining groundwater level behavior in WW1 and WW2 is identical to the pre-mining behavior in SW1 in the Sunnyside West Swamp Heath, which at that time had not been undermined. This provides further evidence for a lack of mining-related impacts at the West Wolgan Swamp.

An identical pattern of groundwater movements is also evident after the undermining of SW1 in January 2009. These patterns are very similar to the patterns in WW1 and WW2 at the same time, and there is no discernible difference in the pre- and post-mining patterns or in the SW1 data and the WW1/WW2 data.

WW1 and WW1 showed a decline in groundwater level following the passage of LW 950 past the site in July 2009, but this was not due to mining. The low groundwater levels between September 2009 and early 2010 were due to abnormally low rainfall over this period, as there was a similar decline in the level in SW1. This again is evident in the decline of the rainfall residual mass during this period. Additionally, during this time, the data logger in WW1 malfunctioned and had to be replaced. These below average rainfall conditions reversed in late 2010 about the time that LW 413 passed SW1, and the groundwater level patterns returned to normal in both swamps. Again, there was no material difference between the groundwater level behaviour in the swamp after the passage of this longwall panel.

**Conclusions**

The recent pattern of groundwater level movements in piezometer SW1 in the Sunnyside West Swamp Heath is consistent with the response measured prior to undermining by LW 412 in March 2009 (and almost identical to the movements in WW1 and WW2). The data indicate conclusively that there has been no impact from the mining in LW 412 or LW 413 on the hydrogeological conditions recorded within the swamp at SW1. No mining-related impacts are evident from the hydrogeological data, even though this swamp experienced near-maximum subsidence for the panel, which would have been of the order of 1.2 metres.
Similar analyses have also confirmed that mining at Angus Place has had no impact on the West Wolgan Swamp, where the post-mining groundwater level patterns have been compared to patterns in the Sunnyside West Swamp Heath and found to be near-identical. The groundwater level movements in both swamps are closely related to the rainfall residual mass, which reinforces the fact that both swamps are periodically waterlogged swamps.

# Impacts of mining on upland peat swamps and water bodies in the Sydney Basin

## *3.5.1 Observed longwall mining impacts on upland peat swamps*

### 3.5.1.2 East Wolgan Swamp, Newnes Plateau (Western Coalfield)

The IESC Report includes a table, **Table 3.3**, at page 45 that describes the timeline and impact information from available references on East Wolgan Swamp. This table is incomplete and relies heavily on information provided in the report prepared by the Colong Foundation for Wilderness titled, Impacts of Coal Mining on the Gardens of Stone (Muir 2010).

A comprehensive assessment of the impacts to East Wolgan Swamp is included in the SVMEP EIS and the APMEP EIS, specifically in Chapter 2 and Chapter 8 of those reports.

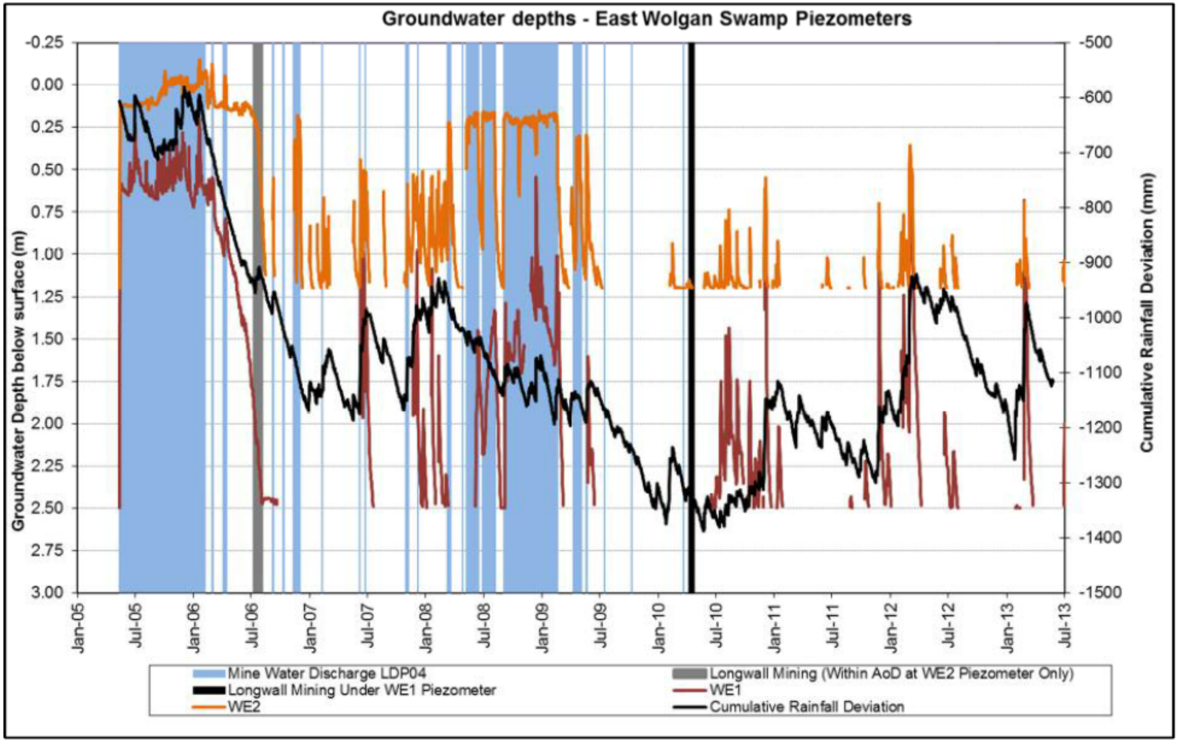
A factual timeline of events and impacts related to East Wolgan Swamp is included below.

| Key Information | Reference |
|---|---|
| Impacts to East Wolgan Swamp hydrology recorded at swamp piezometers (including impacts to peat layer) | Aurecon 2009 |
| Investigation into the causal factors leading to impacts completed (refer to Aurecon, 2009 and SVMEP EIS at www.centennialcoal.com.au) | Aurecon 2009 |
| DEWHA investigation completed in 2010 | Goldney et al 2010 |
| Cease water discharge to East Wolgan Swamp | April 2010 |
| Centennial commences investigation into mine re-design to reduce longwall void width | 2010 |
| Centennial implements mine re-design | 2011 |
| Enforceable undertaking entered into (note: an Enforceable Undertaking is not issued, it is an agreement between two parties to undertake certain actions, it is not an admission of fault, refer to section 4 of the Enforceable Undertaking) | October 2011 |
| Referral made to DotE to remediate East Wolgan Swamp | August 2012 |
| Application made to OEH to remediate East Wolgan Swamp | July 2012 |
| Referral approval (not controlled) granted | September 2014 |
| Approval from OEH for remediation received | November 2013 |
| Remediation commences | January 2014 |
| Angus Place EPBC referral for LW900W and 910 | May 2011 |
| Angus Place EPBC 2011/5952 issued | April 2012 |
| Springvale EPBC referral for LW 415 to 417 | May 2011 |
| Springvale EPBC 2011/5949 issued | March 2012 |
| Springvale THPSS Monitoring and Management Plan developed and approved (refer to centennialcoal.com.au for supporting documentation) | October 2013 |

Groundwater levels at East Wolgan Swamp began to decline rapidly in February 2006 when Centennial commissioned the Water Transfer Scheme (WTS), which transferred water pumped from the mine via a pipeline off the Newnes Plateau for use by industrial water users (Wallerawang Power Station).

Hydrographs of East Wolgan Swamp piezometers WE1 and WE2, presented with the timing of mine water discharge and longwall mining as well as the cumulative rainfall deviation trend show strong correlations between groundwater levels and mine water discharges prior to mining. Following the cessation of mine water discharges, the hydrograph trends can be seen to be strongly influenced by rainfall.

There are periods (in excess of two years) during which pre-mining data for WE1 piezometer was not influenced by mine water discharge (March 2006 to March 2008), which may be used to characterise the pre-mining hydrology of East Wolgan Swamp.
It is important to note that, at both piezometer locations, the data shows that the standing water level was at or below the WE1 piezometer instrument (indicated by discontinuities in the hydrograph trend) for most of the periods not influenced by mine water discharge. The standing water levels rise in response to rainfall events which are in excess of the long-term average trends and fall in response to less than average rainfall trends. The responses are typically immediate and of short duration, indicated by the "spikes" in the hydrograph trends. When the data recorded during mine water discharged is removed, the same trend can be seen in the pre-mining baseline data at WE1 piezometer (March 2006 to March 2008). Based on this baseline data it is concluded that East Wolgan Swamp was a periodically waterlogged swamp before commencement of mining activities.



In 2004, in consultation with EPA, Centennial installed infrastructure to transfer water off the Newnes Plateau (Water Transfer Scheme, WTS) for use by industrial users (Delta Electricity, now Energy Australia).
The WTS represented a multi-million dollar investment for Centennial, which was designed to service the life of mine needs to remove water from the mine and discharge it at a mutually agreed location and allowed the water to be used by a local industrial user (Delta Electricity). At that time the WTS was awarded several green globe awards by the NSW Government Department of Energy, Utilities, and Sustainability as follows:

- water recycling and conservation leadership
- water and energy savings action plan - excellence achievement
- water champion business achievement

Springvale and Angus Place mine water management system on the Newnes Plateau has been modified through the following management measures to eliminate discharge related impacts to Newnes Plateau swamps.

Water was discharged into East Wolgan Swamp and Narrow Swamp via licensed discharge points LDP004 and LDP005 on Newnes Plateau between 1997 and 2006 at volumes of up to 12Ml/day.

The sustained water discharges changed the swamp hydrology (and vegetation community) from periodically waterlogged to permanently waterlogged. When mine water discharge was initially removed in 2006, the resultant drying of the swamp caused a major impact to swamp vegetation. Between May 2008 and March 2009 emergency mine water discharge was released at up to 12 ML/day into East Wolgan Swamp. Springvale Coal ceased discharging into East Wolgan and Narrow Swamps in April 2010.

Goldney et al (2010) concluded the following with regard to East Wolgan Swamp: 'Site 10 (East Wolgan Samples a and b): There has been a significant and catastrophic impact on this swamp, where ecological and geomorphic thresholds have been exceeded.
Shrub components had disappeared, a significant thickness of peat had been washed away and a heavy deposit of patchy sand of unknown origin was deposited over what remains of the swamp bed. We attributed this swamp's destruction principally to mine water discharge. However, we are unable to determine the role of longwall mining as a contributing factor since mine water discharge impacts have very likely masked the longwall mining impacts. We have determined that these impacts were very likely significant."

The findings of the Goldney et al (2010) report are supported by further research by University of Queensland. An extract from ACARP Project - C20046 Report (Monitoring surface condition of upland swamps subject to mining subsidence with very high-resolution imagery) is included below:

"Imagery collected by the small-UAS clearly show spatially discrete impacts on the vegetation within a shrub swamp associated with mine discharge flow channel (Fig. 21a,d), including slumping and scouring of peat and underlying sand (Fig. 21b) and trampling as a result of subsidence monitoring (Fig 21e). Mine water discharge rates were as high as 240l.sec-1 which, combined with a continuous slope of 1.53 degrees along the length of the shrub swamp (25m decline over 960m), resulted in a channel up to 28m wide. Vegetation outside the flow path of the mine associated water is still intact present (Fig. 22). As imagery was collected in mid-June (late autumn) condition is difficult to assess from imagery.

To allow classification of shrub swamp impacts a 15cm GSD orthophoto product was segmented using multi-resolution segmentation algorithm (eCognition Developer v8.7 scale 30, shape 20, compactness 30) resulting in recognizable features in the image. The segments were converted to polygon features and exported to ArcGIS (v10.1, ESRI, CA, U.S.A.). Manual interpretation was then applied to each segment to assign a class of shrub vegetation, bare ground/dead vegetation or other. Dead vegetation was characterized by high reflectance while bare peat in eroded areas was dark in colour. Shrub vegetation was defined by a combination of colour, surface elevation and texture. The imagery detected both live vegetation and areas of bare ground allowing the spatial extent of disturbance to be classified in two categories (Fig. 22). Waypoints (Fig. 22; e.g., 14 and 15) could be separated in two categories even if they had similar estimates of bare ground (10-25 percent), high estimates of leaf litter (55-80%), and differed only in low percentage cover estimates of vegetation. For example, waypoint 14 had cover from a common shrub swamp species Leptospermum obovatum (7%), while waypoint 15 had small low growing species, including Baumea rubiginosa (6%) and Centella asiatica (5%). In contrast to ground surveys, the classification process utilized surrounding information to quantify natural breaks in shrub swamp habitat and disturbed areas over a broad geographic area. The utility of small UAS can bridge the gap between data collected from the ground (local) and information captured using remote sensing tools (regional), to provide broad landform assessments covering key conservation concerns in protected and threatened ecosystems (Kerr and Ostrovsky, 2003; Turner et al., 2003).

The primary cause for vegetation loss appears to be the flow path of mine discharge water through the studied shrub swamp community. This conclusion is supported by the presence of shrub swamp species surrounding impacted areas caused by discharge events which ended in March 2010. The extensive areas of dead vegetation and bare ground remaining more than three years later demonstrates a sustained and extensive degradation of this community. UAS imagery combined with field survey demonstrates the capacity for assessment of impacts at an actionable scale by applying ground derived knowledge to spatial extents.
Manual delimitation of extent and context of spatially discrete impacts to vegetation is not necessarily quantitative but provides coverage of entire shrub swamp communities at a known date without impact to the community.

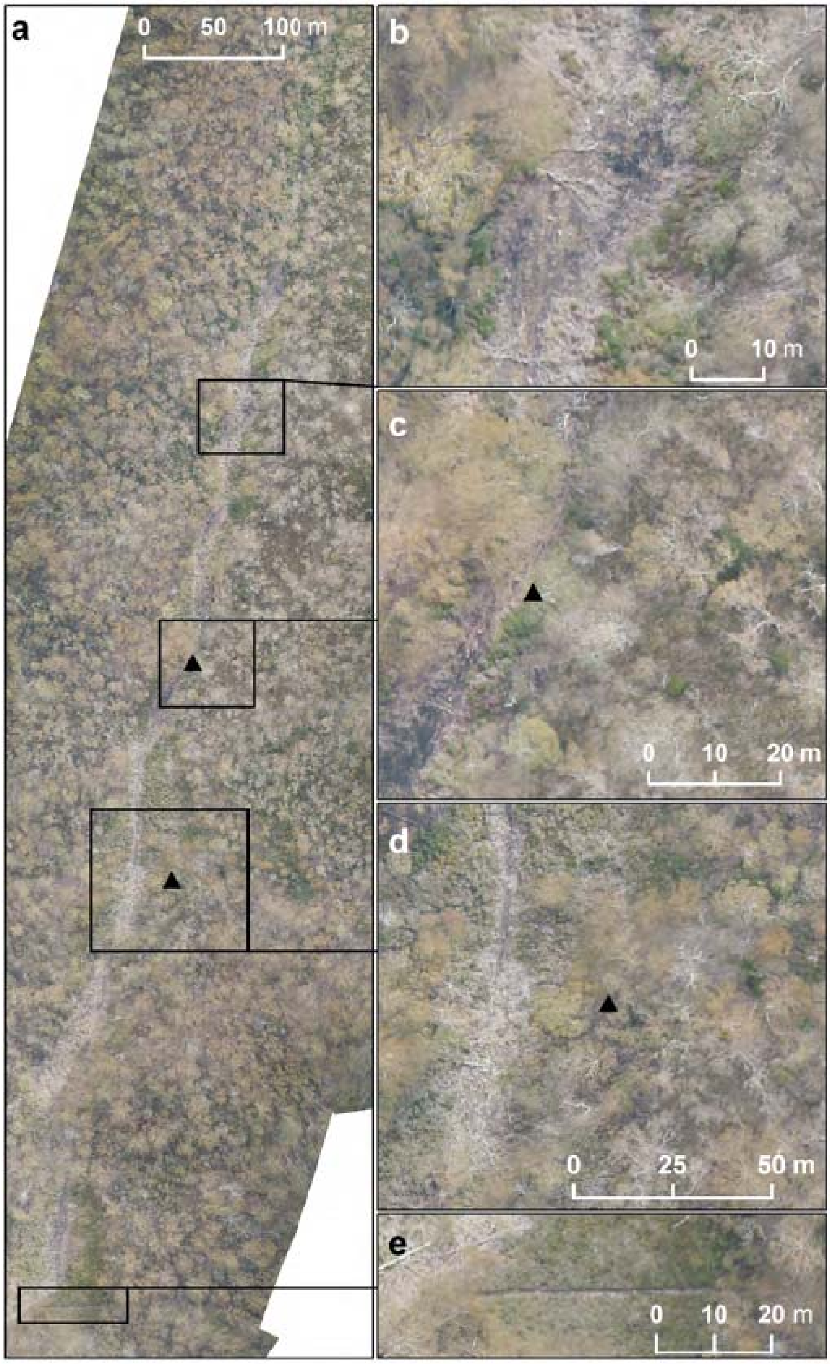


Figure 21: (a) UAS orthophoto mosaic of a shrub swamp collected in June 2013 showing outline of community as described in VISmap 2231 by New South Wales Office of Environment and Heritage. (b). Detail of slump towards downstream end of swamp caused by preferential flow of mine discharge water to below ground strata. (c) Detail image of location of monitoring plot EW01. (d) Detail image of location of EW02 monitoring plot. (e) Upstream end of shrub swamp community showing trampling impact of subsidence monitoring line.

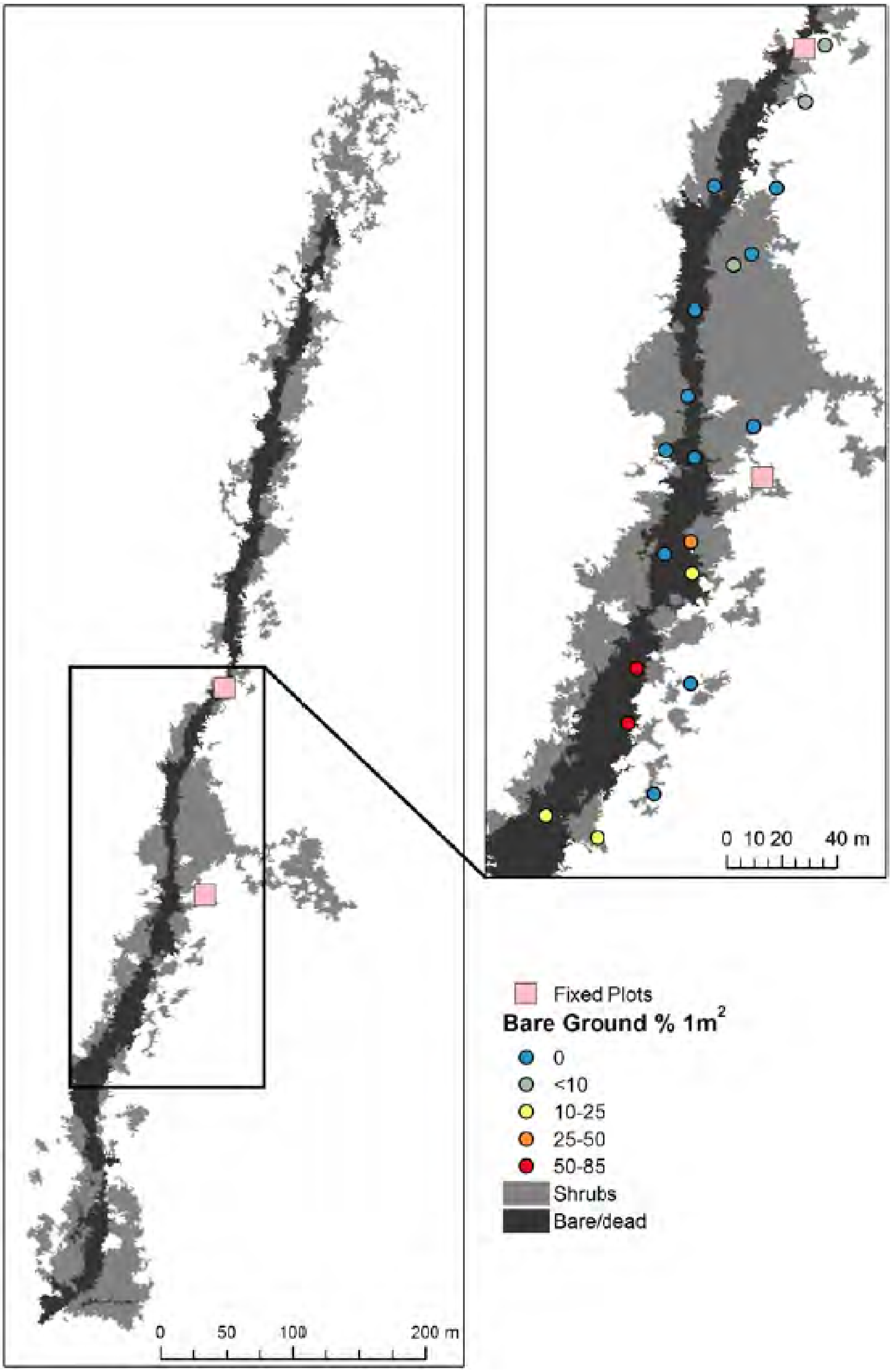


Figure 22: (main) Thematic map of a shrub swamp describing shrub vegetation and dead or bare ground. (inset) Area of mini-plot vegetation assessment ranked by proportion of bare ground identified in 1m2 plot."

The key co-incident factors related to cavity formation at East Wolgan Swamp (into which water discharge flowed and erosion / peat slumping occurred) are listed below:

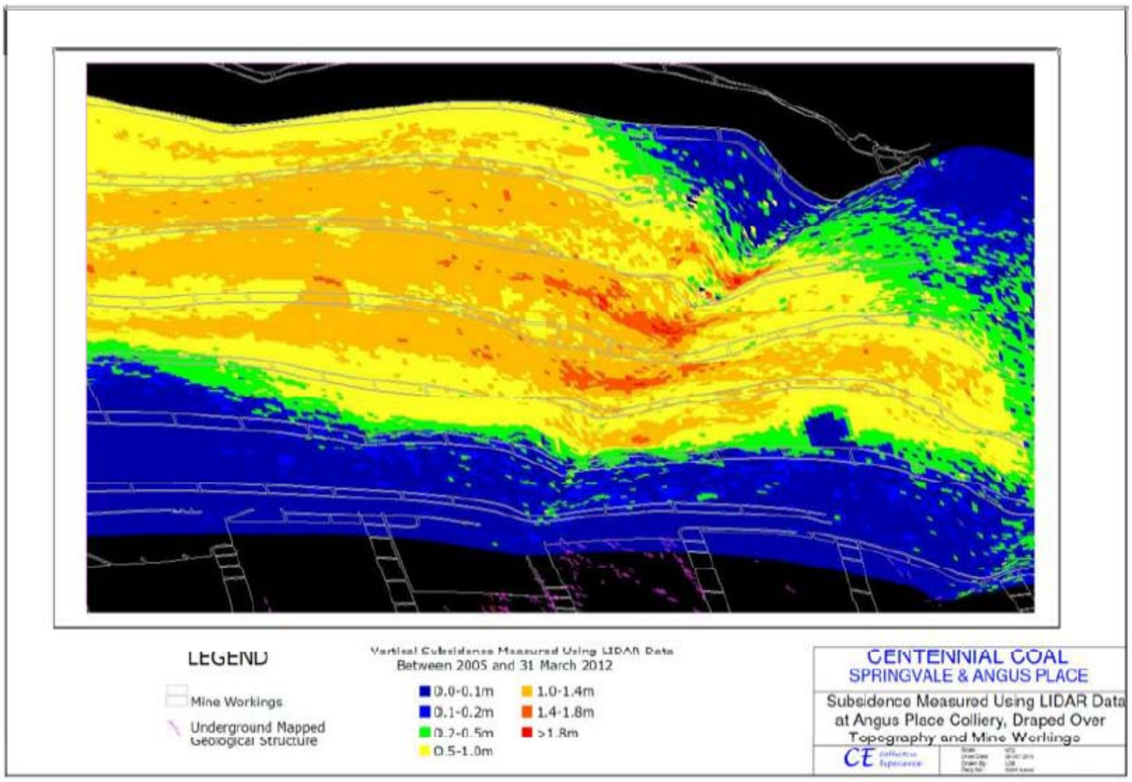
- licensed mine water discharge at rates of up to 12Ml/day;
- intersection of major geological fault structures;
- orientation of the longwall panel subparallel to the major structures;
- steepness and depth of East Wolgan Swamp valley at northern end;
- prevailing in-situ stress direction and magnitude (Springvale longwalls sub-perpendicular to principal horizontal stress direction);
- critical width longwall panel design;
- location of the geological structure close to the permanent barrier pillar (at cavity location); and
- interaction of Angus Place and Springvale mine workings and subsidence effects due to close proximity (at cavity location).

There is no data to validate the assertion of pre-mining flows. Evidence of return of natural flows to East Wolgan Swamp in the period since 2010 is discussed in EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau – Supplementary Data Volume 1 (2013).

#### 3.5.1.4 Narrow Swamp, Newnes Plateau (Western Coalfield)

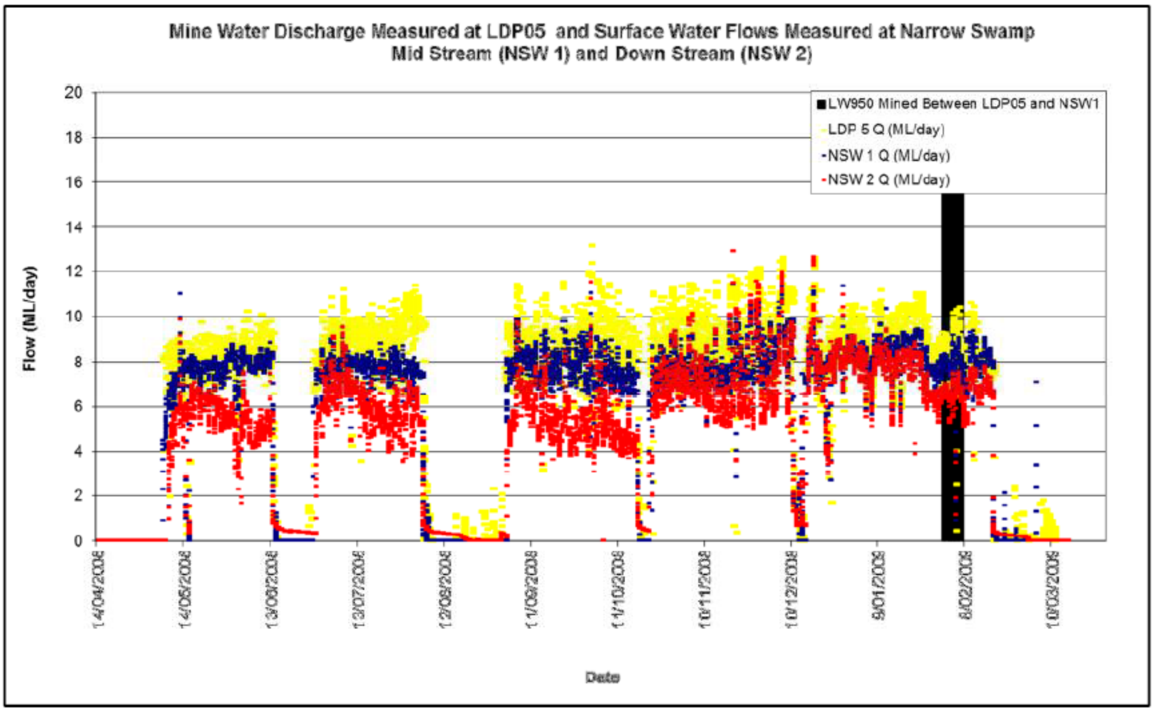
Narrow Swamp was undermined by Longwall 920 in March 2004, Longwall 940 in May 2007 and Longwall 950 in February 2009.

Subsidence monitoring from Angus Place A and F subsidence monitoring lines across the surface valleys associated with the Wolgan River Lineament (which contain Narrow Swamp and East Wolgan Swamp) has identified greater subsidence levels (up to 1.75m) compared to previous predictions. Further analysis of subsidence associated with major geological structures was conducted using LiDAR data (from pre-mining survey in 2005 compared with post-mining data from 2012). LiDAR subsidence data draped over topography from the Digital Terrain Model and mine workings shows subsidence levels in excess of previously predicted values (>1.4 m) can be clearly seen to be concentrated around the valley that contains Narrow Swamp (and identifies the western flank of the Wolgan River Lineament major geological structure zone). These elevated levels of subsidence did not cause changes to swamp hydrology at Narrow Swamp.



A graph of mine water discharge at Angus Place Colliery's Licensed Discharge Point 5 (upstream of Narrow Swamp) compared to two downstream flow monitoring stations at Narrow Swamp shows that there is a similarity of the trend of mine water discharge volumes compared to upstream and downstream flow monitoring (similar losses through the monitoring period from pre-mining to post-mining period). The monitoring data shows that the three longwall panels which have passed under Narrow Swamp during the period of licensed mine water discharge (i.e. Angus Place LW920 in 2004, LW940 in 2007 and LW950 in February 2009) have caused no significant loss of flow in the watercourse.

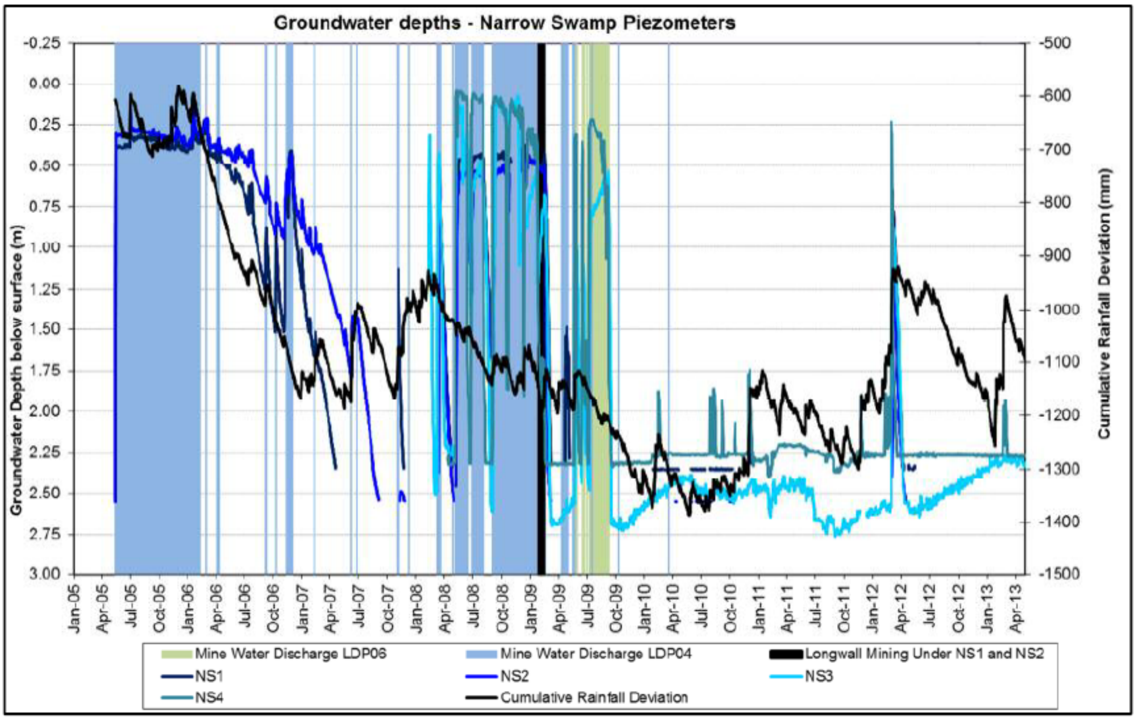
Flow monitoring carried out in this swamp prior to the extraction of LW950 has shown that approximately 91% of the discharge from Angus Place Colliery LDP005 reached a weir (NSW1) in the centre of the Narrow Swamp. After undermining by LW950 in February 2009, the monitoring indicated no change in the percentage of the discharge that reached NSW1. In addition, the percentage of discharge from NSW1, which reached a weir at the northern end of the Narrow Swamp (NSW2), was also 91%. Two longwall panels have undermined the Narrow Swamp in the section of the watercourse between NSW1 and NSW2, and so the flow monitoring indicates that the mining to date has not resulted in any significant cracking in the base of the swamp.



A hydrograph of Narrow Swamp piezometers NS1, NS2, NS3 and NS4 presented with the timing of mine water discharge and longwall mining as well as the cumulative rainfall deviation trend shows that the timing of mining was similar to that of the cessation of mine water discharges at LDP05 in February 2009, but the dominant influencing factor can be seen to be mine water discharges.

Following the cessation of mine water discharges, the hydrograph trends can be seen to be strongly influenced by rainfall. The standing water levels rise in response to rainfall events that are in excess of the long term average trends and fall in response to less than average rainfall trends. The responses are typically immediate and of short duration, indicated by the ‘spikes’ in the hydrograph trends.

When the data recorded during mine water discharged is removed, the same trend can be seen in the pre-mining baseline data. There is approximately 12 months pre-mining data (between March 2007 nd March 2008) that is not affected by mine water discharge, which clearly shows that the swamp was periodically waterlogged prior to mining. It remains periodically waterlogged following mining.



Goldney et al (2010) reported the following in terms of Narrow Swamp: 'Site 5 (Narrow Swamp South): A significantly impacted THPS which we attributed to a combination of mine discharge and sediment movement. Lack of baseline data pre-LWM made it difficult to assess this site. As argued above we have ruled out drought as a likely explanation. Any other minor impacts due to LWM would be completely masked by the greater impacts.

'Site 9 (Narrow Swamp North): There has been a significant and catastrophic impact on this swamp, where ecological and geomorphic thresholds have been exceeded. Based on snagged clumps of vegetation we were able to ascertain that at times the depth of water has reached up to 1 m across a 75 m wide bed. That represents a very considerable flow and one potentially very destructive. Shrub components had disappeared (no mean feat), a significant thickness of peat had been washed away and a heavy deposit of patchy sand of unknown origin was deposited over what remains of the swamp bed. We attributed this swamp's destruction to mine water discharge, since this appears to be the only viable explanation.'.

OEH approved the undertaking restoration actions at East Wolgan Swamp and Narrow Swamp, and issued a certificate under Section 95 of the TSC Act on 25 November 2013. Approved remediation works have been carried out since January 2014 in East Wolgan Swamp and will also be conducted in 2014 in Narrow Swamp.

### 3.5.1.5 Junction Swamp, Newnes Plateau (Western Coalfield)

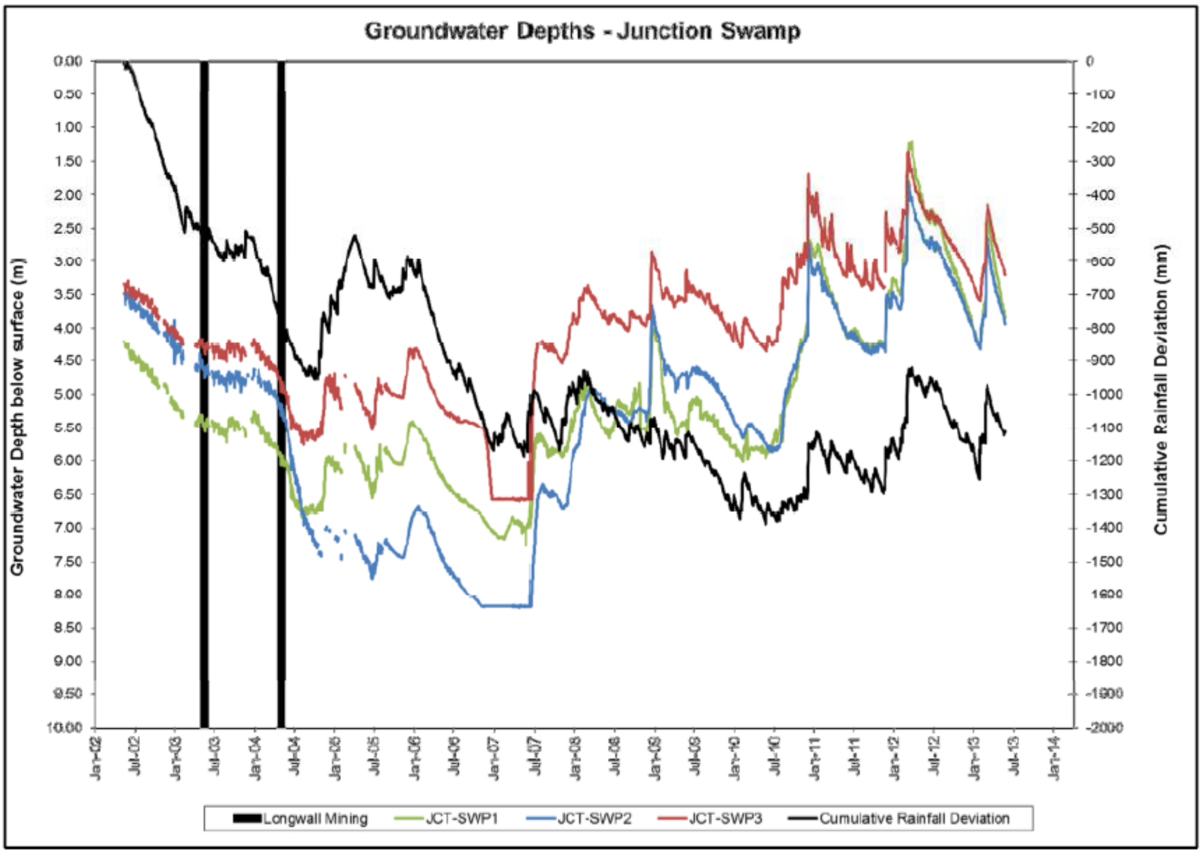
Table 3.5 Junction Swamp: timeline and impact information from available references. (pp47)

Surface water flow from the swamp was unaffected by LW 408, but ceased after the passage of this panel due to the ongoing rainfall residual mass deficit and the reduced downstream groundwater gradient. The flow from the swamp did not recommence until December 2010, even though the downstream groundwater gradient was above the threshold gradient for a period of two months. This suggests that there has been some tilting of the unconfined aquifer that has possibly changed the subsurface flow direction.

**Longwall 940 is in excess of 2km away from Junction Swamp**

There is a very strong correlation between the trendlines of standing water levels beneath the swamp and the cumulative rainfall deviation trendline for all swamp piezometers over the eleven years of monitoring at this location.

This data indicates that the swamp is periodically waterlogged (standing water levels respond to rainfall). The data also indicates that there has been no significant vertical drainage of groundwater from the aquifer supporting the swamp (i.e. no significant impacts to swamp hydrology) in response to longwall mining as the standing water levels now are similar to pre-mining levels (Corbett et al 2014).



## 3.5.1.6 Kangaroo Creek and swamps, Newnes Plateau (Western Coalfield) (pp48)

There is no data to substantiate the statement “Kangaroo Creek and its associated swamps (Figure 3.10) on the Newnes Plateau have experienced decreased flow since May 1996” (Muir 2010).

Kangaroo Creek Dam monitoring conducted in the period 2009 -2012 shows that the dam has contained water on 22 out of 24 monitoring occasions (conducted monthly or bi-monthly). This dam lies downstream of Kangaroo Creek (upper) Swamp, which was undermined by Springvale Longwall 401 in 1996.

In the Save Our Swamps - Newnes Plateau Shrub Swamp Aerial Assessment Project Report (2010), Kangaroo Creek Swamp (upper) was assessed to be in "Good" condition (no visible impact) in all categories (channelisation, desiccation, erosion, swamp crossing, access track, blackberry) except pine wildings, where a minor impact assessment was made. This swamp was undermined by Springvale Mine Longwall 401 in 1996. In the absence of data, this information suggests either:

1. No significant impact from longwall mining

2. Recovery of the swamp system over time

Either way, no long term impacts from longwall mining were detected.

The photo in “Figure 3.14 Dieback of the swamp on Kangaroo Creek above longwall 940, indicating a permanent change in groundwater conditions, 2009 (Muir 2010)” appears to be taken in the watercourse between KC upper and KC middle swamps, and not within a mapped swamp community. Co-ordinates of photo are required to verify it is within a mapped swamp community.

The photo above is the mapped Kangaroo Creek (mid) Swamp in July 2013. Flora monitoring at Kangaroo Creek Shrub Swamp indicated no trend of decreasing condition and that species abundance is not declining.

**Table 3.6 Kangaroo Creek and swamps: timeline and impact information from available references. (pp49)**

There is no data to substantiate the statement “Kangaroo Creek and its associated swamps (Figure 3.10) on the Newnes Plateau have experienced decreased flow since May 1996” (Muir 2010).

In the Save Our Swamps - Newnes Plateau Shrub Swamp Aerial Assessment Project Report (2010), Kangaroo Creek Swamp (upper) was assessed to be in "Good" condition (no visible impact) in all categories (channelisation, desiccation, erosion, swamp crossing, access track, blackberry) except pine wildings, where a minor impact assessment was made. This swamp was undermined by Springvale Mine Longwall 401 in 1996. In the absence of data, this information suggests either:

1. No significant impact from longwall mining

2. Recovery of the swamp system over time

Either way, no long term impacts from longwall mining were detected.

### Kangaroo Creek (Mid) Swamp

Figure 1 shows Kangaroo Creek Piezometer Monitoring Data (KC1 and KC2) and Cumulative Rainfall Deviation over the period between 2006 and 2014. It shows hydrographs of the swamp piezometers installed at Kangaroo Creek Swamp, together with the cumulative rainfall deviation, which is indicated by the black trendline. Note that there is a very strong correlation between the trendline of standing water level beneath the swamp and the cumulative rainfall deviation trendline for the KC2 piezometer over the eight years of monitoring at this location. This data indicated that the swamp is periodically waterlogged at this location (standing water levels respond to rainfall). The data also indicates that there have been no significant impacts to swamp hydrology in response to longwall mining at KC2. Groundwater levels at KC1 appear to have been affected by the longwall mining of Angus Place LW940, which was below the lower reaches of the swamp, as there was a sudden reduction in groundwater levels in June 2008, unrelated to rainfall.

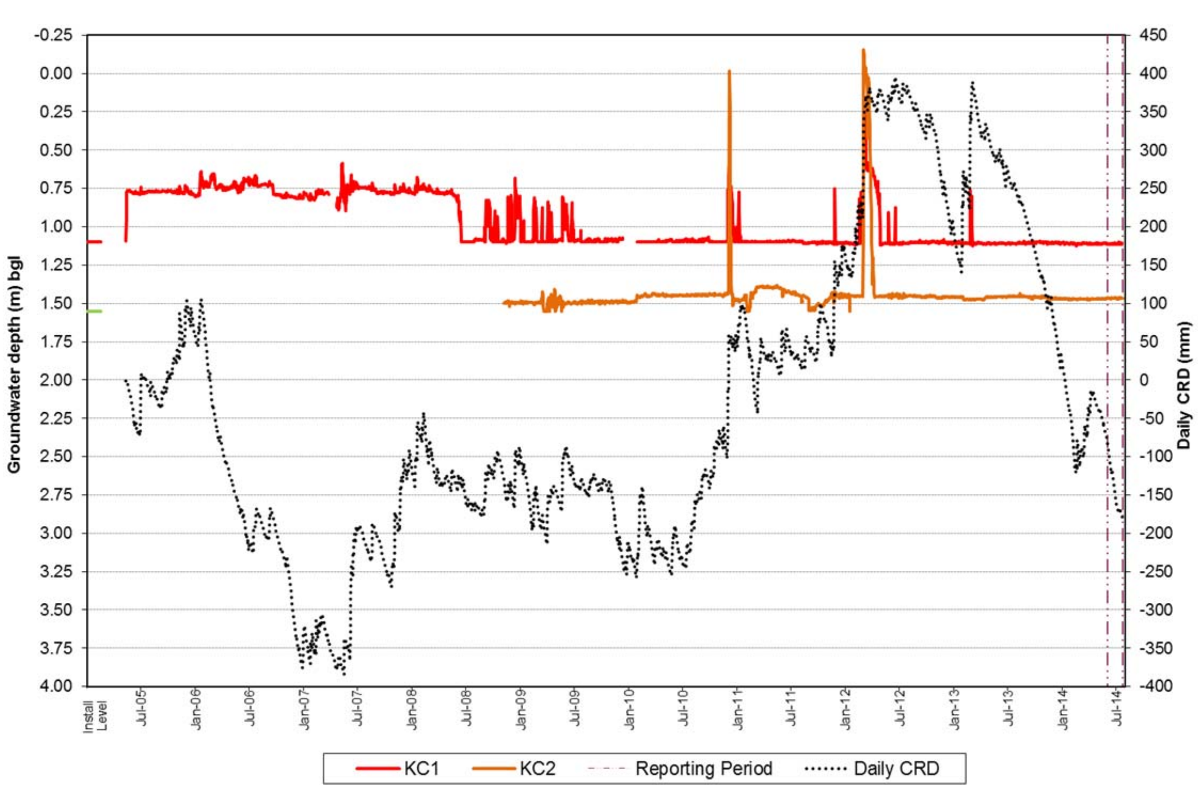


Figure 1 – Kangaroo Creek Piezometer Monitoring Data and Cumulative Rainfall Deviation

Kangaroo Creek Shrub Swamp is fed by a perennial spring. This spring, which in turn is fed by the aquifer-aquitard systems within the Burralow Formation, was unaffected by mining and the creek remained permanently wet below the spring. This, together with the presence of healthy hanging swamps along the valley walls surrounding Kangaroo Creek Shrub Swamp, indicates that the water supply from the spring and valley wall seepage has not been interrupted by longwall mining and that groundwater inputs to the swamp hydrological system remain intact.

Plate 5 (2013) Spring (left) and hanging swamp (right) at Kangaroo Creek Shrub Swamp

Plate 6 (2013) Waterhole upstream of Kangaroo Creek Shrub Swamp (left) and Kangaroo Creek Shrub Swamp (right)

Plates 5 and 6 illustrate that the Burralow Formation aquifer/ aquitard system has not been affected by longwall mining, as evidenced by the Spring, Waterhole and Hanging Swamps surrounding Kangaroo Creek Shrub Swamp. Flora monitoring at Kangaroo Creek Shrub Swamp indicated no trend of decreasing condition and that species abundance is not declining. The available evidence indicates that underground mining has not resulted in any negative effects on Kangaroo Creek Shrub Swamp. Investigation of mining related impacts at Kangaroo Creek Swamp showed that high levels of differential subsidence movements were measured, including strains (up to 6 mm/m tensile and 26mm/m compressive) and tilts (up to 13mm/m). The reasons for the high levels of differential movement are as follows.

• Mine Design: Longwall Void Width (w) to Depth of Cover (H) ratio of 0.94 to 1.04 (Critical Width). NB These are the highest w/H ratios of any of the longwalls at Angus Place and Springvale.

• Major Geological Structure Zone: Kangaroo Creek is located within the Kangaroo Creek Lineament, which has been identified as a 'Type 1' Geological Structure Zone.

• Topography: Valley slope angles >18 degrees.

• Location of Kangaroo Creek Swamp being near the western end of Angus Place Colliery's LW940 and LW950 (adjacent to permanent barrier pillar).

Investigations have concluded that for the Kangaroo Creek Swamp, the presence of major fault zones and incised valleys in combination with mine design factors caused localised hydrological impacts.

The CRD trend also helps to understand changes in presence and flows of surface water. Since March 2013, there has been rainfall deficit in excess of 550mm (a significant proportion of the annual average Newnes Plateau rainfall of 1092mm). The rainfall deficit in the past 18 months is greater than any period since the end of 2005 (including the drought of 2006-2007). This helps to explain the lack of surface water present in recent monitoring periods e.g. February, June and August 2014 (and photos taken in May 2014 for the purpose of community submissions to the Angus Place and Springvale Mine Extension Project EISs). The photo used in the EIS was taken on 16 July 2013 and can be seen to be consistent with monitoring photos in prior and subsequent periods. In the five years of photographic monitoring since the measured reduction in groundwater levels at KC1 piezometer, there have only been three monitoring events out of 41 monthly or bi-monthly monitoring events where water has not been present in the waterhole (February 2014, June 2014 and August 2014). On these occasions groundwater seeps from upstream can still be seen to be present.

# Prediction, mitigation, management and monitoring of impacts

## 4.1 Prediction of mining impacts on upland peat swamps

At Southern Coalfield mines, where the depths of cover are greater than 400 metres, conventional horizontal movements are a small component of observed valley ground movements. However, subsidence monitoring within valleys over the Angus Place and Springvale Coal mines, where the depths of cover are less than 400 metres, has shown that systematic or conventional horizontal movements can represent a much greater proportion of the measured valley ground movements. As discussed in the latest valley closure report, sometimes the conventional horizontal movement components are additive to the valley closure movements and at other times these components reduce the valley closure movements and this is one of the reasons why there is considerable scatter in the monitored ground movements in valleys.

Hence, the new ACARP valley closure prediction models, which were developed based solely on data from the deeper Southern Coalfield mines without adjustments for conventional horizontal movement components, do not provide accurate valley closure predictions for valleys where the depths of cover are less than 400 metres and additional research work is now required to develop appropriate ground movement models for mines at these shallower depths of cover (MSEC 2014).

Measured strains at Springvale and Angus Place have been in excess of 0.5mm/m tensile and 2mm/m compressive, without causing measurable impacts to groundwater levels in THPSS. In the case of Kangaroo Creek Swamp, where changes to groundwater levels were caused by mine subsidence in 2008, measured strains were 6mm/m tensile and 26mm/m compressive. At East Wolgan Swamp, where localised cracking in the base of the swamp were caused by mine subsidence, measured strains were 13mmm tensile and 17mm/m compressive. In both of these cases the w/H ratio (longwall panel width / depth of cover) was in excess of 1.0 (critical mine design). Where mine design with lower w/H ratios has been used in the past, measured differential subsidence values have been lower and impacts to THPSS hydrology have not been measured (Corbett at al 2014). This reference is to the Southern Coalfield, where the geological and stress regime is different to the Western Coalfields. The subsidence response behaviour of the Burralow Formation claystone aquitards is measurably different to that of the Hawkesbury Sandstone(Corbett at al 2014, EPBC 2011/5949 Application to Allow Longwall Mining Beneath THPSS on the Newnes Plateau (2013) Vol. 1-3 and Appendices). (pp64)

The NSW Department of Mineral Resources (now Department of Resources and Energy) *Guideline for Application for Subsidence Management Approvals EDG17* states:

*"The Application Area is defined as the surface area that is likely to be affected by the proposed underground coal mining. It should not be smaller than:*

*(1) A surface area defined by the cover depths, Angle of Draw of 35° and the limit of the proposed extraction area in mining leases of the Southern Coalfield, and*

*(2) A surface area defined by the cover depths, Angle of Draw of 26.5° and the limit of the proposed extraction area in mining leases of all other NSW Coalfields."*

It is noteworthy that the Southern Coalfield is excluded from the recommended 26.5 degree design angle of draw within the Guideline, for reasons related to geology, surface topography and depth of cover (explained in more detail in Springvale Colliery's *EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau*

(March 2013)). A value of 35 degrees is recommended for the Southern Coalfield, however, the recommended value for the Western Coalfield (including Springvale and Angus Place) is 26.5 degrees.

## 4.2 Mitigation of longwall mining impacts

As described in the SVMEP EIS, the APMEP EIS, the Response to Submissions and this report,ine design modifications have been implemented at Springvale and Angus Place in order to reduce subsidence related ground movements.

Marhnyes Hole was successfully remediated using cementitous grouting techniques.

## 4.3 Time lag between mining and observation of impacts

Monitoring of Newnes Plateau Swamps commenced in 2002. With the exception of swaps impacted by mine water discharge (Goldney et al (2010)), vegetation monitoring has not identified third order impacts resulting from mine subsidence.

"Third Order" impacts to vegetation communities have only been measured in areas where licensed mine water discharge through THPSS was conducted. Flora monitoring at Kangaroo Creek Shrub Swamp indicated no trend of decreasing condition and that species abundance is not declining.

Subsidence has not caused effects to THPSS hydrology at Springvale and Angus Place at East Wolgan Swamp and Kangaroo Creek Swamp. In other cases (Junction Swamp, West Wolgan Swamp, Narrow Swamp, Sunnyside West Swamp) subsidence effects to hydrology have not been measured. Through detailed investigations, the multiple causative factors which led to isolated subsidence impacts to swamp hydrology have been identified and the mine design has been modified to reduce future subsidence effects to swamp hydrology.

## 4.4 Trigger action response plans

Springvale THPSS MMP has statistically derived triggers and BACI design and was approved by DoE in September 2013.

Analysis regarding East Wolgan Swamp, West Wolgan Swamp and Narrow Swamp, is factually incorrect in many areas – refer to response to IESC report “**Temperate Highland Peat Swamps on Sandstone: longwall mining engineering design - subsidence prediction, buffer distances and mine design options”**.

There is a failure to recognise the effects of mine water discharge (identified in Goldney et al (2010)), or the multiple lines of evidence presented in the SVMEP EIS and the APMEP EIS. A significant body of work completed by Centennial Coal for the referrals submitted to the DotE in 2011 for both Springvale Mine and Angus Place Collieryt has not been referenced or utilised in the IESC Report. This body of work, consisting of some 13 reports, not including the Preliminary Documentation produced to support the applications, is available on the Centennial Coal website, www.centennialcoal.com.au and has been available there since early 2014.

### *5.3.1 Proposed upland peat swamp remediation techniques*

The report commissioned by DEWHA (Goldney et al 2010) is not referenced.

Remediation works also required approval from NSW Government Office of Environment and Heritage. A Section 95 certificate was not issued by OEH until November 2013.

The Section 95 certificate issued by OEH is conditioned with inspections by relevant stakeholders of any fractures in the base of East Wolgan Swamp and the development of additional remediation plans following inspection.

East Wolgan Swamp Remediation Plan

Helicopters have been used for materials transport in the remediation works conducted to date.

Assessment of appropriate work and materials storage areas has been conducted in conjunction with qualified ecologists.
Monitoring of remediated sites is ongoing.

Shade and cover are used in the remediation works through the use of jute matting and brush matting in rehabilitated areas.

Weed removal has been conducted as part of remediation works

Photographic monitoring and downstream water quality monitoring indicates recovery of hydrological systems within East Wolgan Swamp. Vegetation condition downstream of the impacted site indicates that normal hydrological processes are intact. Analysis is available in EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau – Supplementary Data Volume 1 (2013). East Wolgan Swamp has been assessed as a periodically waterlogged swamp based on piezometer data and hydrogeology model. The 14Ml/day was mine water discharge which was the principal cause of impacts to East Wolgan Swamp and Narrow Swamp (as identified by Goldney et al (2010) and UQ (2014)). These flows were not natural flows and there is no monitoring to indicate consistent volumes of water flows through any NPSS.

### 5.3.2.3 Waratah Rivulet

Publicly available information of the status of this work in July 2012 (Helensurgh Coal Pty Ltd by Gilbert and Associates (July 2012) Assessment of the Success of WRS3 Remediation Works in Re-Establishing Surface Flow) is summarised in EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau – Supplementary Data Volume 1 (2013). The report concluded in part "Because the rate of pool water level recession between rainfall/runoff events is consistent with the downstream pools and it can be concluded that the remediation works have resulted in flow holding capacity in Pool A which is consistent with pools outside the area affected by mine subsidence over this period."

# Conclusions

## 6.1 Impacts on peat swamps

There are many cases where impacts have not been recorded following longwall mining under THPSS on the Newnes Plateau. Goldney et al (2010) reported that impacts at Narrow Swamp and East Wolgan Swamp were largely a result of mine water discharge through those swamps. In two instances (Kangaroo Creek Swamp and East Wolgan Swamp) subsidence impact to swamp hydrology have been detected. Investigations have revealed the multiple co-incident factors which aligned to cause the impacts at East Wolgan Swamp and Kangaroo Creek Swamp and future mine design has been modified to mitigate similar impacts in the future. In the cast of Kangaroo Creek Swamp, vegetation monitoring at Kangaroo Creek Swamp has not demonstrated changes to the flora community within the swamp in the period since changes to standing water levels were monitored at KC1 piezometer in 2008.

## 6.2 Impact prediction and mitigation

Geophysical methods were used to detect cracking in the base of East Wolgan Swamp at the cavity location (including ground penetrating radar and resitivity surveys). The results are documented in EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau – Supplementary Data Volume 1 (2013)

The HCPL PUR grouting programs are used to seal cracking in outcropping rock bars.

However, it is considered that this technology is transferrable and can be used to seal cracks

in swamp bases as a swamp *base* is analogous to a rock bar, albeit one covered with peat and sand.”

The use of cementitious grouts has also been used to successfully remediate subsidence induced cracking which led to water loss in watercourses in the Southern Coalfield. Injection grouting with cementitious grouts was successfully used for rock bar rehabilitation in the Georges River.

Where alluvial material overlies sandstone, injection grouting though drill rods has also been used successfully to seal void under the alluvial material (soil / peat). This technique was also used in the Georges river, where 1-2m of loose sediment was grouted through using purpose designed grouting pipes.

In the case of East Wolgan Swamp, subsidence impacts to rock underlying the swamp are very localised and allow for targeted rehabilitation

## 6.3 Monitoring

Springvale's THPSS MMP developed and approved under EPBC2011/5949 has a BACI design. Monitoring on the Newnes Plateau commenced in 2002.

The following excerpt from Springvale Mine’s EPBC Approval 2011/5949 Condition 1 Application of March 2013 specifically discusses “hard engineering” solutions which may be employed in the event of major impacts to THPSS caused by cracking of underlying rock:

“Hard Engineering Solutions

Hard engineering solutions may be required where cracking of the base of a THPSS may cause drainage of water away from the THPSS, which may have the potential to affect to the health of the system. Aquifer modelling and the groundwater and swamp health case studies presented in this document show that this is extremely unlikely. However, proven technologies related to other mining operations developed to remediate cracking of rock structures are now discussed. The integrity of the water retaining structure is restored through the implementation of these remediation strategies. The strategies have been researched and modified so as to suit the specific THPSS systems above the Springvale mining operation.

### 6.2.1 Injection Grouting

Grouting of rock formations has been occurring since the 1800's (Heidarzadeh et al (2007)), the technology has evolved since this time. It can be used in a range of different applications. Grouting is utilised to either stabilise rock formations or to manage the flow of groundwater and has been implemented successfully for decades in underground coal minesin Australia and overseas.

This technology has been recently adapted to seal mine subsidence related surface and subsurface cracking in rock bars in the southern coalfields of NSW.

"Injection grouting" is the process of injecting grout using pre-drilled holes into a cracked rock bar or swamp substrate. Grouting involves injecting a permanent low permeability material into cracked areas to provide a seal to control vertical or horizontal water flows. There are various types of grouts that can be used but generally they will be either cement based or polyurethane resins (PUR). The use of injection grouting for remediating subsidence cracking has been pioneered in the southern coalfields of NSW and has been used to successfully repair cracking in surface and near surface rock substrates.

Grout is pumped into the targeted area at low pressure once the grouting holes have been drilled. High viscosity grouts are used for vertical fracturing as the setting time for vertical holes needs to be shorter to optimise the use of the grout which flows faster in vertical cracks under the influence of gravity. Lower viscosity grouts would be used where horizontal cross linking of cracks is present.

A specific example of where PUR grouting has been shown to successfully repair a rock substrate can be seen at Helensburgh Coal Pty Ltd (HCPL) in the NSW Southern Coalfields. Experience at HCPL has shown that grouting using PUR can be used to successfully fill cracks ranging from small sub millimetre sized cracks to open fractures greater than 100mm.

A trial was conducted at HCPL on the WRS4 rock bar in the Waratah Rivulet and was followed by a remediation report (Waratah Rivulet Remediation Trial Activities – Completion Report (2007)). The main findings of the remediation report were:

- PUR is non-toxic
- PUR injection can be conducted in an environmentally acceptable fashion
- PUR injection is suitable for sealing cracking in rocks from less than 1mm to greater than 100mm
- Pre and post permeability testing showed that permeability was reduced by several orders of magnitude following PUR injection
- The PUR injection process was transferrable to other areas where cracking of rock had occurred

The HCPL PUR grouting programs are used to seal cracking in outcropping rock bars. However, it is considered that this technology is transferrable and can be used to seal cracks in swamp bases as a swamp base is analogous to a rock bar, albeit one covered with peat and sand."

The use of cementitious grouts has also been used to successfully remediate subsidence induced cracking which led to water loss in watercourses in the Southern Coalfield. Injection grouting with cementitious grouts was successfully used for rock bar rehabilitation in the Georges River.

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In the case of East Wolgan Swamp, subsidence impacts to rock underlying the swamp are very localised and allow for targeted rehabilitation.

The S.95 certificate issued by OEH is conditioned with inspections by relevant stakeholders of any fractures in the base of East Wolgan Swamp and the development of additional remediation plans following inspection.

Detailed analysis of the key co-incident factors related to cavity formation at East Wolgan Swamp (into which mine water discharge flowed and erosion / peat slumping occurred) are summarised in Corbett et al (2014):

- licensed mine water discharge at rates of up to 12Ml/day;
- intersection of major geological fault structures;
- orientation of the longwall panel subparallel to the major structures;
- steepness and depth of East Wolgan Swamp valley at northern end;
- prevailing in-situ stress direction and magnitude (Springvale longwalls sub-perpendicular to principal horizontal stress direction);
- critical width longwall panel design;
- location of the geological structure close to the permanent barrier pillar (at cavity location); and
- interaction of Angus Place and Springvale mine workings and subsidence effects dueto close proximity (at cavity location).

These factors are not present at future proposed mining locations.

## 6.4 Remediation

The following excerpt from Springvale Mine’s EPBC Approval 2011/5949 Condition 1 Application of March 2013 specifically discusses “hard engineering” solutions which may be employed in the event of major impacts to THPSS caused by cracking of underlying rock:

“Hard Engineering Solutions
Hard engineering solutions may be required where cracking of the base of a THPSS may cause drainage of water away from the THPSS, which may have the potential to affect to the health of the system. Aquifer modelling and the groundwater and swamp health case studies presented in this document show that this is extremely unlikely. However, proven technologies related to other mining operations developed to remediate cracking of rock structures are now discussed. The integrity of the water retaining structure is restored

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Grouting of rock formations has been occurring since the 1800's (Heidarzadeh et al (2007)), the technology has evolved since this time. It can be used in a range of different applications. Grouting is utilised to either stabilise rock formations or to manage the flow of groundwater and has been implemented successfully for decades in underground coal minesin Australia and overseas.

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## Data Regarding Remediation Case Study (Metropolitan Colliery – Waratah Rivulet Rockbar Remediation)

The following information summarises the findings of reports into the Waratah Rivulet Rockbar Remediation Works at Metropolitan Colliery.

- Specific reports supporting case study are included in References
- Analysis of data presented in the graph showing water level in pools before and after PUR injection is presented below

The following is an excerpt from the Helensurgh Coal Pty Ltd Waratah Rivulet Remediation Trial Activities – Completion Report (October 2008**)**

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## “OVERALL HYDROLOGICAL PERFORMANCE

Water levels in Pool F were reportedly first affected during the longwall mining of Panel 12 in October 2005. Pool levels were further affected by mining of Longwall Panel 13.

Water levels in Pool A were also affected by mining. The pool has not been fully remediated and continues to show obvious signs of subsidence induced underflow.

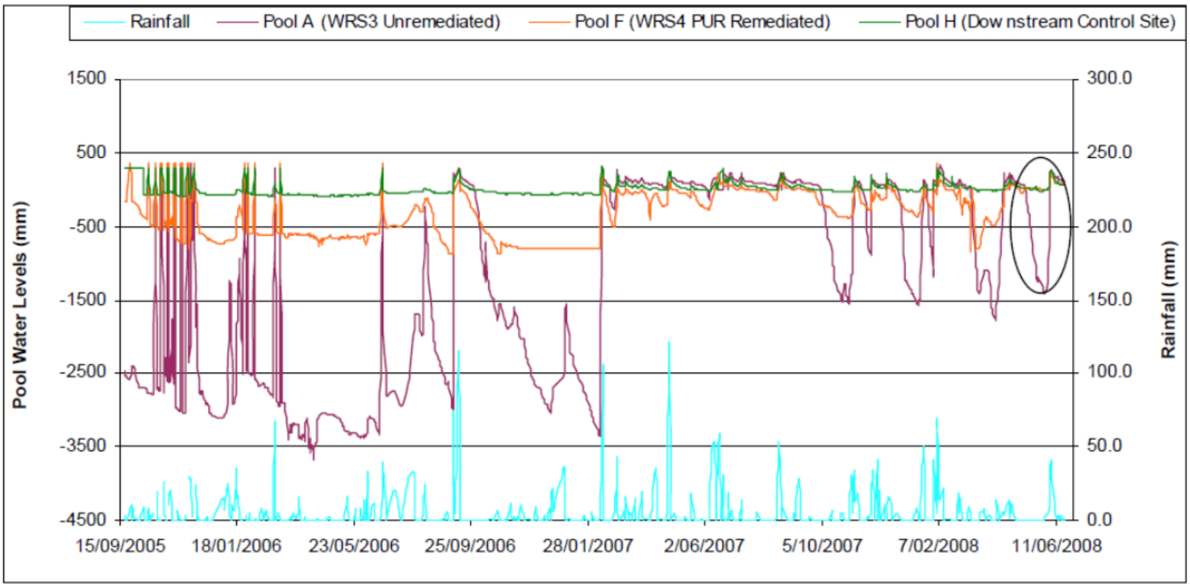
Pool H is located downstream of Pool F and approximately 120m downstream of previous longwall mining activities. The hydrological characteristics of Pool H have not been affected by subsidence. Pool H is a similar size to Pool F and has a similar pool/rock bar morphology.

Comparison of recorded water level behaviour in these three pools, both before and after the remediation trials at Pool F, provides a means of assessing the success of the trial. Specifically, this data allows a comparison of pool water level responses in Pool F (before and after the trial) to those observed in Pool H and Pool A.

During periods of moderate or high flow in Waratah Rivulet, the water level in subsidence affected pools is similar to a pool un-affected by subsidence. During dry periods when flows in the Rivulet are in a low, recessionary regime the water level in pools affected by subsidence recede faster than they do in unaffected pools. Water levels in natural pools will decline below their ‘cease to flow’ level (ie stop overflowing) if the combined effects of evaporation from the pool surface and slow leakage through the downstream rock is greater than inflow rate.

Graph 1 shows recorded pool water levels in the 3 pools from 20 September 2005 to 20 June 2008. It is readily apparent that water levels in both Pools A and F have regularly declined rapidly during low flow periods whilst water levels in Pool H have generally remained near the CTF (zero) level. Water levels in Pool A have receded further at least in part because the pool is significantly deeper than Pool F.

**Graph 1 Recorded Pool Water Levels in Pools A, F and H**

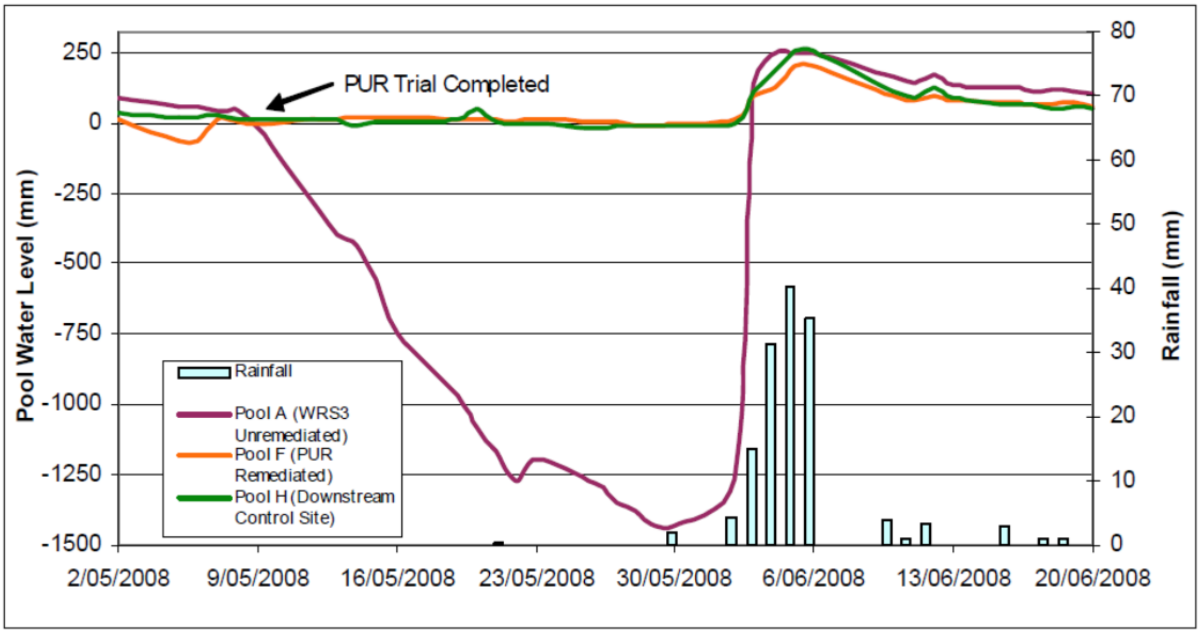


Note: See Graph 2 for further detail of circled data.

The remediation trial commenced on 17 March 2008 and was completed on the 13 May 2008. There is an obvious comparative difference in water level response in Pool F prior to 18 April 2008 and pool levels after this date. Water levels in pool F have mirrored those in Pool H after 18 April 2008 but not before. Water levels in Pool A continued to show the effects of subsidence during this period.

Graph 2 shows a magnification of the period from near the end of the trial until the 20 June 2008. This clearly shows water level responses in Pool F have mirrored those in Pool H (i.e. have been similar to natural pool behaviour). As indicated above, this behaviour is in stark contrast to the water level responses in Pool A over this period. The rainfall over this period is also shown on Graph 2. There was 138 mm of rainfall recorded in the period 13 May to 13 June 2008 with no rain recorded from the 13 May until the 29 May 2008. This indicates that any residual leakage in Pool F is low relative to low flows which were likely to have occurred over this period.

**Graph 2 Pool Water Level Responses to PUR Trial**

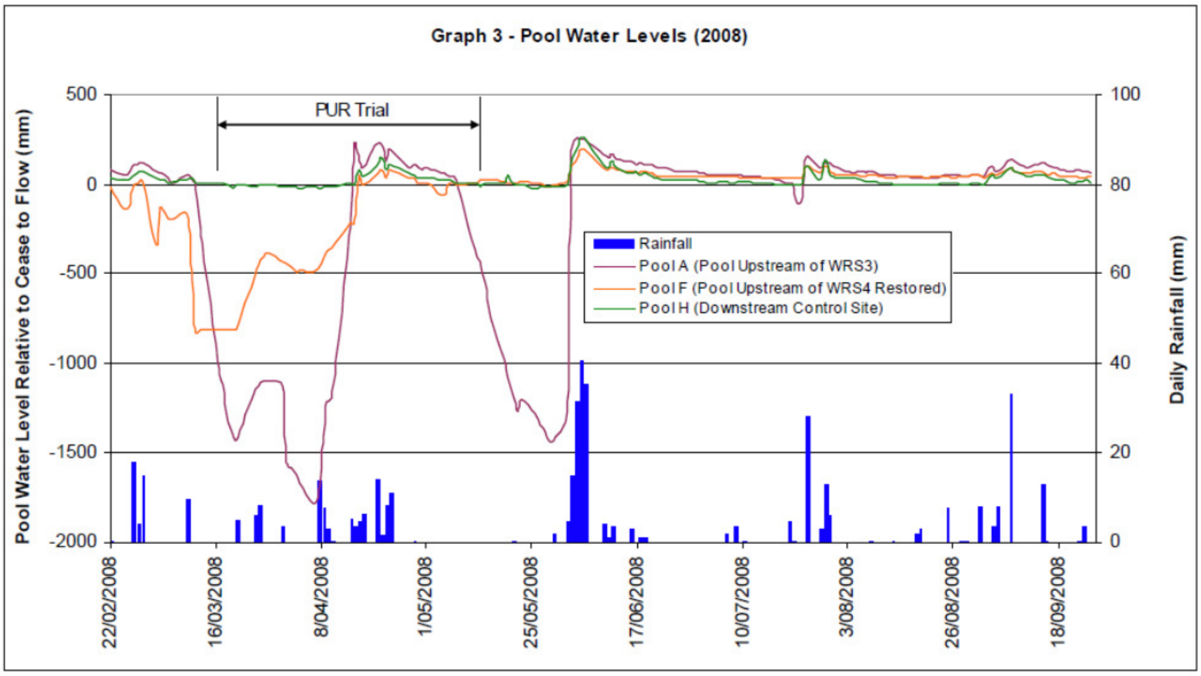


Note: On 5 and 6 June 2008, pool level instrumentation was submerged due to a rainfall event. Pool levels for this period are conservatively assumed to be the highest calibrated pool level measurement.

Graph 3 presents pool water level data to 26 September 2008. There continues to be a clear difference in the water level response in Pool F prior to 18 April 2008 and after this date. Graph 3 indicates that a further recession in the water levels in Pool A occurred in late July 2008, however there was no similar response in Pool F.

HCPL will continue to collect data regarding the remediated hydrological characteristics of Pool F. The current data set enables the conclusion to be drawn that water levels in the pool have behaved in a similar fashion to those in a natural pool after the trial. Flows in Waratah Rivulet since remediation were low during the period from the 13th to the 29th May 2008 – during which time the pool water levels responses in Pool F were indistinguishable from those recorded Pool H (unaffected by subsidence). A further recession in the water levels in Pool A occurred in late July 2008, however there was no similar response in Pool F. Therefore it can be concluded that water level responses in Pool F have changed markedly as a result of the trial, indicating a significant reduction in leakage as a result of successful remediation.

**Graph 3 Pool Water Levels to September 2008**



### 5.5 40 DAY TEST WORK

In accordance with Approval Condition 8d, two cored holes were obtained from the grout curtain to recover samples for 40 day test work, including acid digestion, leaching and microscopic characterisation.
The results of the 40 day testing of the grouting product are described in Appendix 3. Comparison of the data for acid digestion of polyurethane with the leached metals shows that the presence of trace metals including iron within the structure of the polyurethane does not result in their leaching in creek or demineralised water. These results indicate that the incorporation of metals from sandstone during mixing of the polyurethane is not a significant inclusion as polyurethane is essentially a very inert material. Downstream TOC and DOC concentrations in Waratah Rivulet waters show no increase associated with grouting activities. Based on the results, there is considered to be no reason to undertake any XRD or XRF analysis of polyurethane.

### 5.6 SUMMARY

Observation of PUR in core confirmed that the product had infiltrated and filled both the fine and larger void spaces.
The expanded trial further confirmed that the modified drill/injection sequence of drill and inject single holes in turn would be more effective compared with drilling and injecting a series of holes.
The hydraulic conductivity tests further confirmed that the hydraulic conductivity of a PUR filled fracture was of the order of $10^{-7}$m/s, at least several orders of magnitude lower than an open fracture network.
HCPL will continue to collect data regarding the remediated hydrological characteristics of Pool F. The current data set enables the conclusion to be drawn that water levels in the pool have behaved in a similar fashion to those in a natural pool after the trial. Flows in Waratah Rivulet since remediation were low during the period from the 13th to the 29th May 2008 – during which time the pool water levels responses in Pool F were indistinguishable from those recorded Pool H (unaffected by subsidence). A further recession in the water levels in Pool A occurred in late July 2008, however there was no similar response in Pool F. Therefore it can be concluded that water level responses in Pool F have changed markedly as a result of the trial, indicating a significant reduction in leakage as a result of successful remediation.
The water quality tests confirmed that PUR injection had no impact on the water quality.
The environmental controls were very effective."

## Demonstration of Ongoing Success of Remediation

The following is an excerpt from a report for Helensurgh Coal Pty Ltd by Gilbert and Associates (July 2012) Assessment of the Success of WRS3 Remediation Works in Re-Establishing Surface Flow. This refers to Pool A from the previous section, which is upstream of the WRS3 rockbar, which was also remediated using PUR injection techniques.

### “3.1 Assessment of the Behaviour of Pool A over the Period 1/1/2011 to 3/5/2012

The recorded (continuous) and manual (daily) water level observations in Pool A are plotted on Figure 2 relative to the Pool cease-to-flow level (i.e. the pool water level at which it just ceases overflowing the downstream rock bar - WRS3). The continuous data and manual observations cover the period 1 January 2011 to 3 May 2012.
The data demonstrates that pool water levels fell below the cease-to-flow level between the 7 February 2011 and 19 March 2011, but have remained above the cease-to-flow level continuously from the 19 March 2011 through to the end of the available data (3 May 2012). There is generally a close correspondence between (manually) observed and recorded water level data. There was however a period of missing data from the continuous record between 21 December 2011 and the 9 February 2012. The manual observations during this period show that water levels in Pool A remained above the cease-to-flow level.

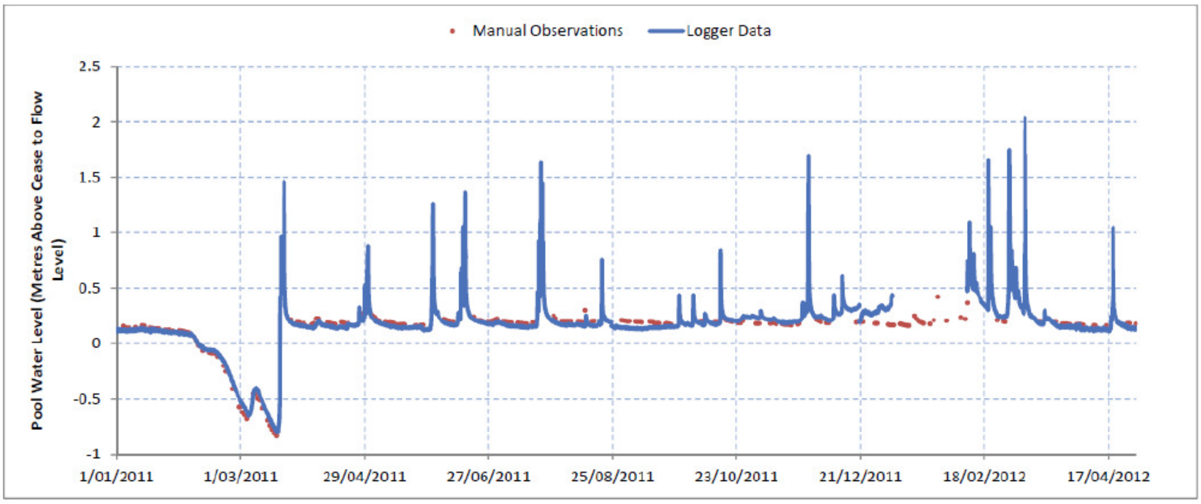


**Figure 2 Observed and Recorded Water Level Data for Pool A (1 January 2011 to 3 May 2012)**

A comparison was also made between the recorded pool water level behaviour of Pool A and other Pools on Waratah Rivulet downstream of expected mine subsidence effects. Again the pool water level data has been converted to depth above the cease-to-flow levels of the pools – refer Figure 3. It is apparent that Pool A has mirrored the water level behaviour of the other downstream pools indicating that after 19 March 2011 its behaviour has been consistent with un-impacted pools. Because the rate of pool water level recession between rainfall/runoff events is consistent with the downstream pools and it can be concluded that the remediation works have resulted in flow holding capacity in Pool A which is consistent with pools outside the area affected by mine subsidence over this period.
A similar comparison with pools on Woronora River, which is outside the mine affected area, shows that the water level responses in Pool A has been consistent with those measured in the Woronora River pools – refer Figure 4. Again the water level pool holding capacity, as evidenced by the recorded pool water level recessions, are consistent with the pools in Woronora River over this period.

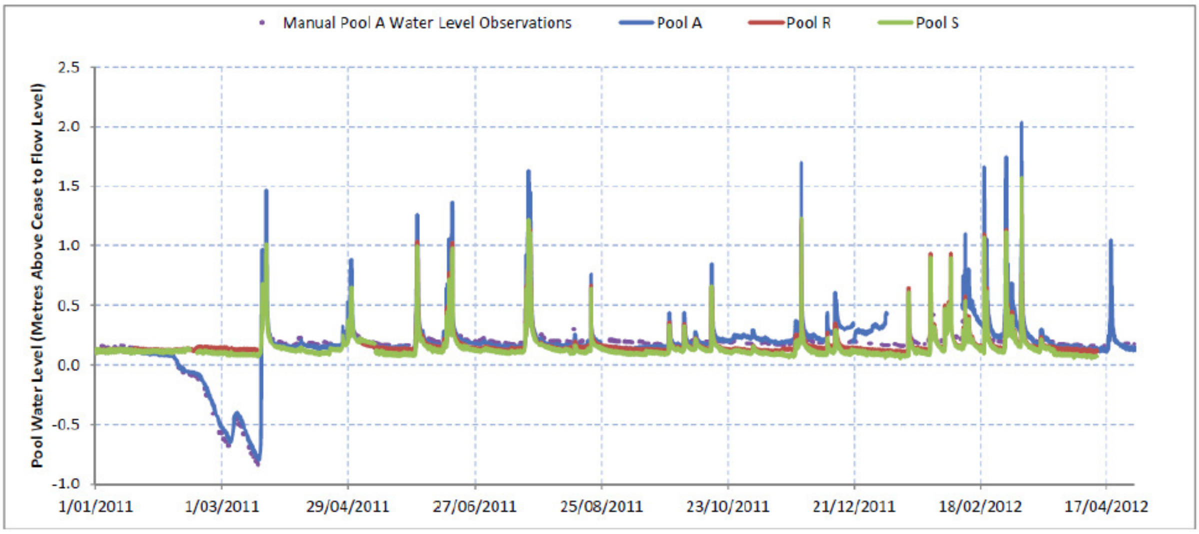


**Figure 3 Comparison of Pool A Water Level Hydrograph with Downstream Pools R and S – Waratah Rivulet**

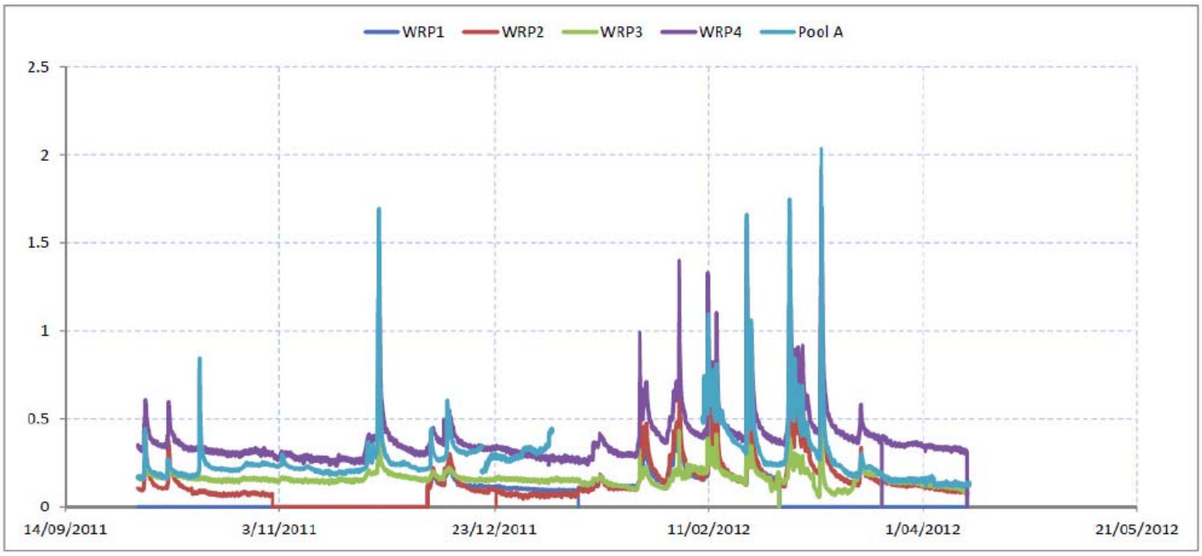


**Figure 4 Comparison of Pool A Water Level Hydrograph with Pools WRP1, WRP2, WRP3 and WRP4 on Woronora River"**

The HCPL PUR grouting programs are used to seal cracking in outcropping rock bars. However, it is considered that this technology is transferrable and can be used to seal cracks in swamp bases as a swamp base is analogous to a rock bar, albeit one covered with peat and sand."

## Remediation Using Cementitious Grouts

The use of cementitious grouts has also been used to successfully remediate subsidence induced cracking which led to water loss in watercourses in the Southern Coalfield. Injection grouting with cementitious grouts was successfully used for rock bar rehabilitation in the Georges River (Good et al 2010).

Where alluvial material overlies sandstone, injection grouting though drill rods has also been used successfully to seal void under the alluvial material (soil / peat). This technique was also used in the Georges river, where 1-2m of loose sediment was grouted through using purpose designed grouting pipes (Good et al 2010).

The following are excerpts from BHP Billiton West Cliff Mine (2006) Environmental Management System Georges River Report, Assessment of Georges River Remediation Longwalls 5A1-4.

“Grouting of fractures within the riverbed has significantly increased surface flow and pool water holding capacity in the impacted areas. Three techniques were used to deliver grout to the affected sections of the river which included:

- Shallow pattern grouting within Pools 8, 9, 14 and 16B and 17 and
- Deep angled drilled holes targeting fractures 5-10m below bed level in Pool 15 and
- A grout curtain has been installed at Jutts Crossing between Pools 9 and 10

These techniques significantly increased water flow over the rockbar during low flow conditions” (Brassington et al 2006).

“Prior to remediation there were appreciable differences between flow upstream and downstream of mining impacts, with up to 1Ml/day being redirected from surface to groundwater flow. Floods in February, May and June 2003, April, October and December 2004, and February and July 2005 resulted in reduced losses and this may indicate processes of natural sealing.

Mitigation has achieved a significant and measurable reduction of the impact to the Georges River resulting from subsidence. All sections of the Georges River that were impacts by mining have been rehabilitated to a standard satisfactory to the approval for mining in this area. This standard is based on achieving river health as close to pre-mining conditions as possible. The works undertaken in Pool 8, 9, 14 and 15 demonstrate that this goal can be attained” (Brassington et al 2006).

In the case of East Wolgan Swamp, subsidence impacts to rock underlying the swamp are very localised and allow for targeted rehabilitation.

The S.95 certificate issued by OEH is conditioned with inspections by relevant stakeholders of any fractures in the base of East Wolgan Swamp and the development of additional remediation plans following inspection.

### *6.4.1 Knowledge gaps*

Detailed analysis of impacts to Newnes Pleateau THPSS and causal factors for has been conducted and documented in publicly available documents including:
Goldney et al (2010), EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau – Supplementary Data Volume 1 (2013) and Corbett et al (2014). None of these documents or their associated analyses are acknowledged or referenced.

## 7 References

A number of relevant publicly available references were not used in the preparation of these reports. These include:

Forster, I., (2009) Aurecon Report Ref: 7049-010 Newnes Plateau Shrub Swamp Management Plan Investigation of Irregular Surface Movement in East Wolgan Swamp

Goldney, D., Mactaggart B., and Merrick, N. (2010) Determining Whether Or Not A Significant Impact Has Occurred On Temperate Highland Peat Swamps On Sandstone Within The Angus Place Colliery Lease On The Newnes Plateau

Forster, I., (2011) Aurecon Report Ref: 208354, Geotechnical Investigation Report Wolgan East Investigation

Speer, J., (2011) Alpha GeoScience Report, Final Report: AG-293 Geophysical Survey Ground Penetrating Radar And Resistivity Investigation Of East Wolgan Swamp On The Newnes Plateau

Ditton, S., (2013) DgS Report No. SPV-003/6 Further Discussion on the Potential Impacts to Sunnyside East and Carne West Temperate Highland Peat Swamps on Sandstone due to the Proposed Springvale LWs 416 to 418

McHugh, E., (2013) The Geology of the Shrub Swamps within Angus Place/Springvale Collieries

Fletcher, A., Brownstein, G., Blick, R., Johns, C., Erskine, P. (2013) Assessment of Flora Impacts Associated with Subsidence

Helensurgh Coal Pty Ltd (2008) Waratah Rivulet Remediation Trial Activities – Completion Report

Gilbert and Associates (2012) Metropolitan Collieries - Assessment of the Success of WRS3 Remediation Works in Re-Establishing Surface Flow.

Springvale Coal Pty Ltd (2013) EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau – Supplementary Data Volume 1 – 3 and Appendices

Brassington, G., Wood, J., Walsh, R., Coleman, S., Jamieson, M. (2006) BHP Billiton West Cliff Mine Environmental Management System Georges River Report, Assessment of Georges River Remediation Longwalls 5A1-4

Good, R., Hope, G., Blunden, B. (2010) Dendrobium Area 3A Swamp Impact, Monitoring, Management and Contingency Plan

Fletcher, A. and Erskine, P. (2014) Monitoring surface condition of upland swamps subject to mining subsidence with very high-resolution imagery (ACARP Project - C20046)

DgS Report No. SPV-003/7b (2014) Subsurface Fracture Zone Assessment above the Proposed Springvale and Angus Place Mine Extension Project Area Longwalls

Corbett, P., White, E., Kirsch, B., (2014) Hydrogeological Characterisation of Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau

Corbett, P., White, E., Kirsch, B., (2014) Case Studies of Groundwater Response to Mine Subsidence in the Western Coalfields of NSW

Kay, D., (2014) Peer Review of Mine Subsidence Induced Height of Fracturing Issues for Angus Place and Springvale Collieries (MSEC)

Merrick, N., (2014) Peer Review – Angus Place and Springvale Colliery Operations Groundwater Assessment (HydroSimulations P/L Report HS2014/11)

Centennial Coal

# Response to the Independent Expert Scientific Committee on Coal Seam Gas and Coal Mining Knowledge Report

## Temperate Highland Peat Swamps on Sandstone: Longwall Mining Engineering Design – Subsidence Predictions, Buffer Distances and Mine Design Options

September 2014

# Introduction

The following is a response by Centennial Coal to the Independent Expert Scientific Committee on Coal Seam Gas and Coal Mining Knowledge Report: Temperate Highland Peat Swamps on Sandstone: Longwall Mining Engineering Design – Subsidence Predictions, Buffer Distances and Mine Design Options (the IESC Report). In general the IESC Report:

- does not consider all of the relevant publicly available information in developing arguments about the effects of longwall mining on Temperate Highland Peat Swamps on Sandstone communities (THPSS).
- Where publicly available data has been used in the preparation of this report, certain data has been excluded where it does not support the position argued in the IESC report.
- Certain reference sources cited in the IESC report contain material which is not based on data and is biased against coal mining.

These general observations are further described in this report. For ease of reference, the structure of this report is based on the structure of the IESC report, and has been appended to the Response to Submissions to add a summary of relevant information from publicly available sources. In some areas this extends to a rebuttal of the data analysis or arguments presented in the report.

Centennial acknowledged in Chapter 2 and Chapter 8 of the Springvale Mine Extension Project Environmental Impact Statement (SVMEP EIS) and the Angus Place Colliery Mine Extension Project Environmental Impact Statement (APMEP EIS) that longwall mining has caused impacts to certain THPSS, however, as identified in these documents, this has not been the case in all instances. Chapter 2 of both the SVMEP EIS and the APMEP EIS acknowledged that subsidence impacts to swamp hydrology have been noted at two swamps (Kangaroo Creek Swamp and East Wolgan Swamp). Where impacts to certain THPSS on the Newnes Plateau have occurred, Centennial has conducted extensive research to understand the causes of the impacts. Centennial has used the findings of the research to avoid and mitigate both past and future impacts of longwall mining and related activities to THPSS on the Newnes Plateau.

Extensive research and investigation, lead primarily by work commissioned by the then DEWHA (the Goldney 2010 Report), has shown that impacts to THPSS on the Newnes Plateau have been caused primarily by:

- Licenced discharge of mine water through THPSS
- Changes to swamp hydrology caused by cracking of rock substrate beneath THPSS as a result of mine subsidence

The Goldney 2010 Report found that *the principal cause of impacts* to East Wolgan Swamp and Narrow Swamp was mine water discharge. This finding has been reinforced by research conducted by the University of Queensland. Neither these reports, nor Centennial's response to the findings, have been referenced in the IESC Report. The finding of major impacts caused by mine water discharge is not acknowledged in the IESC Report. As a result of the finding, Centennial has not discharged mine water through THPSS on the Newnes Plateau since 2010 and is committed to managing mine water through the Water Transfer Scheme (WTS), which transfers mine water off the Newnes Plateau.

Following completion of the DEWHA investigation and the Goldney 2010 Report, in November 2011, Centennial (through its Joint Venture) and the Minister for the Environment entered into an Enforceable Undertaking under section 486DA of the Environment Protection and Biodiversity Conservation Act 1999. Under this Enforceable Undertaking, the Joint Venture entered into a research agreement with the Australian National University to undertake a comprehensive research program into THPSS[1].

With the conclusion of these investigations, in 2011, Centennial made applications to the Minister for the Environment to extract coal from Springvale Mine longwall 415 to 417 (EPBC2011/5949) and from the Angus Place Colliery longwall 900W and 910. In 2012, the Minister for the Environment conditionally approved these applications. The primary condition of approval was the need to demonstrate that sub-critical longwall panel design would not result in anomalous subsidence impacts to THPSS.

To demonstrate this, changes to the mine design were are based on reduced mining void widths and increased chain pillar widths. The changes have been made in the context of cover depths in proposed future mining areas in the vicinity of THPSS and are designed to a criterion of sub-critical panel geometry. Subsidence modelling indicates that the design changes will result is very significant reductions to total subsidence and differential subsidence movements. These changes were made specifically to reduce the environmental impacts of longwall mining under the Newnes Plateau, and demonstrate Centennial's commitment to sustainable mining practices.

This mine design approach for all future longwall mining described in the SVMEP EIS and the APMEP EIS in the vicinity of THPSS is consistent with that approved for longwall mining beneath THPSS by DotE under EPBC2011/5949.

All documentation supporting this research, investigations, outcomes is available on the Centennial Coal website, www.centennialcoal.com.au.

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[1] In should be noted that in this report, a reference to the federally listed endangered ecological community Temperate Highland Peat Swamps on Sandstone, includes a reference to the State listed endangered ecological communities incorporating the Newnes Plateau Shrub Swamps and Newnes Plateau Hanging Swamps. The extent to which these communities have been described under these listings is discussed further in response to the IESC Report on ecological characteristics of THPSS.

# Overview and Summary

## Mining and Subsidence

In 2008 and 2009, monitoring at Angus Place and Springvale Collieries detected impacts attributable to mining-related activities at two THPSS. Centennial Coal launched an extensive investigative program to determine the factors causing these impacts. Specific investigations were targeted to determine the hydrogeological characteristics of THPSS. The purpose of these investigations was to ascertain the coincident characteristics which lead to THPSS formation and to understand the sensitivity of those characteristics to mine subsidence behaviour.

These investigations include:

- Aurecon Report Ref:7049-010 Newnes Plateau Shrub Swamp Management Plan Investigation of Irregular Surface Movement in East Wolgan Swamp (2009)
- Determining Whether or not a Significant Impact has Occurred on Temperate Highland Peat Swamps on Sandstone within the Angus Place Colliery Lease on the Newnes Plateau, Goldney et at, 2010 (a report prepared for the then Department of Environment, Water, Heritage and the Arts)
- Aurecon Report Ref: 208354, Geotechnical Investigation Report East Wolgan Swamp Investigation, 2011
- Geophysical Survey Ground Penetrating Radar and Resistivity Investigation of East Wolgan Swamp on the Newnes Plateau, Speer (2011)
- DgS Report No SPV-003/6 Further Discussion on the Potential Impacts to Sunnyside East and Carne West Temperate Highland Peat Swamps on Sandstone due to the Proposed LW416 to 1418, Ditton 2013The Geology of the Shrub Swamps within Angus Place/Springvale Collieries, McHugh 2013
- Assessment of Flora Impacts Associated with Subsidence, Fletcher et at, 2013
- EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau – Supplementary Data Volume 1 to 3 and Appendices, Corbett et all, 2013
- Monitoring Surface Condition of Upland Swamps Subject to Mining Subsidence with very high resolution imagery, Fletcher et al, 2014
- DgS Report No SPV-003/7B Subsurface Fracture Zone Assessment above the Proposed Springvale and Angus Place Mine Extension Project Area Longwalls, Ditton, 2014
- Hydrogeological Characterisation of Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau, Corbett et al, 2014
- Case Studies of Groundwater Response to Mine Subsidence in the Western Coalfields of NSW, Corbett et al, 2014
- Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps, Brownstein et al, 2014

The results of these investigations, described further in the SVMEP EIS, the APMEP EIS, the respective Response to Submission Reports and this report, have allowed Centennial Coal to understand the multiple co-incident factors that led to historical mining-related impacts and implement management practices to ensure mining impacts will be avoided in the future or can be appropriately mitigated.

Since the investigations were conducted, Centennial Coal has been proactive in avoiding or minimising potential subsidence impacts to the geodiversity and biodiversity of the mining area using a comprehensive multi-disciplinary risk-based approach to mine planning and mine design in conjunction with a rigorous monitoring program.

The monitoring techniques employed are wide-ranging and complementary and the combined results provide insights into the role those factors such as geology, hydrogeology and topography play in THPSS formation and the effects of mine subsidence on these.

The extensive monitoring and investigation process employed by Centennial Coal, which utilised multiple lines of evidence to support the management decisions, created the foundations for an adaptive management outcome. Mine design changes (in the form of reduced longwall void width and increased chain pillar width) were implemented in 2011 and are planned in all Mine Extension Project (MEP) areas where THPSS are present.

Based on the results of the investigation and changes implemented in response to the investigation, the Federal DotE gave approval to mine beneath THPSS under EPBC2011/5949 in October 2013.

## Monitoring

There is no evidence to support the statement of limited onsite monitoring data to determine the effect of longwall mining subsidence on upland peat swamps on the Newnes Plateau. There are 36 swamp piezometers installed in Newnes Plateau shrub swamps over the Angus Place and Springvale MLs. They were installed over the period 2005-2011 (Corbett et al 2014).

Groundwater aquifer monitoring commenced at Springvale Mine in 2002. The are currently 28 open hole aquifer monitoring piezometers and 26 multi-level vibrating wire piezometers at Springvale and Angus Place.

The results of these monitoring points are described further in the SVMEP EIS, the APMEP EIS (specifically Chapters 2 and 8), the respective Response to Submission Reports and this report.

The peer reviewed THPSS Monitoring and Management Plan (THPSS MMP) which has been approved by the Federal Department of the Environment (DotE) is aligned with **Before-After/Control-Impact (BACI)** design.

## Mitigation

The primary mechanism to mitigate potential impacts to THPSS is mine design. The mine design for the SVMEP and APMEP is described in detail in the respective Environmental Impact Statements (specifically, Chapter 8).

Major design changes have been made to the Springvale and Angus Place mine plan in order to reduce subsidence from longwall mining. These changes are based on the following dimensional changes:

- Void width reduced from 315m to 261m

- Pillar width increased from 45m to 58m

The changes have been made in good faith and at significant cost to the business at a time when there was no guarantee of approval for ongoing mining activities. No subsidence effects to swamp hydrology or flora communities have been identified in areas where sub-critical mine design have been used in the past (refer to Chapter 2 and Chapter 8 of the respective EIS).

The mine design approach for all future longwall mining in the Springvale and Angus Place MEP areas is consistent with that approved for longwall mining beneath THPSS by DotE under EPBC2011/5949.

Future mine dewatering systems have been designed to ensure that discharge of mine water to Newnes Plateau Shrub Swamps is avoided. No mine water discharges into Newnes Plateau THPSS have occurred since April 2010.

## **Remediation**

To date, there has been no requirement or need to undertake hard engineering mitigation on a THPSS on the Newnes Plateau. Regardless, there are examples from other regions where hard engineering mitigation has been successful.

A specific example of where PUR grouting has been shown to successfully repair a rock substrate can be seen at Helensburgh Coal Pty Ltd (HCPL) in the NSW Southern Coalfields. Experience at HCPL has shown that grouting using PUR can be used to successfully fill cracks ranging from small sub millimetre sized cracks to open fractures greater than 100 mm.

A trial was conducted at HCPL on the WRS4 rock bar in the Waratah Rivulet and was followed by a remediation report (Waratah Rivulet Remediation Trial Activities – Completion Report (2007)). The main findings of the remediation report were:

- PUR is non-toxic.
- PUR injection can be conducted in an environmentally acceptable fashion.
- PUR injection is suitable for sealing cracking in rocks from less than 1mm to greater than 100 mm.
- Pre and post permeability testing showed that permeability was reduced by several orders of magnitude following PUR injection.
- The PUR injection process was transferrable to other areas where cracking of rock had occurred.

The HCPL PUR grouting programs are used to seal cracking in outcropping rock bars. However, it is considered that this technology is transferrable and can be used to seal cracks in swamp bases as a swamp base is analogous to a rock bar, albeit one covered with peat and sand.

The use of cementitious grouts has also been used to successfully remediate subsidence induced cracking which led to water loss in watercourses in the Southern Coalfield. Injection grouting with cementitious grouts was successfully used for rock bar rehabilitation in the Georges River.

Where alluvial material overlies sandstone, injection grouting though drill rods has also been used successfully to seal void under the alluvial material (soil / peat). This technique was also used in the Georges River, where 1-2m of loose sediment was grouted through using purpose designed grouting pipes.

# 2 Peat swamps

### THPSS Communities in the Blue Mountains / Newnes Plateau

Centennial Coal has acknowledged the importance of the THPSS in the landscape. Research conducted over the last 5 years (2009 to 2014) by the University of Queensland has worked towards quantifying the nature and extent of the community across the Newnes Plateau. Further work undertaken through the Enforceable Undertaking has been targeted towards:

- The nature and extent of THPSS
- THPSS water balances
- Functionality of swamps
- Environmental history and origins
- Ecology/biodiversity of major structural species
- Contribution to the landscape
- Condition status/mapping
- Monitoring of selected reference sites
- Thresholds for recovery

The University of Queensland is currently conducting research on communities identified as temperate treeless palustrine swamps in a 268 square kilometre area which includes the Newnes Plateau. Based on publicly available combined mapping from the temperate zone of New South Wales and manual interpretation of the numerous vegetation classifications used, a region containing more than 1000 shrub swamp communities per degree of latitude/longitude was identified which contained the communities mapped as Newnes Plateau shrub swamps. A report based on the research will be published and finalised in 2014.

# 3 Geology

### Newnes Plateau Geology / Hydrogeology Related to THPSS Formation

Centennnial Coal has conducted detailed studies into the geology and hydrogeology of the Newnes Plateau, as outlined in the following excerpts from Corbett et al (2014).

Detailed analysis of the lithology was undertaken and the data was incorporated into the Minex geological database to allow three-dimensional modelling of correlatable stratigraphic units (i.e. stratigraphic units that are present on a regional scale). The analysis of the near surface stratigraphy also involved the use of geophysical data from 84 exploration boreholes (i.e. a total of 101 exploration boreholes).

A key finding of the study (McHugh, 2013) was the identification and detailing of the stratigraphy of the Burralow Formation, which overlies the Banks Wall Sandstone. Most previous studies of the Angus Place Colliery and Springvale Mine areas do not typically include the presence of the Burralow Formation, and instead refer to the Banks Wall Sandstone as the uppermost outcropping unit.
At a maximum thickness of approximately 110m, the Burralow Formation above Angus Place and Springvale is thicker than previously proposed in the general Lithgow region. It is noted that CoA (2014) THPSS: Longwall Mining Engineering Design – Subsidence Predictions, Buffer Distances and Mine Design Options, Figure 3.3 identifies the Burralow Formation in the Western Sydney Basin Stratigraphy.

The Burralow Formation consists of medium- to coarse-grained sandstones interbedded with frequent sequences of fine-grained, clay-rich sandstones, siltstones, shales and claystones.

From the 101 bores, the Burralow Formation was determined to contain multiple fine-grained lithological units, which can be several metres thick: their presence differentiates the Burralow Formation from the underlying Banks Wall Sandstone. Correlation of the finer-grained units within the Burralow Formation identified at least seven units, as described in Palaris (2013). Several of the claystone horizons, together with clay-rich, fine-to-medium grained sandstones and shales, were found to be acting as aquitards, or semi-permeable layers. These aquitards retard the vertical movement of groundwater into underlying strata. Instead, much of the groundwater present within the Burralow Formation is redirected laterally down-dip to discharge points in nearby valleys (valley wall seepage), which creates a permanent water source for the formation and maintenance of the NPHS. In the case of NPSS, precipitation is supplemented by moisture from groundwater sources to form several discharge horizons along the course of the host creek in which a shrub swamp is located.

This is presented in Figure 3, whereby the brown contours show the outcropping Burralow Formation units where groundwater seepage would occur. Valley wall seepage, together with direct in-gully input of groundwater via aquitards, permits continuity of hydration for the THPSS during periods of drought. The presence of the Burralow Formation is essential to the formation and persistence of both hanging and shrub swamps (McHugh, 2013). Figure 3 presents a three-dimensional representation of the topography over the eastern area of the Springvale Mining lease. Steep changes in topography occur at the downstream of the THPSS often in the form of water falls.

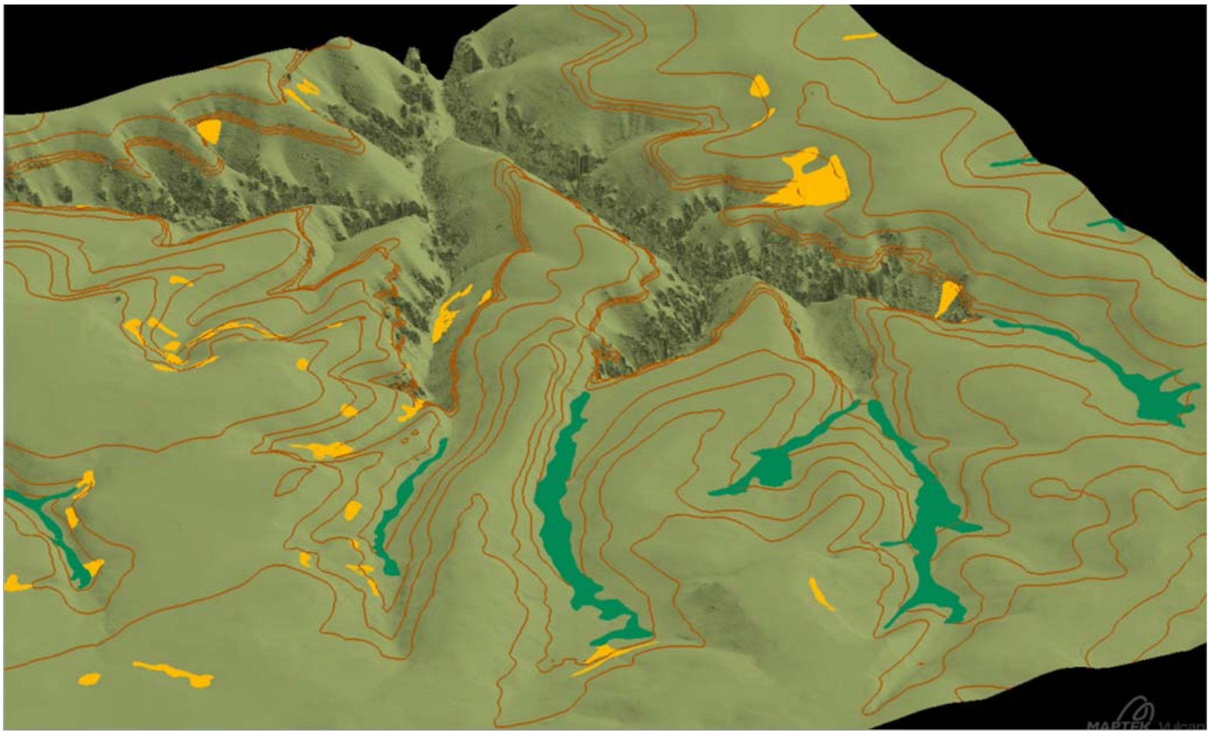
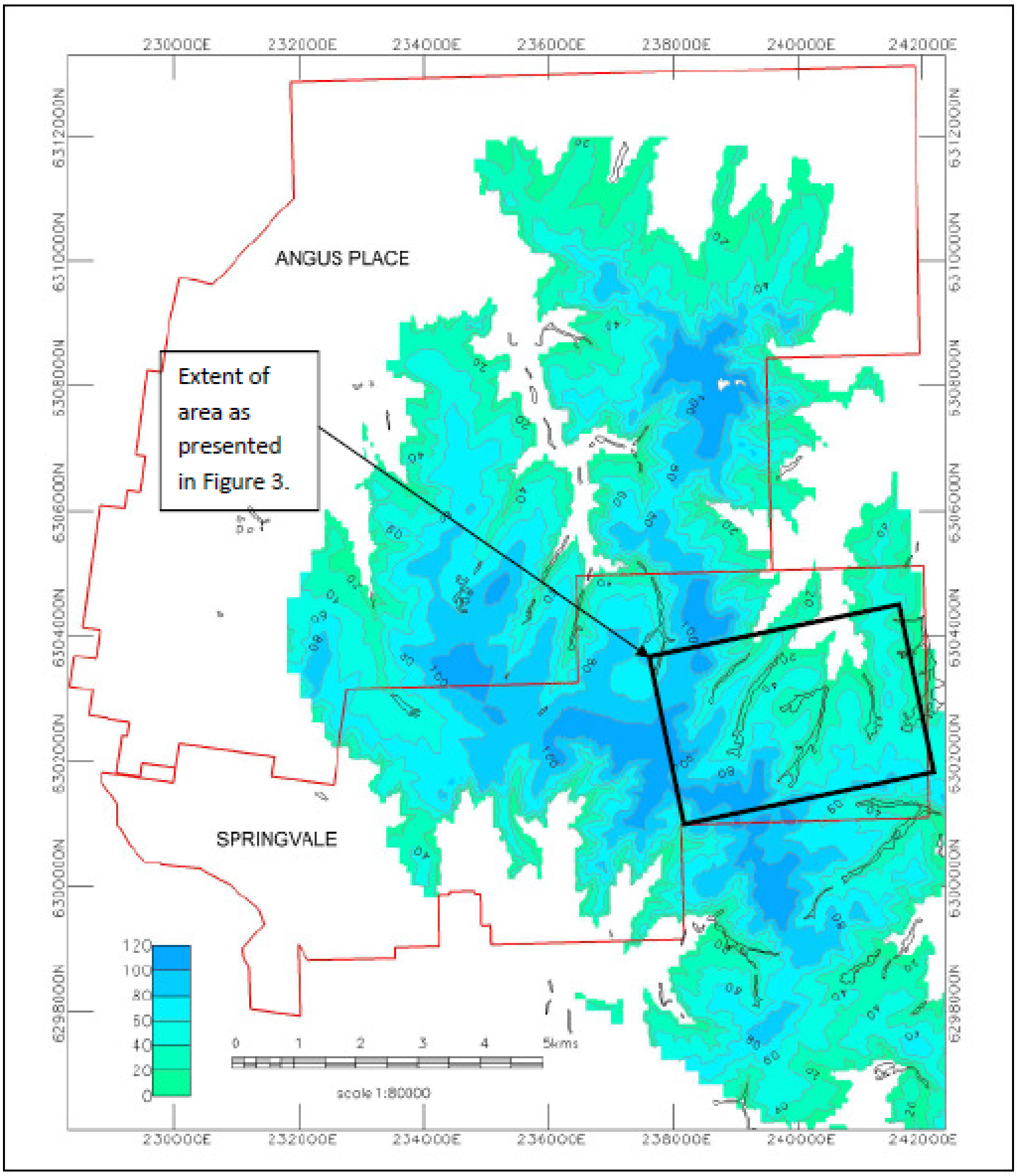


**Figure 3 View of shrub swamps in headwaters of Carne Creek from 3-D geology model**

Figure 4 presents the interpreted extent of the Burralow Formation in both lateral (spatial) and vertical (thickness) extent in relation to the Angus Place and Springvale Mining Leases. Figure 4 also shows the location of swamps in relation to the Burralow Formation and it can be concluded that the majority of the major swamp formations are located in this Formation. The extensive ridge system in the Springvale lease, where the Burralow Formation is at its thickest, provides both a substantial precipitation recharge zone plus an array of aquitards to promote groundwater retention in the streams which flow from this watershed area.



Extent of area as presented in Figure 3.

Figure 4 Isopach drawing of the Burralow Formation in the Angus Place and Springvale Mining Lease Areas together with shrub swamp locations (black outline)

## Swamp hydrology

In the case of Newnes Plateau Shrub Swamps, baseline data from the piezometers indicates that swamp hydrology is variable along individual swamps, and standing water levels are typically influenced by rainfall in the upper reaches and by groundwater in the lower reaches. This demonstrates the increasing groundwater contributions from the multiple outcrops of the Burralow Formation aquitards.

The data from the swamp monitoring has shown that the hydrology of an individual swamp can be ‘periodically waterlogged’ or ‘permanently waterlogged’ or can vary along its length from ‘periodically waterlogged’ to ‘permanently waterlogged’, with transitional behaviour between (Corbett et al 2014).

Monitoring of piezometers in Sunnyside, Sunnyside East, Tri-Star and Carne West swamps indicates that variable hydrology (between periodically waterlogged in the upper reaches and permanently waterlogged in the lower reaches) occurs for swamps to the East of the Newnes Plateau in swamps previously identified as entirely permanently waterlogged.

# 5 Surface subsidence

At Southern Coalfield mines, where the depths of cover are greater than 400 metres, conventional horizontal movements are a small component of observed valley ground movements. However, subsidence monitoring within valleys over the Angus Place and Springvale Coal mines, where the depths of cover are less than 400 metres, has shown that systematic or conventional horizontal movements can represent a much greater proportion of the measured valley ground movements. As discussed in the latest valley closure report, sometimes the conventional horizontal movement components are additive to the valley closure movements and at other times these components reduce the valley closure movements and this is one of the reasons why there is considerable scatter in the monitored ground movements in valleys.

Hence, the new ACARP valley closure prediction models, which were developed based solely on data from the deeper Southern Coalfield mines without adjustments for conventional horizontal movement components, do not provide accurate valley closure predictions for valleys where the depths of cover are less than 400 metres and additional research work is now required to develop appropriate ground movement models for mines at these shallower depths of cover (MSEC 2014).

Measured strains at Springvale and Angus Place have been in excess of 0.5mm/m tensile and 2mm/m compressive, without causing measurable impacts to groundwater levels in THPSS. In the case of Kangaroo Creek Swamp, where changes to groundwater levels were caused by mine subsidence in 2008, measured strains were 6mm/m tensile and 26mm/m compressive. At East Wolgan Swamp, where localised cracking in the base of the swamp were caused by mine subsidence, measured strains were 13mmm tensile and 17mm/m compressive. In both of these cases the w/H ratio (longwall panel width / depth of cover) was in excess of 1.0 (critical mine design). Where mine design with lower w/H ratios has been used in the past, measured differential subsidence values have been lower and impacts to THPSS hydrology have not been measured (Corbett at al 2014). This reference is to the Southern Coalfield, where the geological and stress regime is different to the Western Coalfields. The subsidence response behaviour of the Burralow Formation claystone aquitards is measurably different to that of the Hawkesbury Sandstone(Corbett at al 2014, EPBC 2011/5949 Application to Allow Longwall Mining Beneath THPSS on the Newnes Plateau (2013) Vol. 1-3 and Appendices). (pp64)

The NSW Department of Mineral Resources (now Department of Resources and Energy) *Guideline for Application for Subsidence Management Approvals EDG17* states:

*"The Application Area is defined as the surface area that is likely to be affected by the proposed underground coal mining. It should not be smaller than:*

*(1) A surface area defined by the cover depths, Angle of Draw of 35° and the limit of the proposed extraction area in mining leases of the Southern Coalfield, and*

*(2) A surface area defined by the cover depths, Angle of Draw of 26.5° and the limit of the proposed extraction area in mining leases of all other NSW Coalfields."*

It is noteworthy that the Southern Coalfield is excluded from the recommended 26.5 degree design angle of draw within the Guideline, for reasons related to geology, surface topography and depth of cover (explained in more detail in Springvale Colliery's *EPBC Approval 2011/5949 Application to Allow*

*Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau* (March 2013)). A value of 35 degrees is recommended for the Southern Coalfield, however, the recommended value for the Western Coalfield (including Springvale and Angus Place) is 26.5 degrees.

# 6 Overburden caving processes

The overburden caving mechanisms identified in Section 6 are accepted by Centennial, however, it is observed that the majority of the research work has been conducted in the Southern Coalfield and that differences in geology, topography and stress regimes result in different behaviour in other coalfields. Details of the effects to groundwater systems of overburden caving caused by mine subsidence on the Newnes Plateau are discussed in Section 7 (below).

As an example of the differences in overburden caving behaviour, it is noted that at Springvale, the height of continuous fracturing / panel width has been measured at 0.81 (SPR40 extensometer), which is significantly less than the values of 1-1.6 referenced in the IESC report.

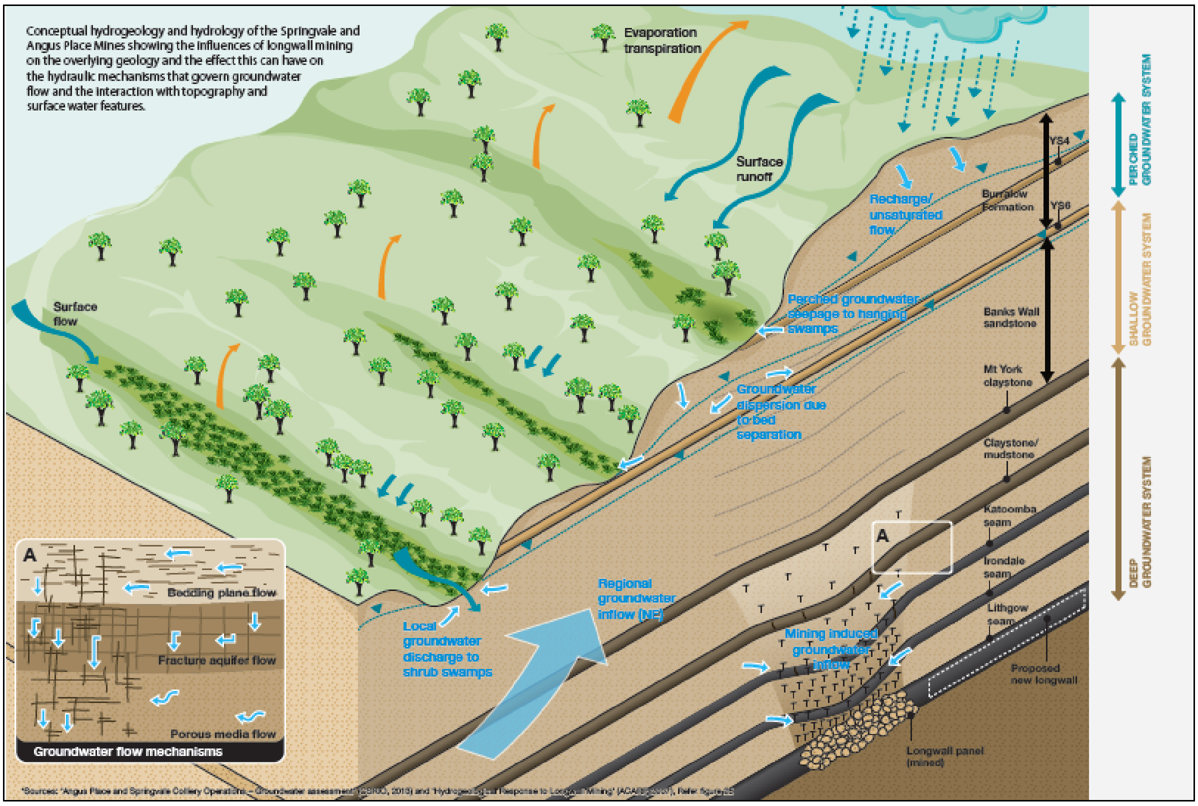
# 7 Groundwater

## 7.1 Introduction

As above, the Burralow Formation overlies the Banks Wall Sandstone in the Angus Place and Springvale Mine Extension Project area.

## 7.3 Examples of peat swamps and associated groundwater systems

A conceptual geological and hydrogeological model was developed for the Newnes Plateau in the Angus Place and Springvale Mine Extension Project, as shown in the figure below. As presented in the Groundwater Impact Assessment for Angus Place and Springvale (RPS, 2014ac) and the main text of the EIS, the hydrogeological system comprises stacked and segregated groundwater systems recharged by rainfall, locally with respect to shallow and perched systems and regionally with respect to the deep groundwater system. The deep groundwater system, within which the target coal seam is located, is essentially isolated from the shallow and perched groundwater systems. The perched system is supported on low permeability aquitards layers identified within the Burralow Formation. Three dimensional geological mapping of the Burralow Formation, based on analysis of 101 boreholes, establishes a clear association between occurrence of shrub swamps and presence of these aquitards plies. Recharge to the perched system is via lateral transmission of percolating infiltration, from rainfall, along contacts between these aquitards. Aquifer interference in the deep groundwater system due to subsidence-induced goaf formation does not extend above the Mount York Claystone. This is supported by the extensive network of Vibrating Wire Piezometers (VWPs) at Angus Place (12 sites) and Springvale (18 sites). The Mount York Claystone is laterally continuous across the site. Modelling indicates that depression in the Coal Seam within the deep groundwater system leads to desaturation of the bottom of the Mount York Claystone. As such there is not a continuous hydraulic connection predicted between the deep groundwater system and the shallow and perched groundwater system. This is supported through field observation.

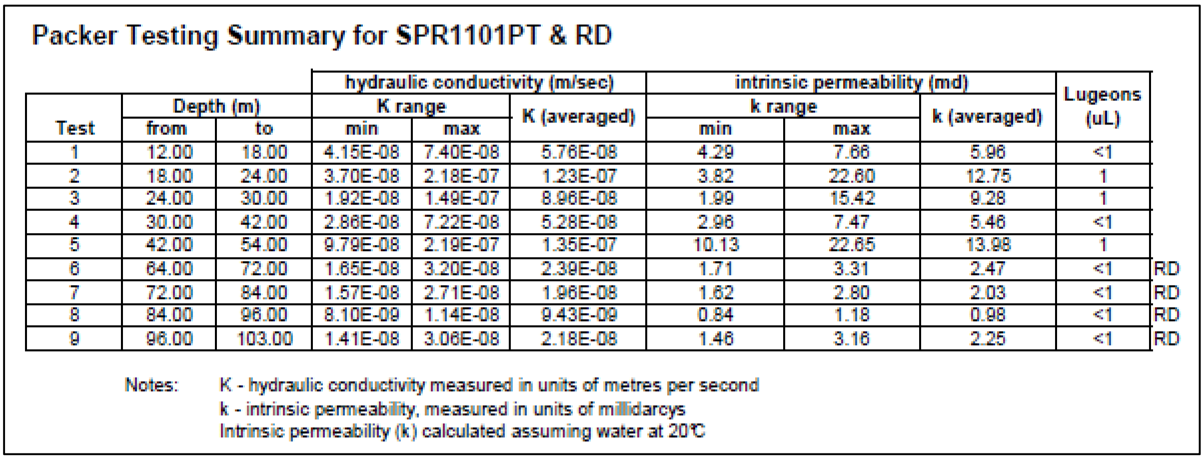


## 7.4 Pre-mining aquifer properties

### *7.4.3 Banks Wall Sandstone*

Borehole permeability testing for the Burralow Formation, which overlies the Banks Wall Sandstone on the Newnes Plateau in the Angus Place and Springvale mining areas, has been conducted in a number of holes. An example of testing conducted for bore SPR1101PT is included below.

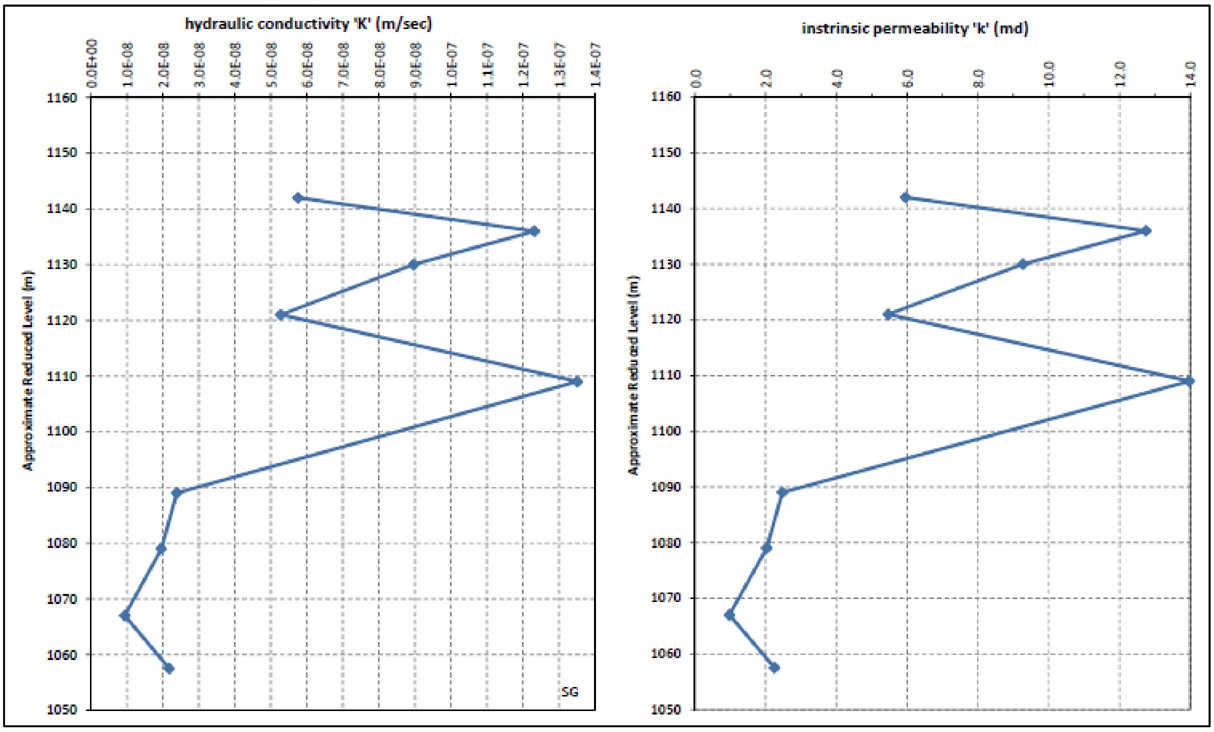
The results of permeability testing are used as inputs into the CSIRO COSFLOW groundwater model.



**Packer Testing Summary for SPR1101PT & RD**

| | | | hydraulic conductivity (m/sec) | | | intrinsic permeability (md) | | | Lugeons (uL) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Test | Depth (m) | | K range | | K (averaged) | k range | | k (averaged) | | |
| | from | to | min | max | | min | max | | | |
| 1 | 12.00 | 18.00 | 4.15E-08 | 7.40E-08 | 5.76E-08 | 4.29 | 7.66 | 5.96 | <1 | |
| 2 | 18.00 | 24.00 | 3.70E-08 | 2.18E-07 | 1.23E-07 | 3.82 | 22.60 | 12.75 | 1 | |
| 3 | 24.00 | 30.00 | 1.92E-08 | 1.49E-07 | 8.96E-08 | 1.99 | 15.42 | 9.28 | 1 | |
| 4 | 30.00 | 42.00 | 2.86E-08 | 7.22E-08 | 5.28E-08 | 2.96 | 7.47 | 5.46 | <1 | |
| 5 | 42.00 | 54.00 | 9.79E-08 | 2.19E-07 | 1.35E-07 | 10.13 | 22.65 | 13.98 | 1 | |
| 6 | 64.00 | 72.00 | 1.65E-08 | 3.20E-08 | 2.39E-08 | 1.71 | 3.31 | 2.47 | <1 | RD |
| 7 | 72.00 | 84.00 | 1.57E-08 | 2.71E-08 | 1.96E-08 | 1.62 | 2.80 | 2.03 | <1 | RD |
| 8 | 84.00 | 96.00 | 8.10E-09 | 1.14E-08 | 9.43E-09 | 0.84 | 1.18 | 0.98 | <1 | RD |
| 9 | 96.00 | 103.00 | 1.41E-08 | 3.06E-08 | 2.18E-08 | 1.46 | 3.16 | 2.25 | <1 | RD |

Notes: K - hydraulic conductivity measured in units of metres per second
k - intrinsic permeability, measured in units of millidarcys
Intrinsic permeability (k) calculated assuming water at 20℃



The relationship between pre-mining and post-mining permeability at Springvale Mine has been researched by CSIRO.  In ACARP report (C18016), the overburden strata were divided into separate deformation zones with distinctive hydrogeological response characteristics. Figure 28 presents a hydrogeological response model developed for Springvale Colliery.

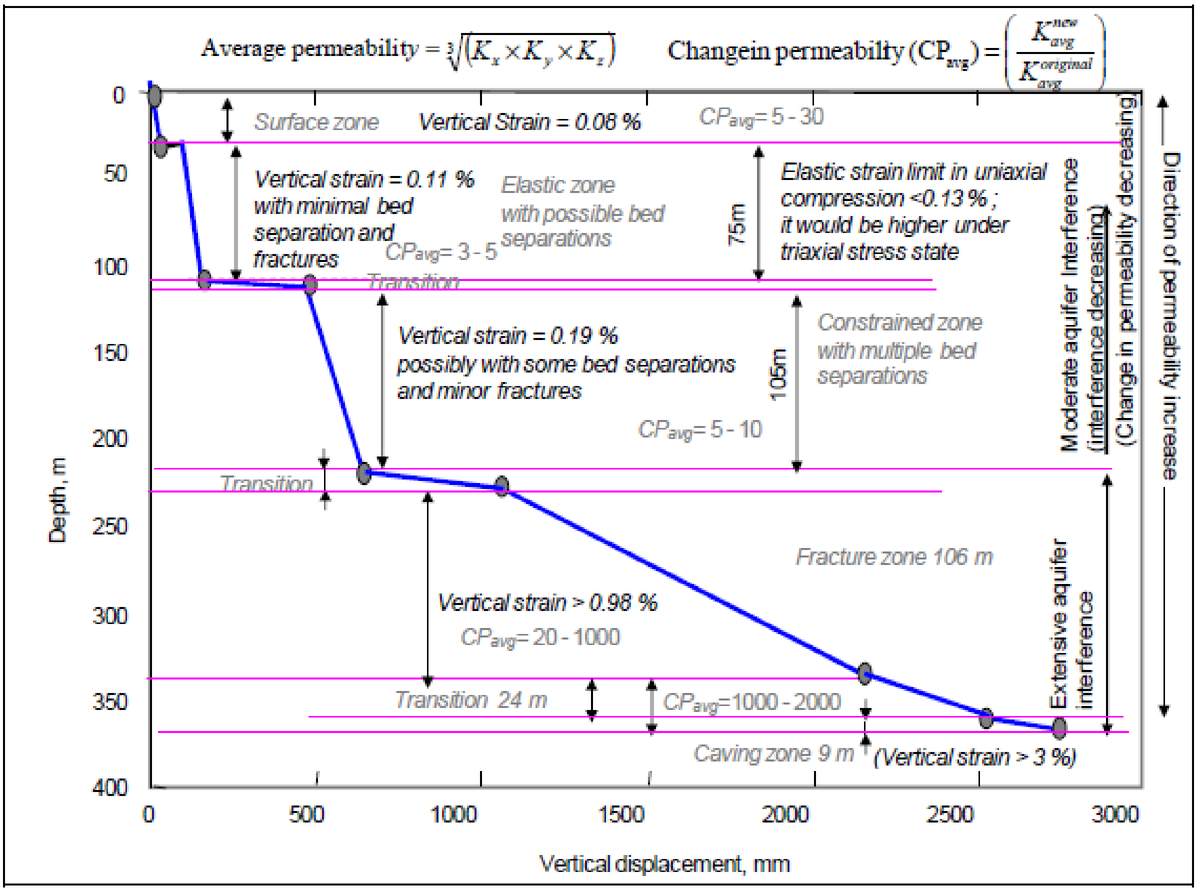


Figure 28 Hydrogeological response model for Springvale Colliery (ACARP C18016)

# 7.5 Impacts of longwall mining on the groundwater system

## *7.5.1 Models of general impacts on the groundwater system*

MSEC conducted a review of estimates of the height of connected fracturing (HoCF) provided in:

- Ditton Geotechnical Services (DgS) report, titled "***Subsurface Fracture Zone Assessment above the Proposed Springvale and Angus Place Mine Extension Project Area Longwalls***", DgS Report No. SPV-003/7b, dated 9th September 2014; and
- Commonwealth Scientific and Industrial Research Organisation (CSIRO) report, titled "***Angus Place and Springvale Colliery Operations – Groundwater Assessments***", Report No. EP132799, dated May 2013.

MSEC provided the following summary on the subsidence induced HoCF.

"The primary porosity of a rock is a measure of the size of void spaces (i.e. the empty or open) between the grains within the rock as a proportion of the total rock volume. When all these void spaces are filled with water the rock is said to be saturated. The secondary porosity exists in rocks due to the presence of fractures, joints, faults and bedding plane partings that were created after the rock was originally formed. This secondary porosity is usually more important in layered sequences of typical sedimentary coalfield strata, but, the secondary porosity cannot be measured in a laboratory since it is impossible to use a large enough sample to represent the rock in situ. Measurements of porosity within a rock mass must be made by field tests to sample a large enough volume of rock. However, the existence of primary or secondary porosity in a rock does not in itself imply the existence of permeability or the ability to transmit water.

Water may flow through a rock mass depending on the size and the length of the available flow path and the available head. Whilst porosity is related to storage capacity, permeability is related to flow. Permeability of a rock is a measure of the ease with which a fluid will pass through that rock. In homogeneous rocks, such as those normally constituting uniform-grained aquifers, permeability is commonly equal in all directions. However, in many of the horizontally bedded consolidated rocks, such as shales, sandstones and claystones of sedimentary coal measures, permeability is measured to be far greater in the horizontal directions parallel to the bedding planes than in a vertical direction. It is easier and more accurate to determine permeability by direct site measurements by means of flow experiments. Henry Darcy, in 1856, was the first to experiment with the flow of water through sand, and he found that the rate of flow through sand is proportional to the hydraulic gradient (Darcy's Law). The constant of proportionality in Darcy's Law is known as the coefficient of permeability. It includes properties of the rock and the fluid and has the dimensions of velocity (i.e. metres per day). The coefficient of permeability of a rock used in the groundwater industry, where the fluid is always water, is known as the hydraulic conductivity. Hydraulic Conductivity is defined as the rate at which water can be transmitted, in cubic metres per day, through a cross sectional area of one square metre normal to the direction of flow, under a hydraulic gradient of one. The units of hydraulic conductivity are usually metres per day or centimetres per second.

A hydraulic conductivity of say 10 metres per day does not mean that water will flow through that rock at the rate of 10 metres per day; it can do so only if the hydraulic gradient is one. If the hydraulic conductivity is 1/1000 then water will flow through the rock at the rate of 0.01 metres per day. The table below provides a range of hydraulic conductivity for typical rocks with the values for highly fractured rocks can be much higher than rocks that are not fractured.

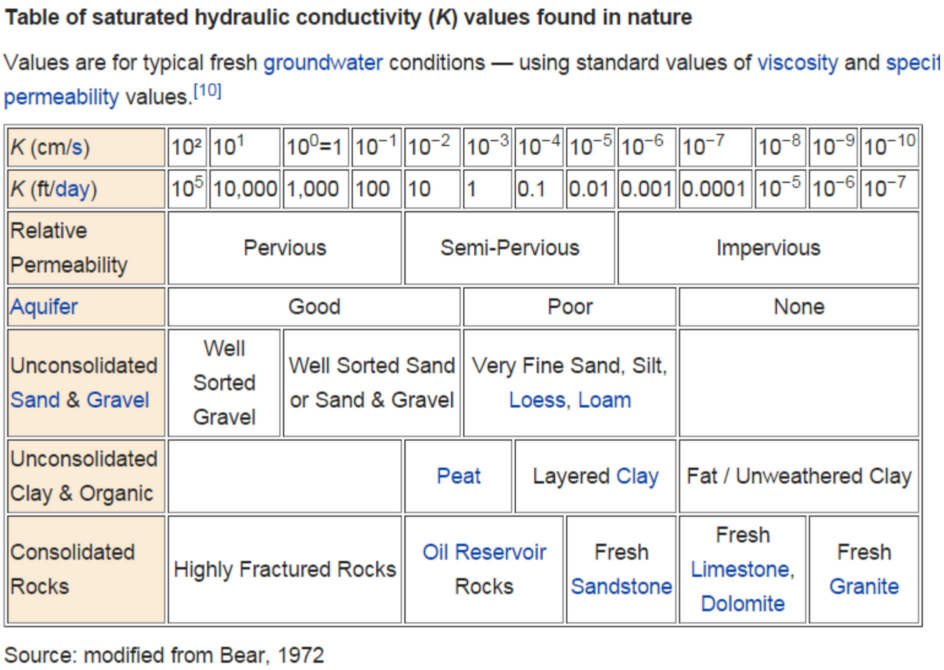


**Table of saturated hydraulic conductivity ($K$) values found in nature**

Values are for typical fresh groundwater conditions — using standard values of viscosity and speci

permeability values.[10]

| $K$ (cm/s) | $10^2$ | $10^1$ | $10^0=1$ | $10^{-1}$ | $10^{-2}$ | $10^{-3}$ | $10^{-4}$ | $10^{-5}$ | $10^{-6}$ | $10^{-7}$ | $10^{-8}$ | $10^{-9}$ | $10^{-10}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $K$ (ft/day) | $10^5$ | 10,000 | 1,000 | 100 | 10 | 1 | 0.1 | 0.01 | 0.001 | 0.0001 | $10^{-5}$ | $10^{-6}$ | $10^{-7}$ |
| Relative Permeability | Pervious | | | | Semi-Pervious | | | | Impervious | | | | |
| Aquifer | Good | | | | | Poor | | | | None | | | |
| Unconsolidated Sand & Gravel | Well Sorted Gravel | | Well Sorted Sand or Sand & Gravel | | | Very Fine Sand, Silt, Loess, Loam | | | | | | | |
| Unconsolidated Clay & Organic | | | | | Peat | | Layered Clay | | | Fat / Unweathered Clay | | | |
| Consolidated Rocks | Highly Fractured Rocks | | | | Oil Reservoir Rocks | | | Fresh Sandstone | | Fresh Limestone, Dolomite | | Fresh Granite | |

Source: modified from Bear, 1972

For water to move through rocks the head available has to overcome surface tension and frictional resistance. It is possible to have rocks of such low hydraulic conductivity that they require large differences in head to overcome the frictional resistance and therefore they only transmit negligible quantities of water except by molecular and surface tension forces; such rocks are termed impervious or impermeable despite the fact that they may process some hydraulic conductivity. Use of this knowledge is made in the design of engineering structures such as rock fill dams. The vertical flow of water through a layered sequence cannot be obtained by using the average vertical hydraulic conductivity of the layers; the prime controls being the layer of lowest vertical hydraulic conductivity and the head acting on it.

It is common for aquifers to be encountered at a number of levels within a layered sequence of horizontally bedded sedimentary rocks, each having a successively deeper standing water level (i.e. the level at which water from the aquifer concerned will stand in a bore exposed to that aquifer). The sequence in water levels is due to there being layers of lower permeabilities within the strata and these retard downward movement of water.

Longwall mining results in surface and sub-surface subsidence displacements and it creates new fractures and opens up or widens pre-existing bedding planes and natural joints within the overburden. The location of and the impacts from these mining induced fractures within the overburden depend on both the mining geometry and the geology and lithology of the strata as discussed below.

The opening of existing joints and bedding planes and the creation of new mining induced cracks within the overburden over a mined panel does increase the permeability of the existing strata layers. The height at which new mining induced fractures (HoF) may form above a mined panel has been measured to be up to 1 to 1.5 times the panel width, depending on the spanning capacity of the overlying strata and the bulking of the goafed strata. However the creation of these new fractures does not necessarily imply that a direct hydraulic connection will exist vertically up through the strata layers to each fracture. Significant volumes of mine inflow only occur from the height where the fractures form a connected continuous path or a conductive network towards the mined opening.

The height of the connected fracturing zone (HoCF) which is defined, for the purposes of this review, as the height of a zone above the seam that mining induced connected or continuous fractures can transmit water from the overlying strata to the mined void, or, the height of a zone above the seam from which water would flow freely into the mine. The HoCF is commonly much lower than the HoF, depending on many factors as is discussed below.

Unfortunately, there have been mining cases at shallow depths of cover where mine subsidence movements have caused extensive surface cracking and where surface water flows were captured and drained down into mine workings. There have also been mining cases where mine subsidence movements impacted on groundwater aquifers that were located at deep and shallow cover above the mine workings. These failures have been observed in all geological regions, especially where the depth of cover was shallow, or, the interburden thickness between the workings and the aquifer was shallow.

On the other hand, there have also been many cases where mining has been successfully carried out at very shallow depths of cover under surface waters, rivers, creeks as well as under various aquifers with negligible, minor or only small losses of water being recorded into the mines.

In 1972 Kapp and Williams advised that 80 years ago coal was successfully mined at shallow cover beneath the Hunter River and Newcastle Harbour. In the Stored Waters Inquiry Report, Reynolds (1977) advised that first workings coal was extensively and successfully mined under Newcastle Harbour and under the ocean off Newcastle with narrow bords and pillars at the following mines taking up to 50% of the coal by plan area with no reported inundations:

- The Winning or Sea Pit, where the depth of cover was more than 140 feet (43 metres);
- Newcastle Coal Mining Company's A and B Pits, where the depth of cover varied from 150 feet (46 metres) to 113 feet (35 metres);
- Burwood Colliery, where the depth of cover was more than 120 feet (36 metres);
- Dudley Colliery, where the depth of cover was more than 100 feet (31 metres);

- Redhead Colliery, where the depth of cover was more than 120 feet (36 metres); and
- John Darling Colliery, where the depth of cover was more than 120 feet (36 metres).

Additionally extensive areas of first workings, panel and pillar second workings, longwall panel extraction and total extraction has taken place under the lake areas south of Newcastle.

Hence, the impacts of mining and subsidence on surface water and groundwater resources have been found to be extremely variable and it is important to appreciate the circumstances for each of these mining cases in order to understand when water may be lost from the surface or aquifers and when mining can be undertaken safely without noticeable impacts on groundwater or surface flows.

The issue of hydraulic connections between the surface water bodies and the mine workings has been the subject of several government inquiries and reports over the past few decades by the NSW State government and more recently by the federal government. The first major inquiry was commenced in 1974 by Mr Justice Reynolds for the State Government of NSW because of the possibility that hydraulic connections between surface stored waters and deep mine workings beneath several major water dams in the Southern Coalfields of NSW could impact on Sydney's water supply. The Stored Waters Inquiry concluded in 1977 that under certain strict conditions mining could be permitted. At depths of cover greater than 120 meters, the extracted panel widths should not exceed one third of the cover depth and the panels should be separated by pillars that had a width of one fifth of the cover depth or fifteen times the height of extraction. Effectively these dimensions were proposed (and were determined to be appropriate) to prevent pillar failure and to maintain a constrained zone above the mined panels that was likely to include at least one of the less permeable layers from the Narrabeen Group.

After this Inquiry was completed a range of field, laboratory and computer simulation studies were undertaken and the results of these studies indicated that the Inquiry recommendations were overly conservative in most circumstances, especially, since a number of very low permeability claystone strata layers, such as the Bald Hill claystone, are now considered to function as aquitards or hydraulic barriers to surface water flowing into the mine workings that have remained relatively "dry" even though many panels had been extracted under the stored waters and known groundwater aquifers.

Based on these developments, mine owners have successfully petitioned, on a number of occasions, the Dam Safety Committee of NSW and other government regulators to approve less conservative mine layouts than those that were recommended by Justice Reynolds as long as they could prove that strata layers of low permeability existed above the predicted heights of interconnected fracturing.

Many engineers, surveyors, geologists and groundwater hydrologists have published reports and papers on the effects of mine subsidence on surface water and groundwater resources. Over the past decade the Australian Coal Industry's Research Program (ACARP) sought research proposals that addressed this issue as one of their key industry problems. Several ACARP research reports have now been published that provide advice on the likely impacts of mining on surface water and aquifers.

Recently some further extensive studies have been published on this issue by the Australian Government Department of Environment, on the advice of the Independent Expert Scientific Committee on Coal Seam Gas and Large Scale Mining Development. This Committee was established as a statutory committee in 2012 by the Australian Government under the *Environment Protection and Biodiversity Conservation Act 1999 (Cth)* in response to community concerns about coal seam gas and coal mining.

Despite the availability of many new reports on this issue, varying opinions have been given on: which subsidence parameter most influences the observed impacts; how best to determine the likely impacts of mining on water resources; and the choice of which computer programmes should be utilised in these studies. Fortunately, some basic concepts and understandings have developed, even though; some authors have not yet understood all the complex issues. Some authors, who only see limited data on a local perspective, rather than on a state wide basis, have assumed the influence of geology is not important, but, the presence of strong or massive strata and the presence of layers of low permeability can have a significant effect on the impact of mining on surface and aquifers and on water inflows into mines. Contrary to what one researcher recently published, i.e. "host geology appears to play a minor role", MSEC believes the impacts of mining and subsidence on surface water and groundwater resources vary significantly due to changes in the local geology and lithology.

The following review of some important research papers provides some interesting background in this field.

Holla 1987 published a paper titled "***Design of mine workings under surface waters in New South Wales***" in 1987 in which he advised; "*Guidelines for mining coal from underneath large bodies of surface water should ideally aim at achieving maximum and efficient recovery of coal resource consistent with the safety of underground mine operations and overlying surface features or improvements. The guidelines prevailing at present in New South Wales (NSW) were framed during the 19705. Even though the basic engineering concepts used for developing them are sound, the guidelines themselves are conservative and over-restrictive given the circumstances and level of available local knowledge at that time.*"

*"Mining under tidal lakes, rivers, streams and the ocean in NSW is controlled in accordance with the provisions of the Coal Mines Regulation Act (NSW Government, 1982) and other regulations framed and administered by the Chief Inspector of Coal Mines. The present regulations are based on Wardell's report (Wardell, 1975) and are designed to minimise water encroachment upon surrounding lands and to contain surface and sub-surface strata movement to levels required to ensure mine safety."*
*"Movement at rockhead under tidal waters (outside HWMSB) is controlled by the following four guidelines.*

1. *The minimum solid strata cover depth for any extraction to occur is 46 m.*
2. *The maximum horizontal tensile strain al rockhead is limited to 7.5 mm/ m.*
3. *For total extraction to occur, the minimum solid strata cover depth should be sixty times the extracted seam thickness.*
4. *Panel and pillar workings can occur with panel width restricted to O.4D and pillar width to 0.120 or eight times the extracted seam thickness, whichever is the greater."*

*"Guideline 3 was obtained from Guideline 2 using the well known relationship that connects strain, subsidence and depth of cover, which is given below.*

*Emax = K x Smax/D where,*
*Emax = maximum tensile strain (non-dimensional)*
*Smax = maximum subsidence (m)*
*D = solid cover depth (m)*
*K = maximum tensile strain coefficient (non·dimensional)"*

*"Wardell (1975) assumed the following values in arriving at the minimum depth of solid strata cover D for mining a seam of thickness T.*

*Emax = 0.0075*
*Smax = 0.6 x T*
*K =0.75*

*D = K x Srnax/Ema> = 0.75 x 0.6 x T 10.0075 ) =60 x T"*

*"Equating 60 times the extracted seam thickness with the rock·head tensile strain of 7.5 mm/m is valid only for the assumed values of Smax: and K. If the input values for Smax and K are changed, the minimum depth of cover would assume a different value for the same rockhead strain of 7.5 mm/ m. In other words, the rockhead tensile strain is the independent and essential criterion, and 60 times the extracted seam thickness is the dependent and nonessential criterion. The guidelines for mining under the Pacific Ocean are assumed to be similar to those for mining under tidal waters."*

Holla (1989) also published a NERRDC funded report titled "***Investigation into Sub-Surface Subsidence***" which documents research to collect information on the heights of caving above the seam and to study the variation in subsidence-surface subsidence for various panel width to depth ratios and the associated vertical strains. Holla reported that

"*During the course of this project, it was considered that the measure of the movement of strata might not adequately demonstrate the possible changes in permeability of the strata due to mining. It was therefore decided to collect additional data on fracturing and bulk permeability of strata before and after mining."*

*"The investigation was carried out in four collieries reflecting different geological and mining environments. The collieries were Ellalong and Wyee collieries in the Newcastle Coalfield, Invincible colliery in the Western Coalfield and Tahmoor colliery in the Southern Coalfield."*

*The zone of caving and bed separation at Ellalong was observed to be 13 times the extracted seam thickness. Longwall panel 2 at the Invincible colliery was sub-critical (the extraction width to mining depth ratio being 1.24) and the zone of caving and bed separation was confined to 9 times the extracted seam thickness. At Wyee, where multi-seam mining was undertaken, the caving extended up to the previously formed goaf, which was 26 m above the extracted seam."*

*"These observed caving heights of 9 to 13 times are significantly larger than the caving height of two to five times the extracted seam thickness reported in the British coalfields. The difference appears to be due to the more competent seam roof strata in NSW caving with much smaller bulking factors than the weak seam roof strata generally found in the UK caving with larger bulking factors."*

*"At the Ellalong borehole, high vertical dilations were confined to a rectangular area behind the face and extended roughly to 50 m height above the seam roof. The average tensile strain in the overburden above the caving zone was 1.28 mm/m. In the region extending 75 m below the surface, the tensile strains were less than 1 mm/m. In the case of the Invincible borehole, high strains developed throughout the overburden which ranged between 1 and 10 mm/m. At the Tahmoor borehole, the strains in the overburden to 165 m depth below the surface were generally small, and the average tensile strain was 0.77 mm/m. Strains varied between less than 0.5 mm/m compressive strain and 4.0 mm/m tensile strain."*

*"The strain contours were layered in all boreholes, which indicates a correlation between strata dilation and geology. this trend was more pronounced at the Invincible borehole, where larger strains were associated with layers of sandstone, siltstone and conglomerate. Layers of mudstone, claystone and coal subsided in blocks, thereby exhibiting smaller strains. Vertical dilation in the overburden tended to be much more closely related to stratigraphy than to proximity to the extracted seam roof."*

*"Generalising the above observation, overburdens consisting of competent strata such as massive sandstones and conglomerates capable of accommodating large vertical strains are likely to subside less resulting in less surface subsidence. Conversely, overburdens consisting of weak mudstones and claystones are likely to develop larger surface subsidence. "*

*"The vertical dilation of strata in the region extending from the surface to 100 m downwards was small both at Ellalong and at Tahmoor, where the mining depths were respectively 370 m and 420 m.*

*Based on the criterion of rock fracture at dilations in excess of 2.5 mm/m, the strata to the depth of 100 m below the surface are expected to remain elastic and free from fracturing. The overburden in such a condition is highly unlikely to provide a continuous hydraulic connection between the surface water body and mine workings."*

Holla provided that following additional comments on the influence of geology of observed subsidence in a later 1991 paper titled "*Some Aspects of Strata Movement relating to Mining under Water Bodies in New South Wales, Australia*":

*"Successful mining layouts for mining coal under large water bodies should ensure that a substantial thickness of overburden strata remains undisturbed to prevent the flooding of mine workings. One of the criteria followed in many countries for controlling sub-surface strata disturbance is to specify a limit on the rockhead tensile strain. However, the generally specified rockhead strains are well in excess of the strain required to cause surface fracturing. It therefore leads to the conclusion that the composition of strata between the cracked zone on the surface and the caved zone above the extracted seam plays an important role in preventing water inflows into mine workings. Ductile beds like shales, mudstones and clay bands appear more effective than sandstone beds of the same thickness."*

*"Mudstones, shales and claystones absorb a large amount of strain energy before fracture. Thus, these beds in the overburden can subside significantly without fracturing and therefore are preferred to sandstones and conglomerates in providing a barrier against downward movement of surface water."*

"*In a tightly constrained condition, many rocks including coal are impermeable and remain so until they are fractured and expanded. In constrained condition, shales, mudstones, siltstones and coal are impermeable, whilst sandstones and conglomerates are considered more permeable. "*

*"In spite of this, most rock materials with a few exceptions have relatively low permeability when compared with the high permeability caused by the joints and fissures in the rock mass. It can be said that the water flow occurs almost entirely through the voids and fissures in the rock mass and not through the rock material. Therefore, the permeability of the rock mass will depend on the degree of jointing and fracturing and the opening and interconnection of these fractures."*

The following comments on the heights of observed caving and cracking (HoF) were copied from a published paper by Mills and O'Grady in 1998 titled "*Impact of Longwall Width on Overburden Behaviour*":

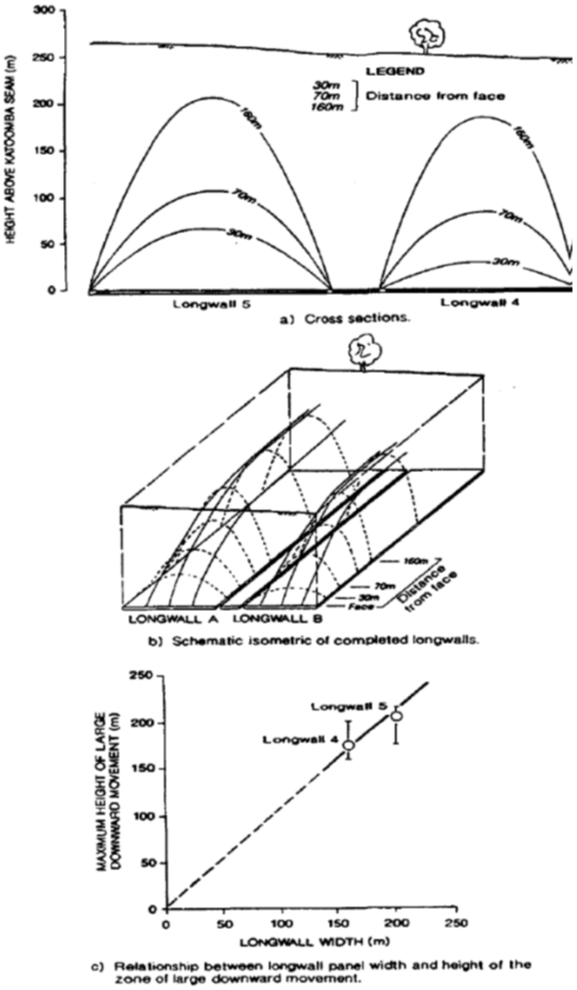
"*Clarence Colliery mines the Katoomba seam, the uppermost seam in the sequence. The immediate overburden strata comprises a sequence of competent interbedded fine grained sandstones and siltstones with some weaker coarse grained sandstones. A major sandstone unit occurs at about 25 m above the seam with another major unit some 50-70 m above the seam. The sandstones in each unit are generally massive and free from bedding."*

*"Four surface extensometers and two subsidence lines over Longwalls 4 and 5. The first extensometer was installed in the centre of Longwall 4 and was monitored during retreat of both panels. Three more extensometers were installed over Longwall 5 on the same cross-section, one in the centre of the panel and the other two offset 65 m toward each gateroad. Subsidence measurements were made on two cross-lines over Longwalls 4 and 5.*

*"Fig. 7 (below) shows the zones of large downward displacement inferred from the extensometer measurements for various distances past the longwall face. The edges of this zone are somewhat arbitrarily defined because the downward movements decrease exponentially. For the purposes of discussion, the 200 mm contour has been assumed to represent the edge of this zone. "*

*"The zone of large displacement was essentially dome shaped above each extracted longwall panel. The sides of the zone were steeper than the front edge. The front edges extended back from the face over the goaf at about 35° from vertical. The sides extended upward from the chain pillars at approximately 20° from vertical."*

*"The study showed that a zone of large downward movement (<0.5 m)—developed at a height above the mining horizon approximately equal to the panel width and the shape of the zone of large downward movement—was approximately a paraboloid, similar to the shape observed in physical model studies. The study also showed that there must be large, open voids created within the overburden strata around the sides of the zone of large downward movement and potentially also at the top of it (in the sandstone strata at this site)"*



a) Cross sections.

b) Schematic isometric of completed longwalls.

c) Relationship between longwall panel width and height of the zone of large downward movement.

*Fig. 7 - Zones of large downward displacement above two Longwall panels of different widths at Clarence Colliery*

(Mills and O'Grady 1988)

The following comments on the HoF and the HoCF have been copied from the ACARP Project C13013 that titled "***Aquifer Inflow Prediction above Longwall Panels***" and dated September 2008 that was prepared by Gale.

*"Water inflow into coal mines has been a design issue for many years. Guidelines as to the potential for water inflow have been developed in many countries based on local experience and the form of mining being undertaken."*

*"In most instances, the guidelines relate to inflows which would endanger underground personnel and operations. In more recent times, water inflow criteria for mines has been widened to include lesser inflows which may not impact on mine safety or operations, but have the potential to reduce water flow within streams and surface aquifers. For the purpose of this report the larger inflows relating to mining safety are defined as mine inflow and the lesser inflow relating to aquifer water loss as environmental inflow."*

*"Extraction of the coal causes caving of the immediate roof (5 to 20m, depending on the strata types) behind the supports to form a goaf. Above this goaf zone, the strata tend part along particular bedding planes and form "beams or plates". These subside onto the goaf as an interlocked but fractured network of bedding planes, pre-existing joints, mining induced fractures and bending related fractures within the beams."*

*"Tensile fracturing and dilation of existing jointing occurs in the upper zones of the overburden as a result of bending strains. The development of these zones is dependent on panel geometry and depth."*

*"Caving and cracked beam subsidence movements tend to occur up to a height of 1-1.7 times the panel width. Examples of this have been monitored by surface to seam extensometers (Mills and O'Grady 1998, Holla and Armstrong 1986, Holla and Buizen 1991, Guo et al. 2005, Hatherley et al. 2003) and predicted to occur from computer models (Gale 2006). This indicates that cracking and deflection related to such caving and cracked beam subsidence could extend to the surface for panel widths greater than 0.75-1 times depth, depending on geology."*

*"Longwall mining creates additional fractures and changes the conductivity of pre-existing fractures. The height that mining related fractures may form has been established from monitoring and computational studies as being 1-1.5 times the panel width.*

*"However, the creation of these fractures alone does not necessarily imply that a direct hydraulic connection exists over this zone. In order for mine inflow to occur, the fractures created must form a connected and conductive network to allow significant volumes of inflow.*

*"The flow quantity and velocity is highly dependent on the conductivity of the in situ fracture networks and those created by mining. Therefore, inflow into a mine is related to the combined insitu and mining induced fracture networks and the extent that they form a connected system to allow migration through the overburden strata.*

*"A review of mine inflow experience from Australia and the UK conducted found that unsafe volumes of water inflow in the UK occur for longwall mines having a rockhead less than 105m to the water source and theoretical tensile strains above 10mm/m. Longwall faces tended to be dry for strains on the strata at the water source less than 4mm/m. It was found that longwall faces were typically wet with strains at 6mm/m and high inflows may occur at strains greater than 10mm/m.*

*"Water inflow experience in Australia was consistent with this experience, albeit with some variance related to geology. Overall, the data suggests that mine inflow (observed inflows) can occur for theoretical strain values above approximately 6mm/m and the severity of inflow increases as the strain increases. Strains above approximately 10mm/m are likely to be associated with significant inflow.*

*"Overall, the results indicate that the overburden above panels having theoretical tensile strains of 4mm/m has flow networks close to the in situ conductivity. This therefore provides a reasonable estimate for the onset of enhanced conductivity of the overburden.*

*"As the subsidence increases the conductivity increases to the point of a highly conductive fractured mass. Average conductivity overburden for panels having a theoretical strain of 10mm/m is typically in the 10-2 to 10-3 m/s range.*

*"Conductivity of 10-1 to 10-2 m/s was noted for strain values greater than 10mm/m. Inflow for the highly conductive cases close to and greater than 10mm/m would be largely controlled by the aquifer properties.*

*"These results are summarised in Figure S1.*

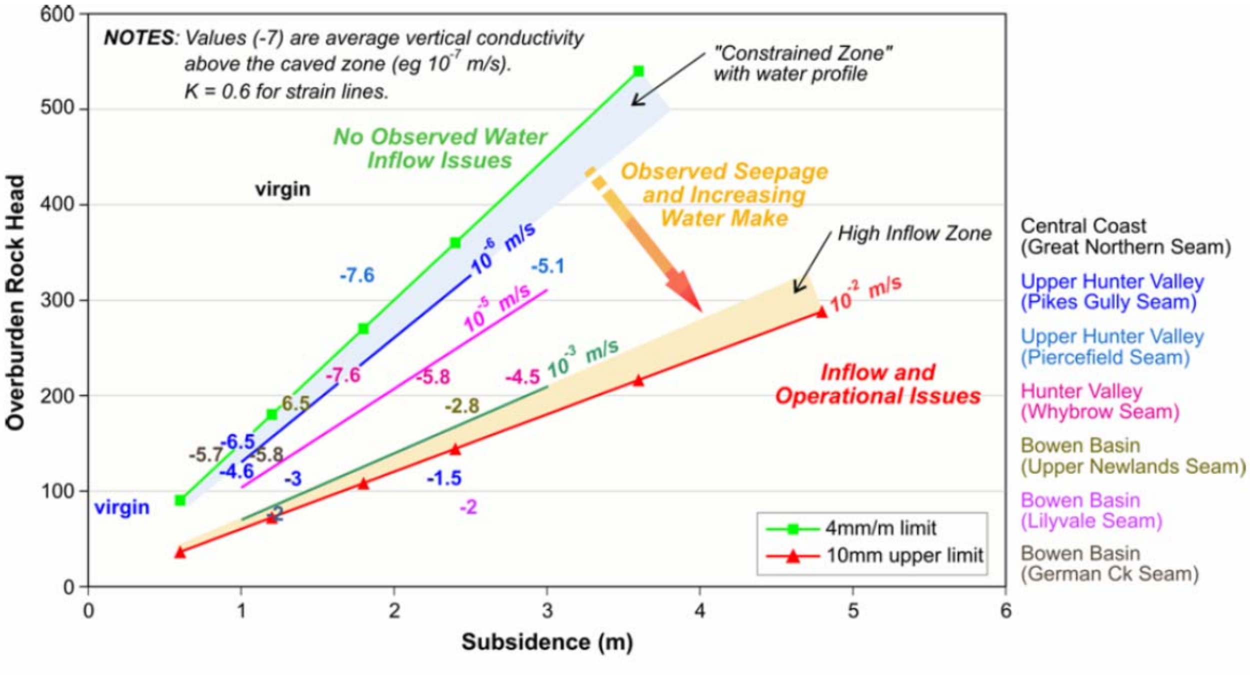


**Figure S1 Average overburden conductivity characteristics relative to subsidence and depth criteria.**

*"In order to evaluate the potential inflow it is essential to assess the surface or aquifer conditions which would provide input into the fractured network as the nature of soils and surface topography may impact on the location and rate at which surface water may connect with the mining fractures.*

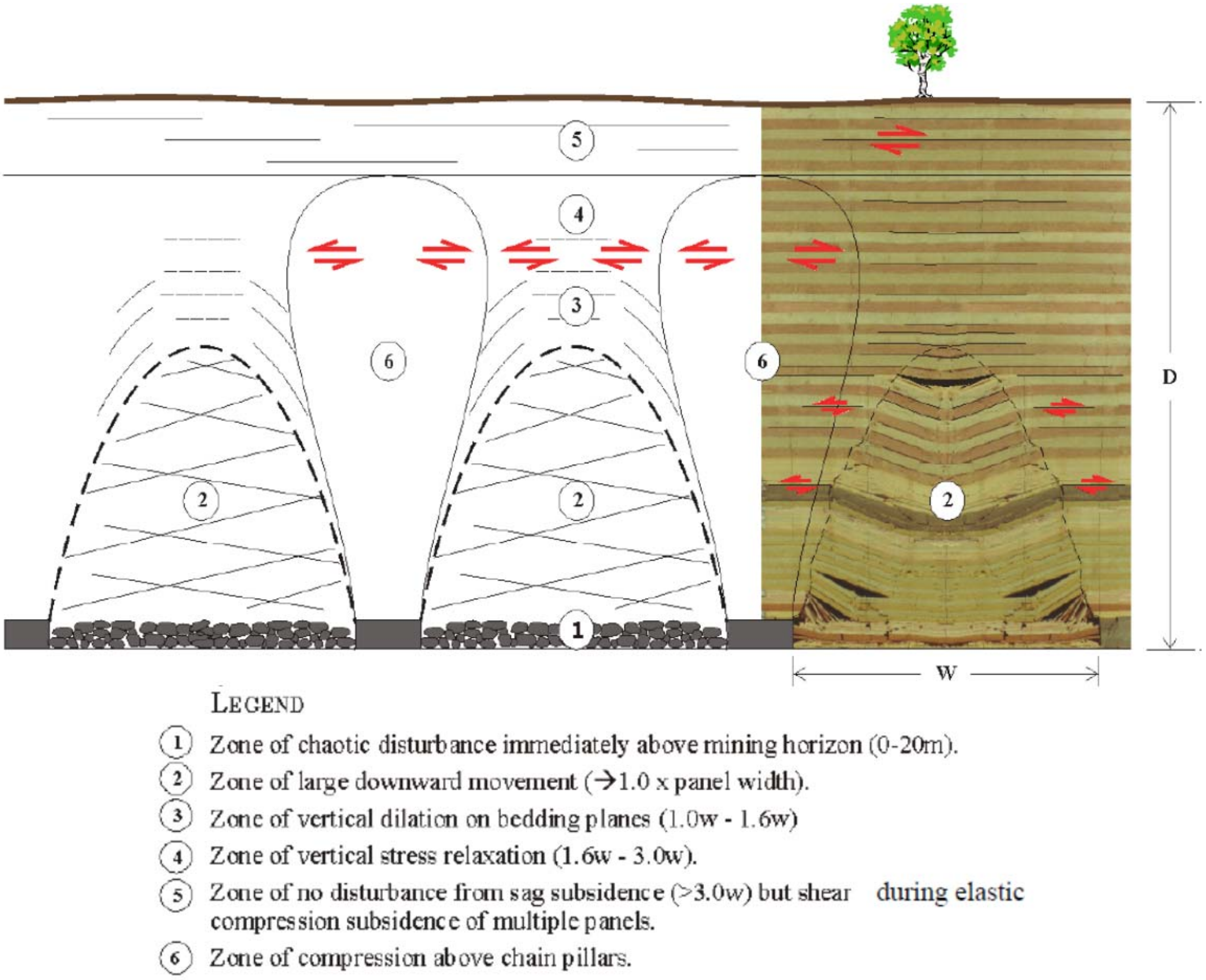
*"The panel width has been found to influence the height that mining induced fractures can extend above the coal seam. However, for mine inflow to occur, the fractures must have formed a connected network to allow observable volumes of inflow. It is considered that the frequency, networking and aperture of those fractures increases with increasing overburden strain and subsidence. Therefore, whilst panel width typically controls the height of fracturing, the network connectivity and conductivity of fractures is controlled by the magnitude of strain and subsidence. Panel width, depth and seam thickness influence strain and subsidence. Therefore there are a number of inter related factors which can influence the result. If a significant thickness of clay material occurs, this may have the effect of constraining the fracture network either due to the fact that it can strain without fracturing or it is able to heal fractures by expansion of the clay."*

Mills (2011) advised in a paper titled "***Developments in Understanding Subsidence with Improved Monitoring***":

*"Subsidence monitoring provides an excellent view of the ground movements at the surface.*

*"Extensometer monitoring presented in Mills and O'Grady (1998) indicates that these zones are arch-shaped above each panel similar to the doming type roadway failures observed in an underground roof fall once all the material has been removed."*

*"The figure below shows a schematic of the zones of ground displacement above multiple longwall panels differentiated in subsidence monitoring and characterised using camera observations, packer testing, piezometer data, and extensometer monitoring. The upper zones shown in Figure 5 are not to scale."*



*"Zone 5, the uppermost zone is essentially undisturbed above single panels. However, when multiple longwall panels are mined adjacent to one another at depth, there is typically significant elastic strata compression subsidence. The broad area subsidence associated with elastic strata compression results in differential shearing on bedding planes within this upper zone. "*

*"The freeing up of these bedding planes contributes to the stress relief movements controlled by topography that tend to be the dominant type of ground movement whenever mining is deep enough for Zone 5 to be present."*

*"In Zone 4, between 1.6 and 3.0 times panel width above the mining horizon, the vertical displacements are consistent in magnitude with elastic relaxation of the pre-mining vertical stresses without the need for physical opening of bedding planes."*

A number of other researchers have also investigated and commented on the likely mechanics of these mining induced strata deformations in order to assess the impact of mining on surface and aquifers. A common approach to the study of these impacts on groundwater issues, has centred on the dividing the overburden strata over a mined panel into a number of zones with different deformation characteristics. The size and nature of these overburden zones have been based on either, sub-surface borehole measurements and fracture observations, or, pore pressure and piezometer readings and permeability monitoring. However, the terminology used by different authors to describe these strata deformation zones above extracted longwalls varies considerably and caution should be taken when comparing the recommendations from differing authors. The important points to note between many of these researchers is whether they were commenting on the likely HoF or the HoCF

Singh and Kendorski (1981) in a paper titled "***Strata Disturbance Prediction for Mining Beneath Surface Water and Waste Impoundments***", proposed the following three zones that he called the fracture zone, the aquiclude zone and the zone of surface cracking.

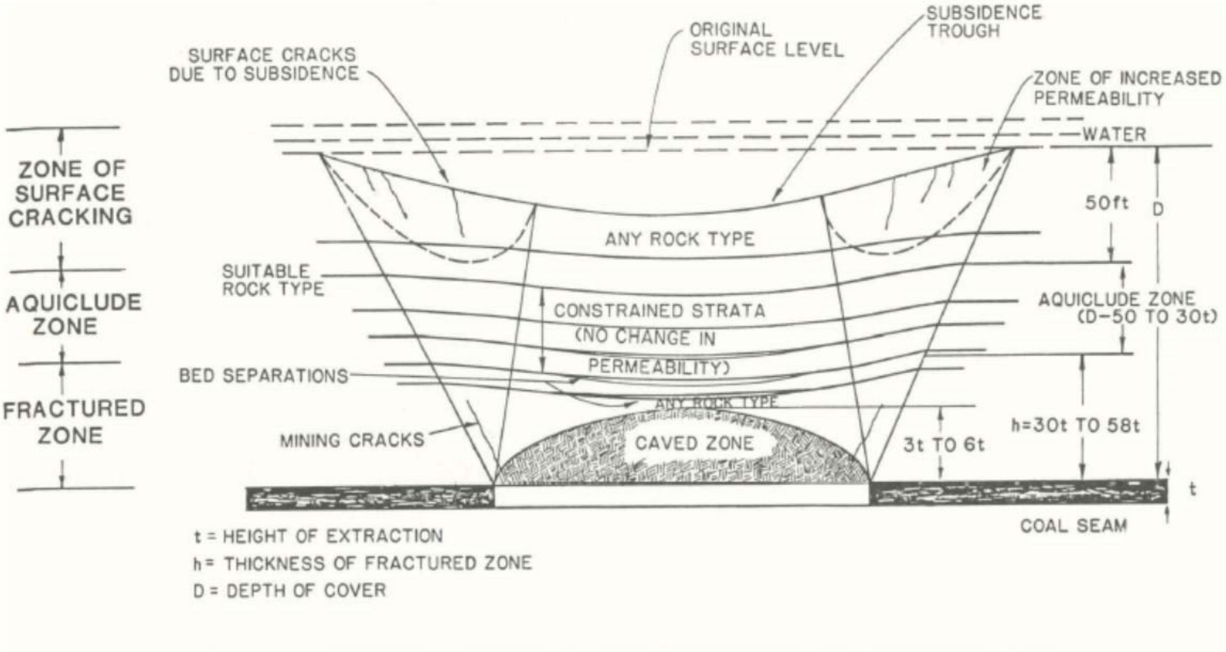
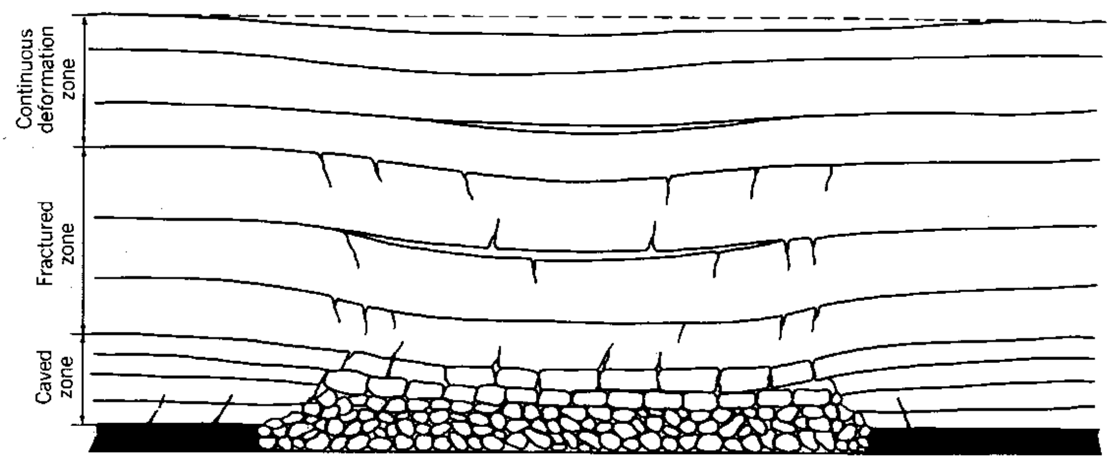


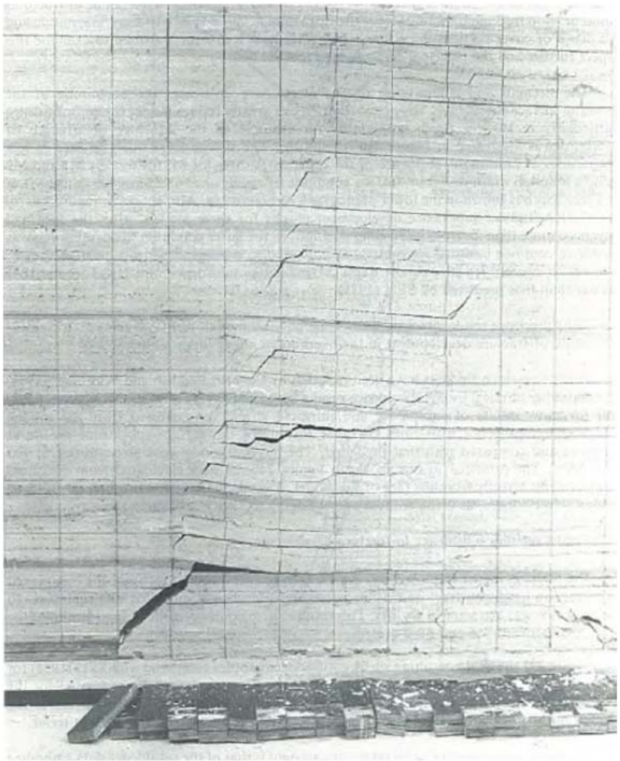
Fig. 4 - Generalized Depiction of Strata Behavior With Total Extraction Mining

Kratzsch (1983) in his text book titled "***Mining Subsidence Engineering*** ", identified four zones, but he named them the immediate roof, the main roof, the intermediate zone and the surface zone.

Peng and Chiang (1984) in his text book titled "***Coal Mine Ground Control***", recognised only three zones as reproduced below.

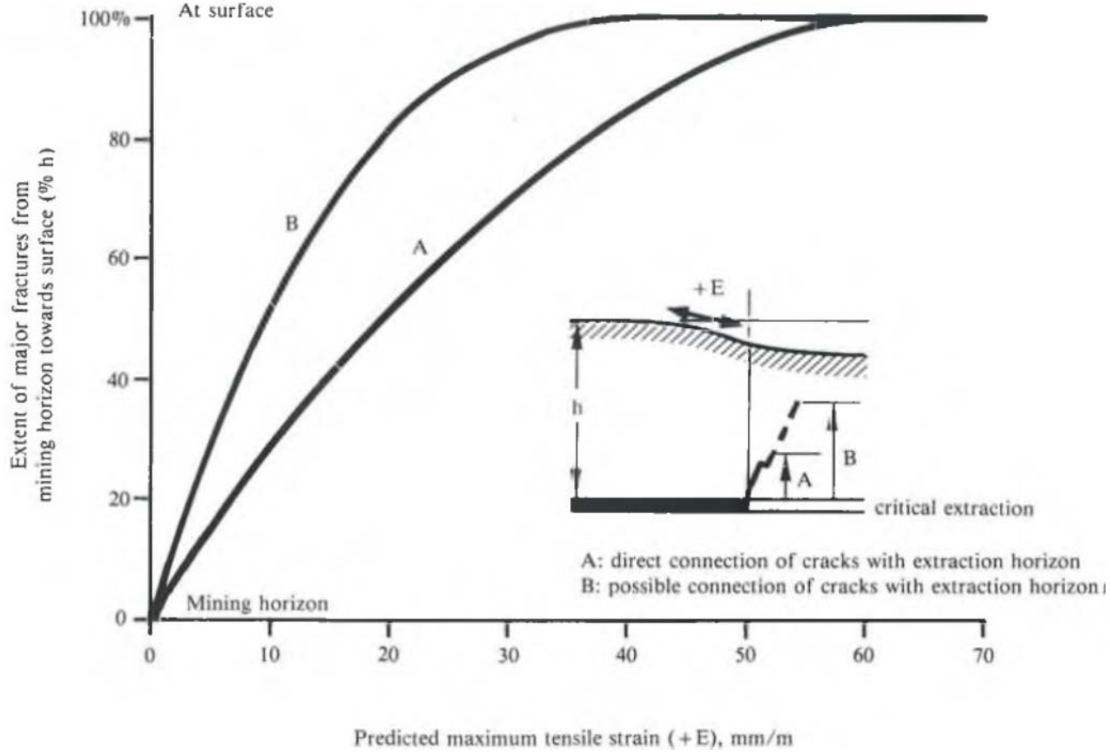


Whittaker and Reddish (1989) in their text book titled "***Subsidence - Occurrence, Prediction and Control***", used physical models built of sand/plaster/water mixes, as shown in the sketch below, that were suitably scaled in strength and size to simulate ground movement of the overburden to illustrate the development of fracture distributions and help understand the subsidence phenomena and strata mechanisms. Two fracturing types were addressed in these models, firstly the maximum height extended by those fractures which were judged to be definitely interconnected with the extraction horizon, (called zone A), and secondly the extent of any appreciable fracture even if they did not necessarily interconnect with the extraction horizon (called zone B).

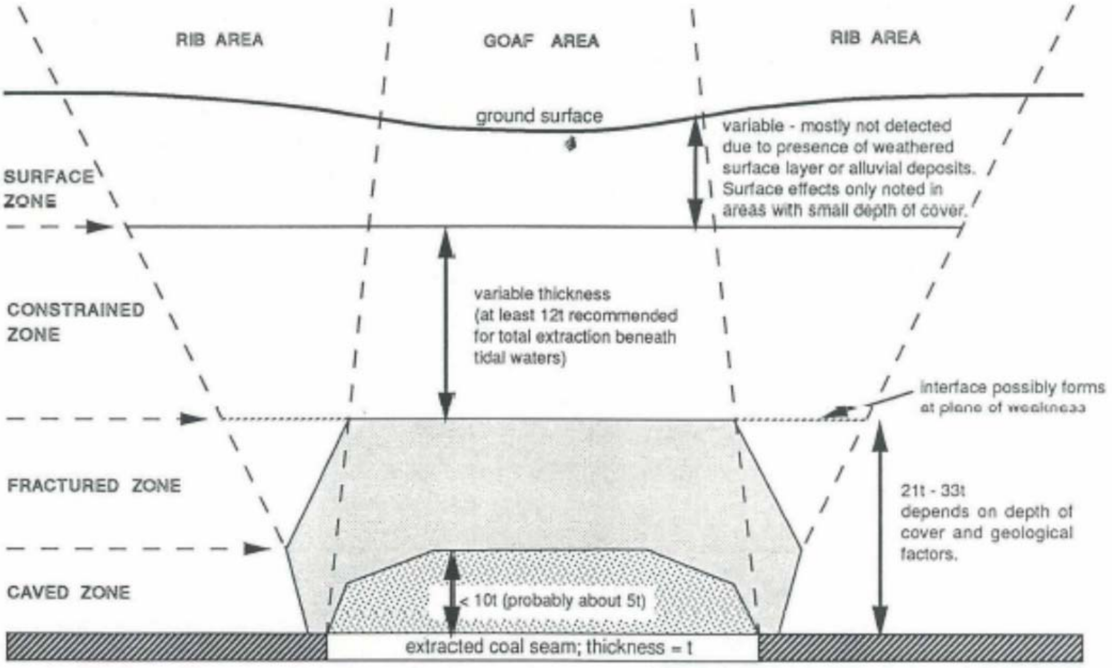


Zone A fracture development was interpreted as being indicative of where free flow from an overlying aquifer would readily occur, whilst the second could be indicative of where there might be a risk of water inflow seeping horizontally from an overlying aquifer but not necessarily flowing downwards to the mine. The second figure below shows an interpretation of these fracture development zones as a proportion of the depth of cover based on maximum tensile stresses in the overburden.

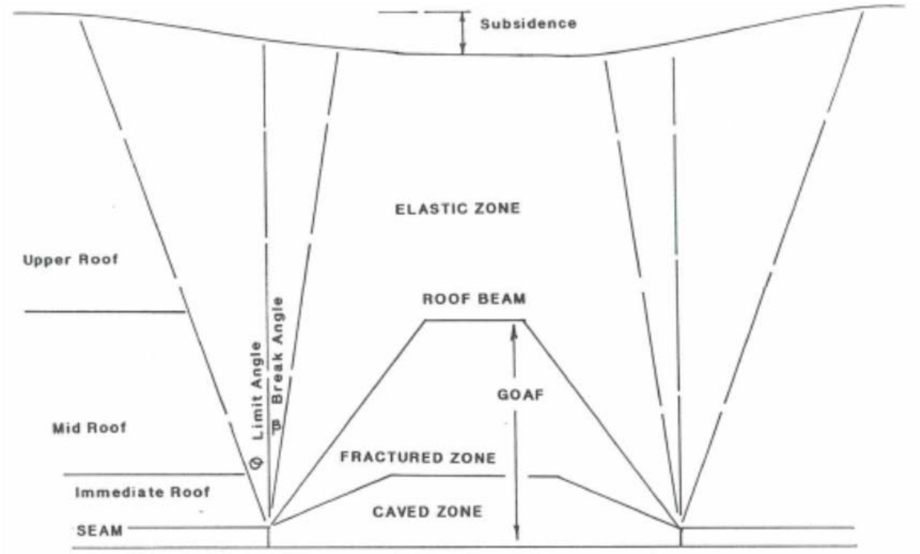
Whittaker and Reddish (1989) also recognised that local geology and depth of mining play important roles, especially in influencing the magnitude and extent of fracture development. They stated that bands of clay and aquicludes that can be located in the overburden can act as major factors in controlling water seeping from overlying horizons even though stronger fractured beds may exist above and below such pliable and impervious bands. It was also noted that the existence of pliable mudstone beds within the strata sequence would tend to inhibit the magnitude and extent of fracture development above the ribside.



Forster and Enever (1992) in their report titled “***Study of the Hydrogeological Response of Overburden Strata to Underground Mining Central Coast - New South Wales***”, undertook a major groundwater investigation over supercritical extraction areas in the Central Coast of NSW and concluded that that overburden could be sub divided into four separate zones, as shown below, with some variations in the definitions of each zone. Forster and Enever noted that while the height of the caved zone over these total extraction areas were related principally to the extracted seam height, seam depth and the nature of the roof lithology, the extent of the overlying disturbed zone was dependent on the strength and deformation properties of the strata and to a lesser extent on the seam thickness, depth of cover and width of the panel.

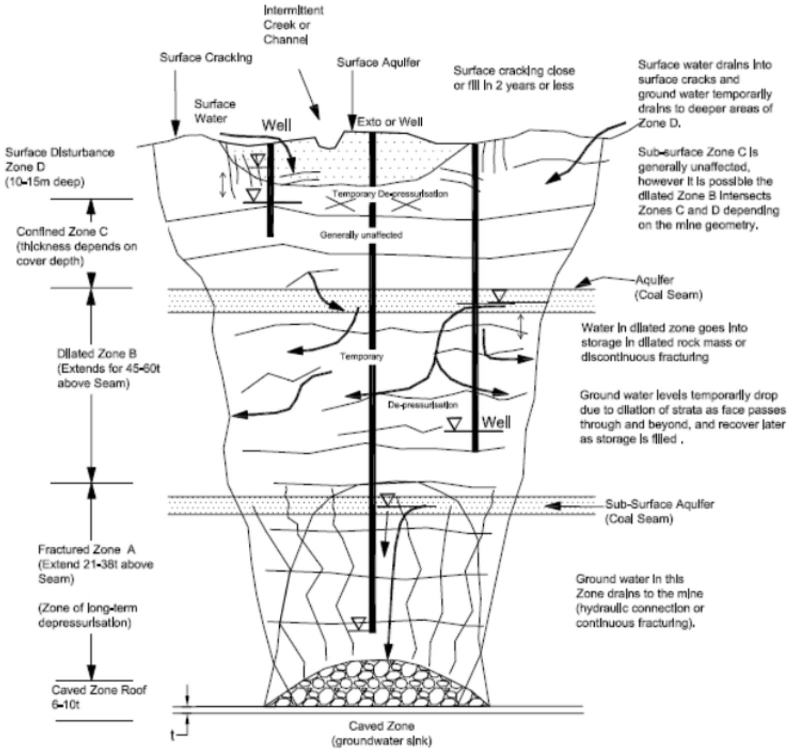


McNally et al (1996) in their paper titled "***Geological factors influencing longwall-induced subsidence***", recognised only three zones, which they referred to as the caved zone, the fractured zone and the elastic zone.

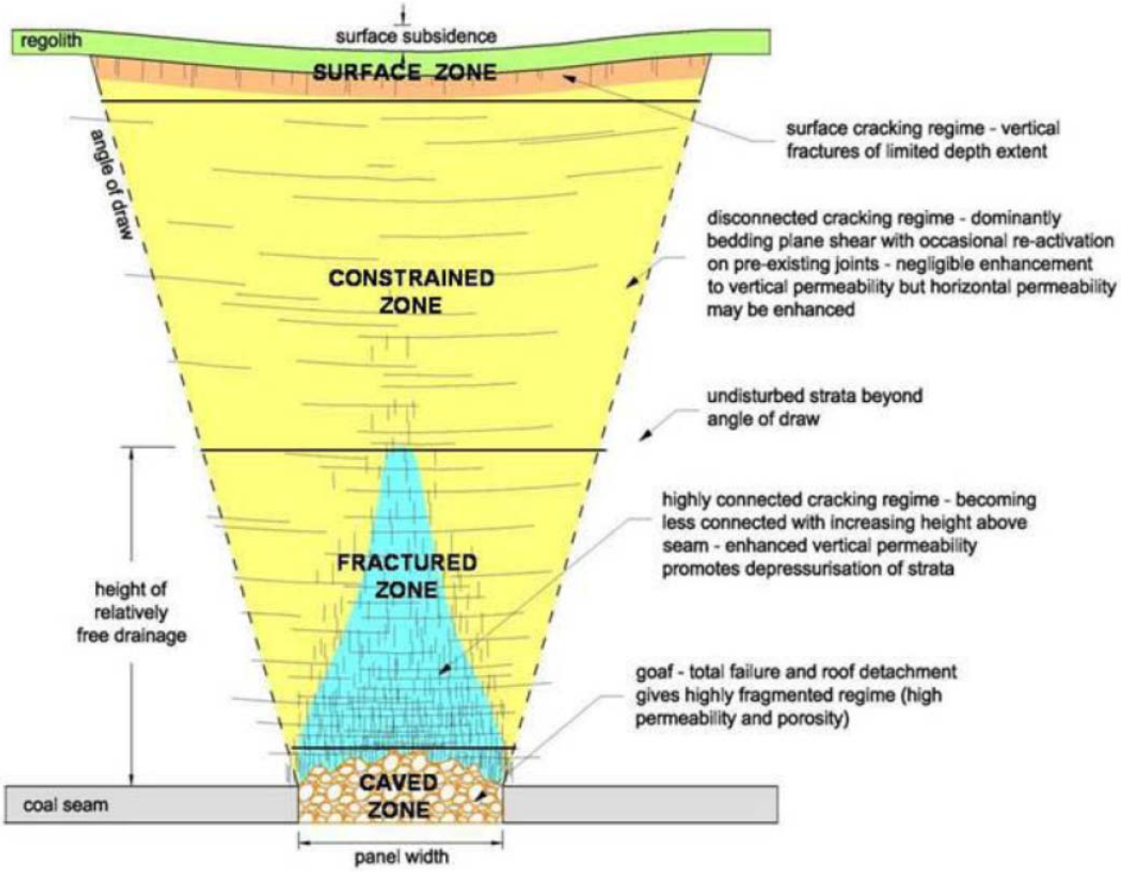


Ditton, Frith and Hill (2003) in their report titled "***Review of Industry Subsidence Data in Relation to the Influence of Overburden Lithology on Subsidence and an Initial Assessment of a Sub-Surface Fracturing Model for Groundwater Analysis***", reviewed the above Whittaker and Reddish Model plus the available borehole data in the Central Coast Region of the Newcastle Coalfield and then derived formulas for the height of continuous fracturing (HoCF), called Zone A, and the height of discontinuous fracturing zone (HoF), called Zone B as discussed by Whittaker and Reddish (1989). Ditton, Frith and Hill confirmed the definitions that the HoCF refers to the height at which a direct connection of the fractures occurs within the overburden and over the workings and represents a direct hydraulic connection for groundwater inflows. The HoF refers to the height at which the horizontal permeability increases as a result of strata de-lamination and fracturing, however, a direct connection of the fractures within this zone and the workings does not occur.

Ditton (2005) in a later report titled "***Surface and Sub-Surface Investigation and Monitoring Plan for LWs 1 to 6 at the Proposed North Wambo Mine***", expanded on these A and B zones by providing the following description of five zones in the following sketch. It can be noted that Ditton has split the constrained zoned, as described by Forster and Enever into the Dilated Zone (B) and the Confined Zone C.



Since then there have been several major government inquiries and Planning and Assessment Commission reviews that have investigated the potential effects of mining on surface and groundwater and the potential loss of water towards mined openings. Most of these reports have included the following sketch that was initially prepared by Mackie in 2007 to explain the nature of fracturing of the overburden over a coal mine. This model has four zones.



From the above discussions, it can be noted that just as the terminology used by the various researchers differs and the means of determining the extents of each of these zones also varies. Indeed some of the difficulties in establishing the heights of the various zones of disturbance above extracted longwalls stem from: the imprecise definitions of the fractured and constrained zones; the differing zone names and clarity regarding whether the discussed fractures were continuous, connected, discontinuous or not connected; the use of different extensometer borehole testing methods; the use of differing permeability or piezometer measuring methods; and differing interpretations of monitoring data.

Some authors have suggested simple equations to estimate the heights of the collapsed and fractured zones based solely on the extracted seam height, whilst others have suggested equations based solely on the widths of extraction, and then others have suggested equations should have been based on the width-to-depth ratios of the extractions. Some authors interpret the influence of geology on the height of the connected collapsed and/or fractured zones to only relate to those geotechnical strength issues that are associated with the possible presence of massive strong strata layers. Whilst others believe that the presence of layers of low permeability, (such as shales, siltstones, mudstones, and tuffs within the overburden), was a more important influencing factor.

The HoCF zone above extracted longwalls is believed to be affected by at least the following factors:

- widths of extraction, (W)
- heights of extraction, (t)
- depths of cover, (H)
- presence and proximity of previous workings, if any, near the current extractions,
- presence of pre-existing natural joints within each strata layer,
- thickness, geology and geomechanical properties of each strata layer,

- angle of break of each strata layer,
- spanning capacity of each strata layer, particularly those layers immediately above the collapsed and fractured zones,
- bulking ratios of each strata layer within the collapsed zone, and the
- groundwater factors such as the presence of and the head in aquiclude or aquitard zones within the overburden and the permeability of each strata layer.

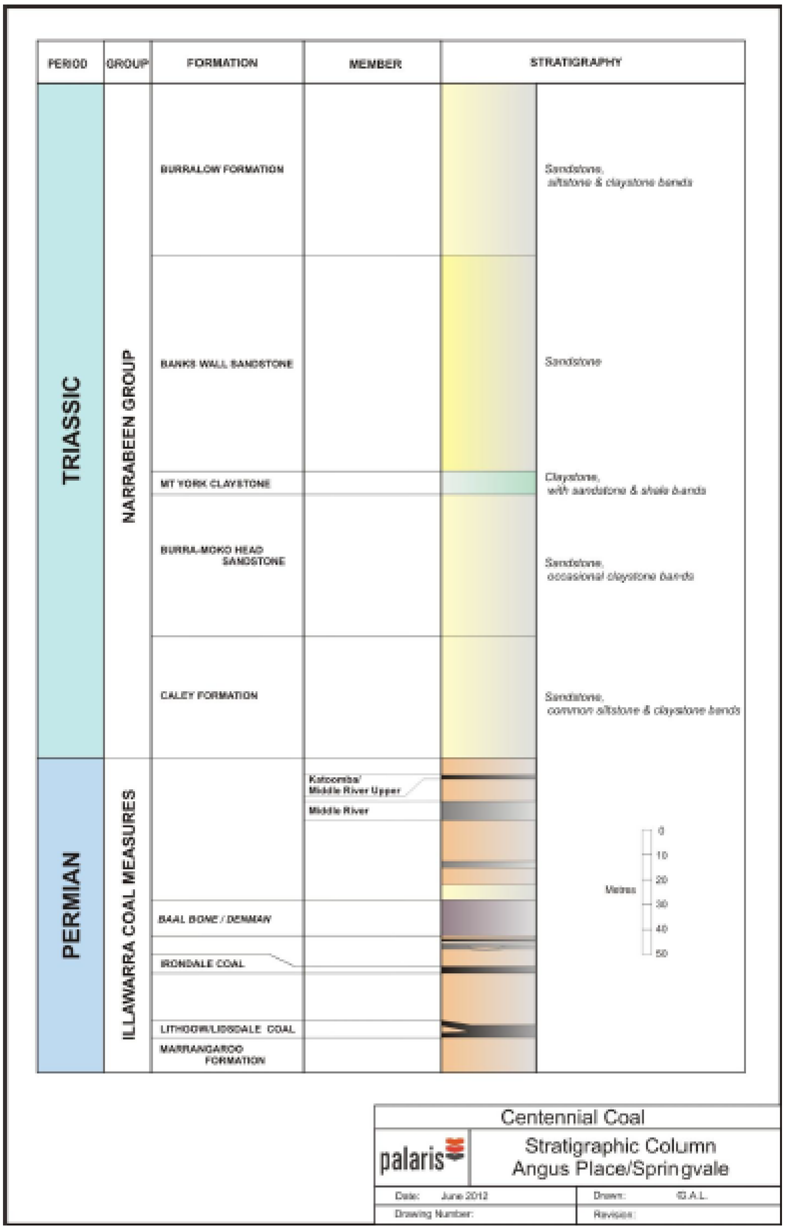
The following listed reports from two recent ACARP funded studies provide extensive discussions on mining induced groundwater flows and computer based modelling techniques that are available to assess the heights of the various defined zones over mined panels and the potential inflows into a mine;

- CSIRO, Guo, Adhikary & Gaveva, (2007), ACARP C14033, "***Hydrogeological Response to Longwall Mining***", and
- SCT, Gale, (2008), ACARP C13013 "***Aquifer Inflow Prediction above Longwall Panels***".

These reports highlight that; the location of and the impact from these mining induced fractures depends on a complex combination of the mining geometry and the lithology and geology of the overburden strata.

The proposed longwalls at the Springvale and Angus Place Mine Extension Projects are located within the Illawarra Coal Measures. Above the coal measures lie the Narrabeen Group of the Triassic period. The surface geology of the terrain that is overlying these panels is located within the Burralow Formation of the upper Narrabeen Group which usually comprise sandstone, claystone and siltstone bands.

Within the Narrabeen Group of rocks, the Burralow Formation and the Mount York Claystone are key stratigraphic horizons in terms of their hydrogeological significance. The groundwater system underlying the Project Application Area has been extensively researched and has been found to be relatively complex with multi-layered units of variable permeability resulting in a number of discrete groundwater flow systems. A number of additional key hydrostratigraphic units have been identified from past investigations as shown in the stratigraphic sequence and geological cross section presented below that have been copied from a report by Palaris titled "***Stratigraphic Setting -Angus Place and Springvale Collieries***", Doc No CEY1535-01, dated March 2013.


PERIOD
GROUP
FORMATION
MEMBER
STRATIGRAPHY
TRIASSIC
NARRABEEN GROUP
BURRALOW FORMATION
Sandstone,
siltstone & claystone bands
BANKS WALL SANDSTONE
Sandstone
MT YORK CLAYSTONE
Claystone,
with sandstone & shale bands
BURRA-MOKO HEAD SANDSTONE
Sandstone,
occasional claystone bands
CALEY FORMATION
Sandstone,
common siltstone & claystone bands
PERMIAN
ILLAWARRA COAL MEASURES
Katoomba/
Middle River Upper
Middle River
BAAL BONE / DENMAN
IRONDALE COAL
LITHGOW/LIDSDALE COAL
MARRANGAROO FORMATION
0
10
20
Metres
30
40
50
Centennial Coal
palaris
Stratigraphic Column
Angus Place/Springvale
Date: June 2012
Drawn: G.A.L.
Drawing Number:
Revision:

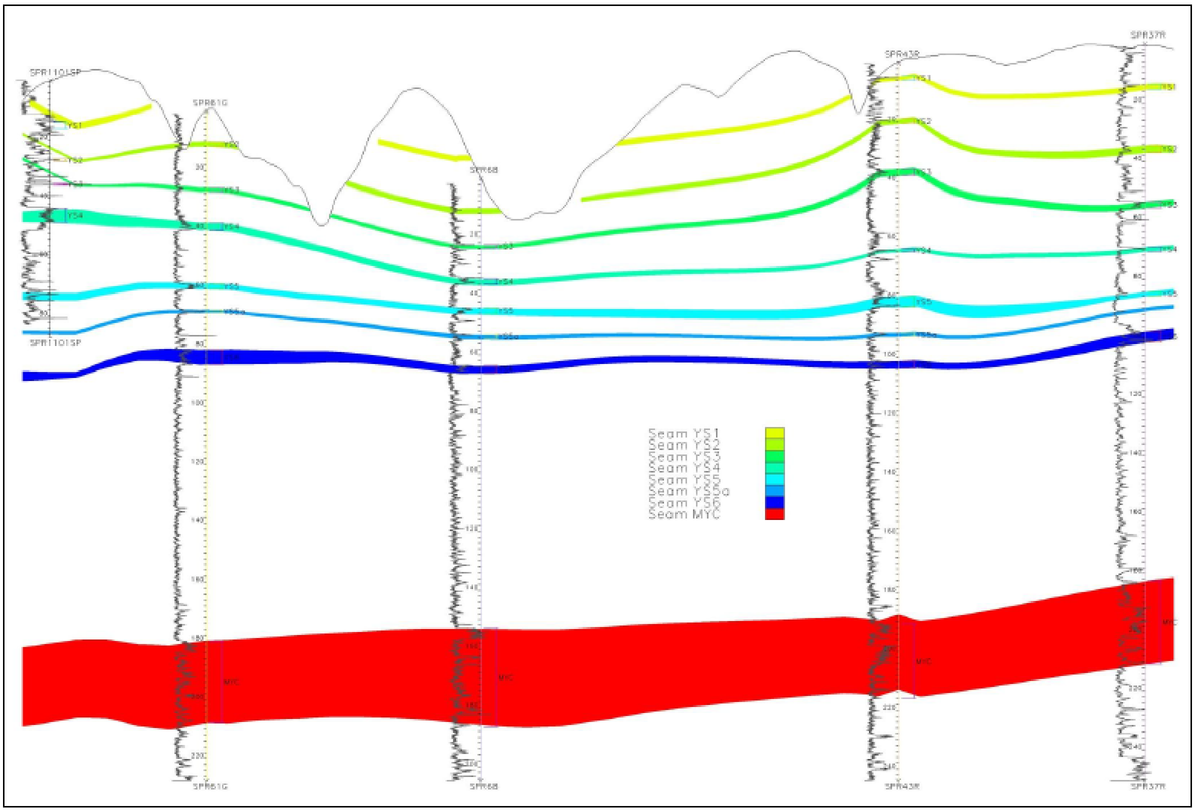
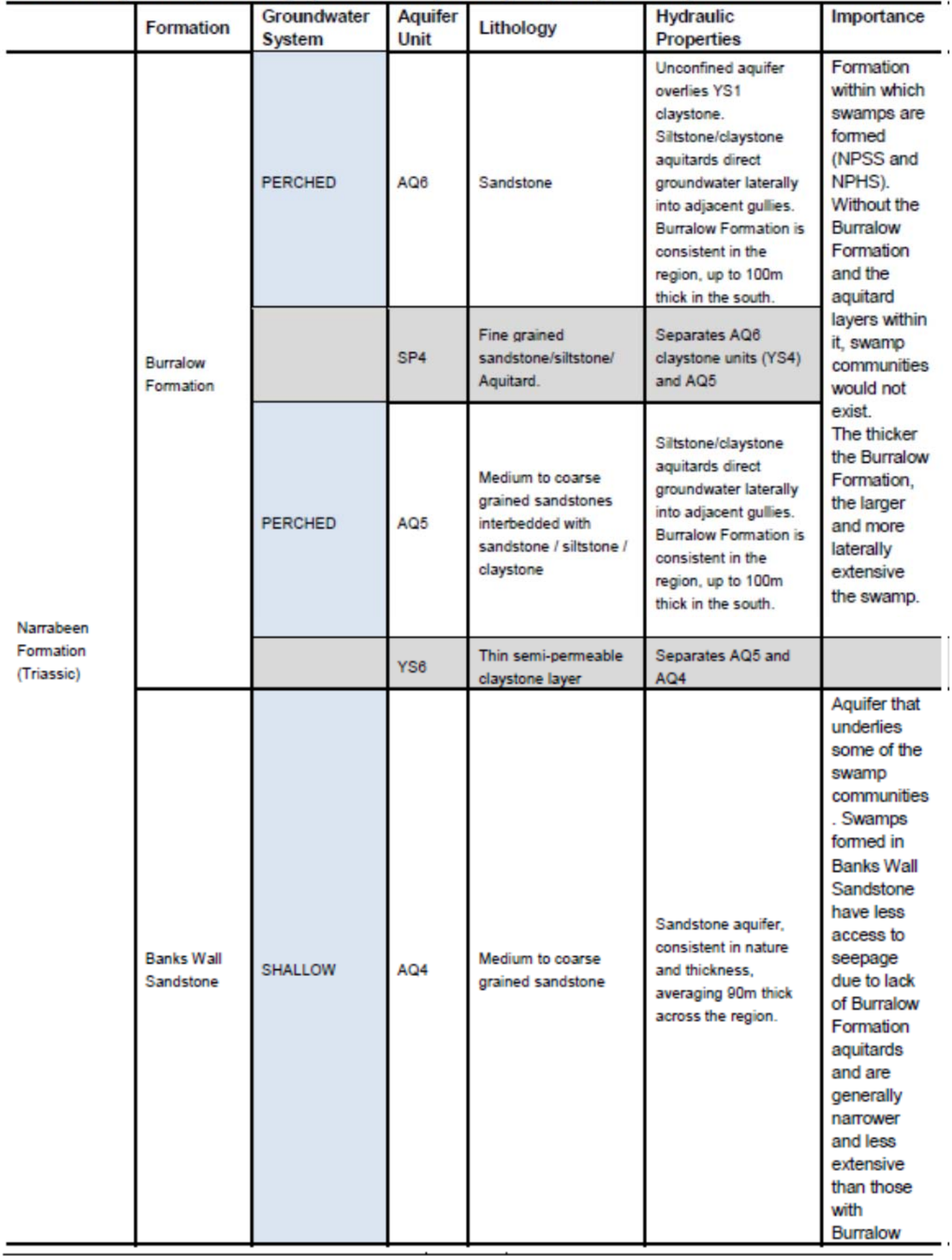


*Figure 1.3 Correlated & Modelled Units in the Narrabeen Group*

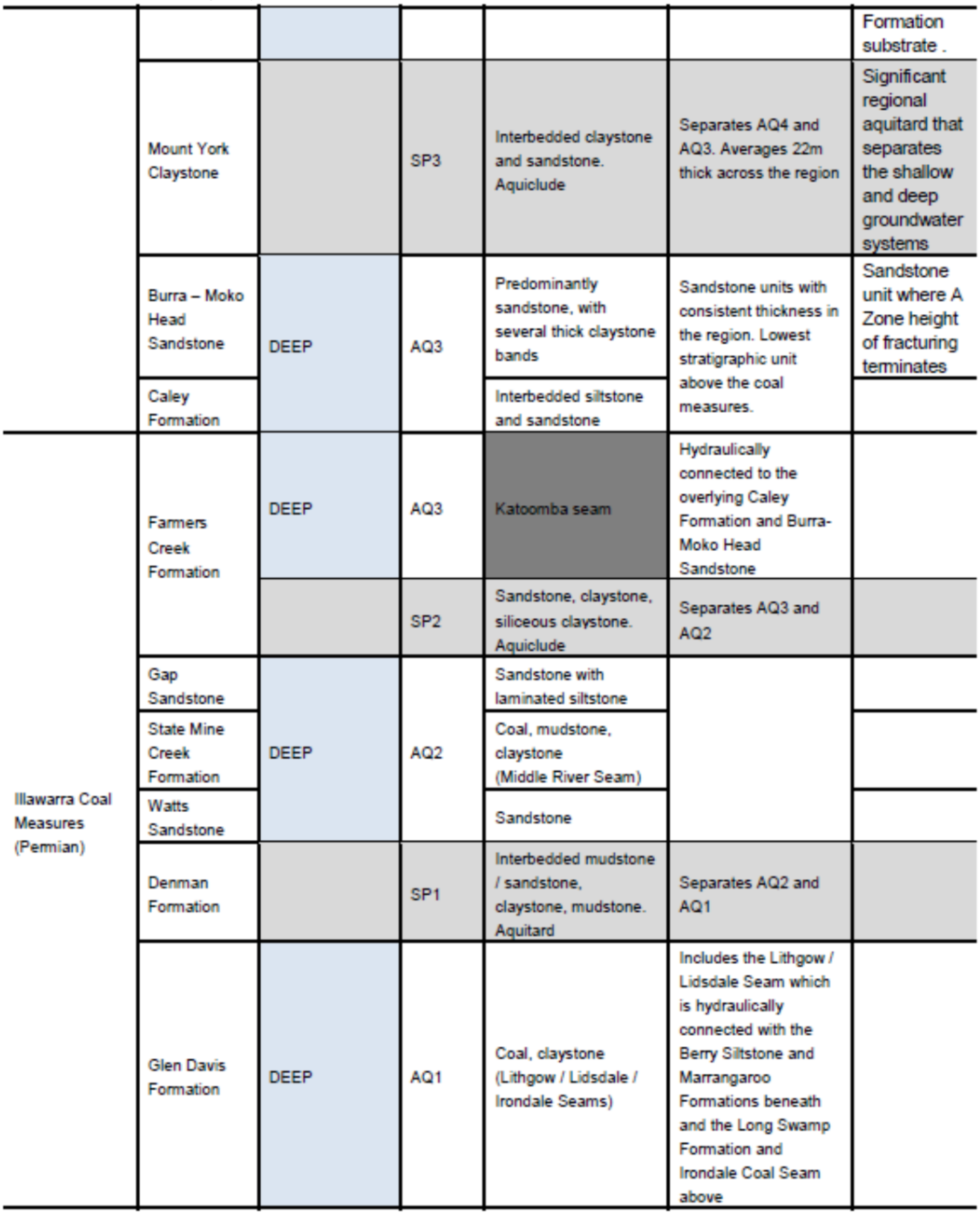
These plots show a series of horizontally layered and bedded, highly laminated and flat-lying sedimentary layered lithologies, which form a complex layered sequence of less-permeable and more-permeable horizons. Each layered sequence has differing grain size, lithification and strength properties which define their range in permeability. The generalised stratigraphy of this area as presented in following Table 2.5, which was copied from the a Golder and Associates report titled "Angus Place Mine Extension Project State Significant Development 5602 Environmental Impact Statement Volume 1: Report", and dated April 2014.

This table presents information on corresponding aquifer designations and less permeable horizons. The hydrostratigraphic sequences were incorporated into the hydrogeological model developed for the site by the above referenced CSIRO report (2013). The stratigraphic sequence were further subdivided into three groundwater systems, separated by the Burralow Formation (SP4) and the Mount York Claystone (SP3), and in the natural environment, are largely independent of each other. These groundwater systems are denoted as perched, shallow and deep groundwater systems respectively.

**Table 2.5 Regional Hydrostratigraphic Summary and Hydrogeological Components**



| | Formation | Groundwater System | Aquifer Unit | Lithology | Hydraulic Properties | Importance |
|---|---|---|---|---|---|---|
| Narrabeen Formation (Triassic) | Burralow Formation | PERCHED | AQ6 | Sandstone | Unconfined aquifer overlies YS1 claystone. Siltstone/claystone aquitards direct groundwater laterally into adjacent gullies. Burralow Formation is consistent in the region, up to 100m thick in the south. | Formation within which swamps are formed (NPSS and NPHS). Without the Burralow Formation and the aquitard layers within it, swamp communities would not exist. The thicker the Burralow Formation, the larger and more laterally extensive the swamp. |
| | | | SP4 | Fine grained sandstone/siltstone/ Aquitard. | Separates AQ6 claystone units (YS4) and AQ5 | |
| | | PERCHED | AQ5 | Medium to coarse grained sandstones interbedded with sandstone / siltstone / claystone | Siltstone/claystone aquitards direct groundwater laterally into adjacent gullies. Burralow Formation is consistent in the region, up to 100m thick in the south. | |
| | | | YS6 | Thin semi-permeable claystone layer | Separates AQ5 and AQ4 | |
| | Banks Wall Sandstone | SHALLOW | AQ4 | Medium to coarse grained sandstone | Sandstone aquifer, consistent in nature and thickness, averaging 90m thick across the region. | Aquifer that underlies some of the swamp communities . Swamps formed in Banks Wall Sandstone have less access to seepage due to lack of Burralow Formation aquitards and are generally narrower and less extensive than those with Burralow |



| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | Formation substrate . |
| | Mount York Claystone | | SP3 | Interbedded claystone and sandstone. Aquiclude | Separates AQ4 and AQ3. Averages 22m thick across the region | Significant regional aquitard that separates the shallow and deep groundwater systems |
| | Burra – Moko Head Sandstone | DEEP | AQ3 | Predominantly sandstone, with several thick claystone bands | Sandstone units with consistent thickness in the region. Lowest stratigraphic unit above the coal measures. | Sandstone unit where A Zone height of fracturing terminates |
| | Caley Formation | | | Interbedded siltstone and sandstone | | |
| Illawarra Coal Measures (Permian) | Farmers Creek Formation | DEEP | AQ3 | Katoomba seam | Hydraulically connected to the overlying Caley Formation and Burra-Moko Head Sandstone | |
| | | | SP2 | Sandstone, claystone, siliceous claystone. Aquiclude | Separates AQ3 and AQ2 | |
| | Gap Sandstone | DEEP | AQ2 | Sandstone with laminated siltstone | | |
| | State Mine Creek Formation | | | Coal, mudstone, claystone (Middle River Seam) | | |
| | Watts Sandstone | | | Sandstone | | |
| | Denman Formation | | SP1 | Interbedded mudstone / sandstone, claystone, mudstone. Aquitard | Separates AQ2 and AQ1 | |
| | Glen Davis Formation | DEEP | AQ1 | Coal, claystone (Lithgow / Lidsdale / Irondale Seams) | Includes the Lithgow / Lidsdale Seam which is hydraulically connected with the Berry Siltstone and Marrangaroo Formations beneath and the Long Swamp Formation and Irondale Coal Seam above | |

The extent, severity and manner of the observed impacts of coal mining on surface water resources and groundwater aquifers vary between different coal mines because every situation is different. The nature and extent of mining induced ground movements around, beneath and near these surface water resources and groundwater aquifers varies considerably due to differing size of the extraction and depth of cover and differing proximities to the water bodies. Each stream, pond or lake is unique in terms of its characteristics and each characteristic (i.e. stream flow conditions, water quality, gradients, valley depths and degree of incision, sediment and nutrient load, bedrock mineralogy, ecosystems and geomorphology) influences the observed consequences and impacts.

Hence, the specific geology of each case should be closely considered as the presence or absence of either strong channels or impermeable layers in the overburden can completely change generalised impact assessment that are only based on longwall widths or seam thicknesses.

The complexity of all these factors requires groundwater impact assessments for mining applications near streams or groundwater aquifers to be undertaken on a case by case basis.

Extensive groundwater testing programs over the years by various researchers have resulted in various hydro-geological models for subsurface behaviour zones. The first such hydro-geological model that was published for NSW conditions was one prepared by Forster and Enever in 1992 that studied various supercritical longwall panels in the Central Coast area of NSW. Several studies, since then, have suggested that the vertical extents of each of the various hydrogeological zones vary depending on many factors, including; the longwall width, extraction height, depth of cover, proximity of previous workings, local geology, overburden rock strength and the permeability and conductivity of the various strata layers in the overburden. Recently Forster wrote a groundwater report for a mine in this Central Coast area providing the following advice; "*The exact level of the top of this zone* (HoCF) *will most likely depend on the position of the numerous tuff layers located in the upper part of the formation. Previous analyses of bore cores indicated that there are up to 100 separate tuff or tuffaceous claystone horizons ranging from 1 mm to more than 3 metres thick in the overburden. Any cracks which penetrate the entire thickness of coarse-grained material in the lower section of the formation should be sealed when they reach the tuff layers, due to plastic deformation or swelling of the reactive clays contained in them. This is even more likely if the cracking results in some groundwater movement. Any one of these tuff layers therefore could form a relatively impermeable horizon that would present a barrier to vertical groundwater movement in the overburden strata, provided that it is located higher than about 65 metres above the* roof of the seam."

Similar more recent studies have highlighted that mine design recommendations should not be applied blindly based on the extracted seam thickness or the longwall panel width as some authors have recently suggested without assessment of the host geology. Careful consideration must always be given to specific site geology as "host geology" does play a significant or major role in determining the HoCF.

Experience in NSW, Queensland and around the world has indicated that, if the right type and thickness of the less permeable strata layers are present above the "fractured zone" and within a "constrained zone", then extraction may take place beneath water bodies without surface water finding its way into the workings. It is now generally recognised that where there are no low permeable layers within the overburden and above the "fractured zone", then, much higher HoCF are observed than where there are many of the lower permeable strata layers. Where there are many low permeable strata layers within the overburden, then, relatively low HoCF have been observed, even where the panels were supercritically wide.

MSEC has reviewed the above referenced CSIRO and DgS Reports and found that they provide detailed information on the existing environment, the groundwater systems, the overburden and the presence of layers of low permeability for this Western Coalfields area. The selection and use of both numerical and empirical models which have been calibrated to site data over many years and used for the Angus Place and Springvale Mine Extension Projects, are believed to represent the current "industry best practice".

MSEC has reviewed these reports and, in our opinion, we consider the assessments of the HoCF for the proposed longwalls at Angus Place and Springvale Collieries that are included in these reports are reasonable for this particular geological region.

It is noted that these reports have provided geologically adjusted and calibrated predictions and assessments of the likely HoCF over the proposed longwalls at Angus Place and Springvale Collieries, which, in our opinion, appear to be appropriate for this geological region and, hence, should provide a satisfactory estimate for the impact assessments on the groundwater systems from the proposed mining for this particular geological region. “

#### 7.5.1.4 Tammetta (2012)

HydroSimulations provided the following review of the Tametta (2012) model: “Comments on the Tammetta conceptual model have also been made in Centennial’s response to *Temperate Highland Peat Swamps on Sandstone: evaluation of mitigation and remediation techniques.* Additional comments are made in the following sections when comparing the Ditton and Tammetta conceptual models and analytical formulas.

There is agreement with the concept of an arched collapsed zone, but there is disagreement as to the height of this zone and also the requirement that it be fully unsaturated, that it "is completely drained of groundwater during caving" to the height H given by the cited formula. It is agreed that "Darcy’s equation is unlikely to be obeyed" at local scale, but at the scale of numerical models an equivalent porous medium is a practical surrogate for characterising the fractured zone and accommodating the water throughput. As the fractured zone permeabilities required to match mine inflows are very much lower than would be expected for pure fracture flow, it is likely that weighted averaging with the fractured zone matrix is appropriate, or the fractures lack sufficient continuity to transmit large volumes of water. In the report extract, it is recognised that the matrix still contains water - "the matrix of rock blocks may continue draining for extended periods". Although the water pressure in the fractures is likely to be atmospheric, when combined with the water pressure in the matrix in an equivalent porous medium, it is likely that a net positive pressure would occur in the modelled representation of the upper part of a fractured zone.

HydroSimulations (2014)[2] conducted a peer review of the groundwater assessment by CSIRO (Adhikary and Wilkins, 2013)[3] for the Angus Place and Springvale Colliery Operations in which this statement was made: " Of particular interest are the resulting pressure head distributions above mined longwall panels (see Figures 62, 63, 76, 77, 78). The results show alternating zones of saturation and desaturation which significantly advances our conceptualisation of the saturation field associated with underground mining - a matter currently under debate in the hydrogeology profession". Figures 63 and 77 are reproduced below for a North-South cross-section.

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[2] HydroSimulations, 2014, Peer Review - Angus Place and Springvale Colliery Operations Groundwater Assessment. Letter Report HC2014/11 prepared for Centennial Angus Place Pty Ltd.

[3] Adhikary, D. P. and Wilkins, A., 2013, Angus Place and Springvale Colliery Operations Groundwater Assessment. CSIRO Report No EP132799 for Angus Place Colliery and Springvale Colliery. May 2013.

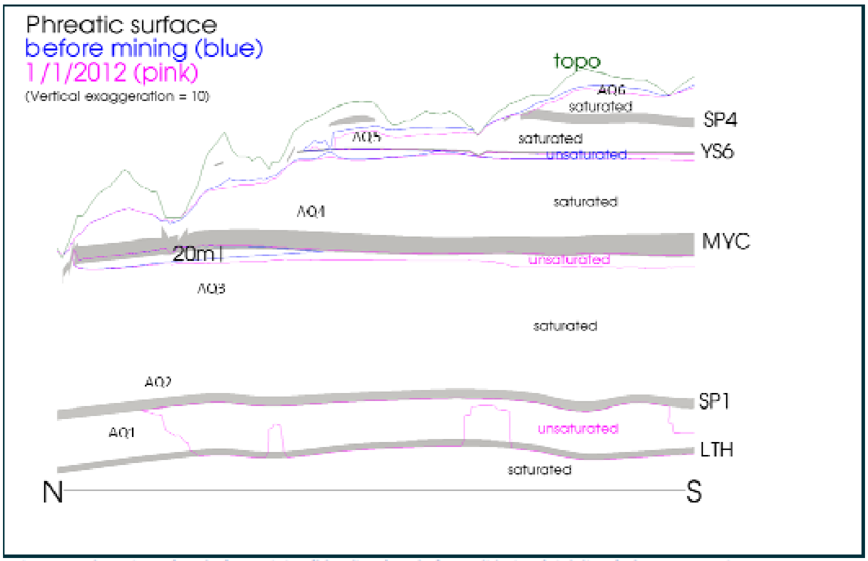

Figure 63 Phreatic surface before mining (blue lines) and after validation (pink lines) along N-S section

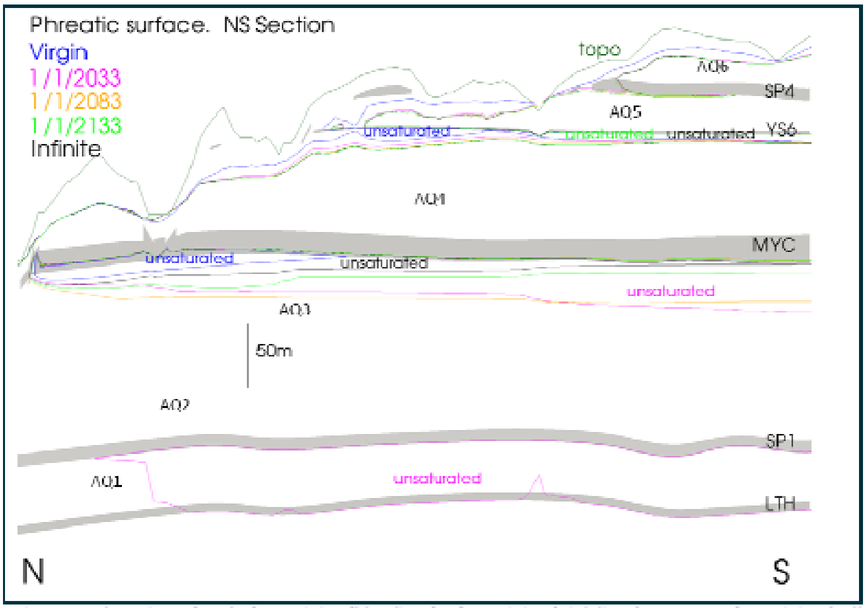

Figure 77 Phreatic surface before mining (blue lines), after mining (pink lines), 50 years after mining (yellow lines), 100 years after mining (green lines) and steady-state after mining (black lines) along N-S section

## Alternative Fractured Zone Algorithms

There are only two known algorithms that aim to estimate the altitude of the deformed zone above an underground mine in terms of more than one causative factor.

The algorithms have been put forward in consulting reports by Steve Ditton of Ditton Geotechnical Services Pty Ltd (DGS) and in a journal paper by Paul Tammetta of Coffey Geosciences Pty Ltd[3]. Their formulas have been differentiated by Noel Merrick and Chris Nicol of HydroSimulations (not previously published) to reveal the sensitivity of fractured zone height to each causative factor. The two approaches have similar sensitivities for cover depth but differ for panel width and mining height. For mining height they are very different and trend in different directions.

The latest formulation of the Ditton model was presented at the Australian Earth Sciences Convention in Newcastle NSW in July 2014 (Ditton and Merrick, 2014)[4].

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

- Mining height [T (Ditton) or t (Tammetta)];
- Cover depth [H (Ditton) or h (Tammetta)]; and
- Longwall panel width [W (both authors)].

In addition, the Ditton model includes effective stratum thickness [t'] as a surrogate for roof rock integrity in one of his two developed models. The second model that uses only mining geometry, with no geology term, is directly comparable to the Tammetta model.

In this report, the underlying formulas for fractured zone height and sensitivity are presented, and then used to compare and contrast the predicted effects for varying panel width (for face widening), cover depth or mining height (for top coal caving).

## Ditton Model Formulas

The Ditton conceptual model is illustrated in Figure 1.

The new Ditton model includes the key fracture height driving parameters of panel width (W), cover depth (H), mining height (T) and local geology factors to estimate the A-Zone and B-Zone horizons above a given longwall panel. Segregation between the A-Zone and B-Zone is based on a threshold vertical strain of 8 mm/m.

Formulas are offered for two models:

Geometry Model, which depends on W, H and T; and

Geology Model, which depends on W, H, T and t' (where t' is the effective thickness[4] of the stratum where the A-Zone height occurs).

The formulas for fractured zone height (A) for single-seam mining are:

Geometry Model: $A = 2.215\, W'^{0.357}\, H^{0.271}\, T^{0.372} \quad +/- \; [0.16 - 0.1\, W']$ (metres)

Geology Model: $A = 1.52\, W'^{0.4}\, H^{0.535}\, T^{0.464}\, t'^{-0.4} \quad +/- \; [0.15 - 0.1\, W']$ (metres)

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

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

The models have been validated to 34 measured Australian case-studies (including West Wallsend, Mandalong, Springvale, Able, Ashton, Austar, Berrima, Metropolitan and Wollemi/North Wambo Mines) with a broad range of mining geometries and geological conditions included. The database also includes three cases in which connective cracking reached the surface (South Bulga, Homestead and Invincible

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[4] Typically 15-20 m in the Gunnedah Coalfield.

Collieries). Statistics for the database are presented in Table 1, and best-fit back-calculated effective beam thicknesses for different coalfields are listed in Table 2.

**Table 1. Statistics for the Ditton Model Database for Australian Coalfields.**

| STATISTIC | Panel Width [W (m)] | Cover Depth [H (m)] | Mining Height [T (m)] |
|---|---|---|---|
| **Mean** | 191 | 254 | 3.0 |
| **Standard Deviation** | 65 | 138 | 0.8 |
| **Minimum** | 110 | 75 | 1.9 |
| **Median** | 179 | 213 | 2.8 |
| **Maximum** | 355 | 500 | 6.0 |

Note that the maximum mining height in the database is 6.0 m.

**Table 2. Minimum Effective Thickness of a Spanning Stratum.**

| COALFIELD | SOUTHERN | WESTERN | NEWCASTLE | HUNTER | GUNNEDAH |
|---|---|---|---|---|---|
| Normal Condition [t'(m)] | 20 - 40 | 20 - 30 | 15 - 20 | 15 - 20 | 15 - 20 |
| Adverse Condition [t'(m)] | 15 | 10 | 10 | 10 | 10 |

The variation of the A-Zone height for each factor is illustrated in Figure 3 to Figure 6. In each figure, the other three parameters are held constant at their database median values.

Ditton (2014, pers. comm.) has a procedure for estimating the increased fractured zone height for multi-seam mining, in which the mining height (T) in the above formulas is replaced by an effective mining height (T') for the upper mined seam that accounts for the additional subsidence caused by mining other seams. This relies on theoretical estimates of subsidence for single or multiple seams. The ratio of the increase in subsidence (due to mining another seam) to the subsidence for a single seam is taken to apply also to the increase in the effective mining height[5].

## Tammetta Model Formula

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[5] One unpublished case study in the Hunter Coalfield showed an increase in the effective mining height of about 70%. This had the effect of increasing the A-height by 27%.

The Tammetta conceptual model is illustrated in Figure 2.

The Tammetta model includes the key fracture height driving parameters of panel width (W), cover depth (h), and mining height (t) to estimate the height of "complete groundwater drainage", which corresponds with the height of the zero-pressure region, an unsaturated "collapsed zone". The model relies on the same parameters as the Ditton Geometry Model. There is no geology factor corresponding to the effective thickness of Ditton's Geology Model.

The formula for collapsed zone height (H) for single-seam mining is:

Geometry Model: $H = 1438 \ln[(4.315 \times 10^{-5})\, h^{0.2}\, t^{1.4}\, W + 0.9818] + 26$ (metres)

Using Ditton's notation to avoid confusion, the formula for collapsed zone height (A) for single-seam mining is equivalent to:

Geometry Model: $A = 1438 \ln[(4.315 \times 10^{-5})\, H^{0.2}\, T^{1.4}\, W + 0.9818] + 26$ (metres)

The 95th percentile (maximum) A-height is estimated by adding 37 m.

The model has been validated to Australian and international case-studies, using hydraulic head and ground movement (extensometer) data. An important assumption is that "*H* is taken as being equal to the top of the zone of large downward movement". This level is said to correspond with zero groundwater pressure, according to the examined head database. Statistics for the database are presented in Table 3.

**Table 3. Statistics for the Tammetta Model Database for Australian and International Coalfields.**

| STATISTIC | Panel Width [W (m)] | Cover Depth [H (m)] | Mining Height [T (m)] |
|---|---|---|---|
| **Minimum** | 110 | 64 | 1.2 |
| **Mean** | 179 | 243 | 2.5 |
| **Maximum** | 260 | 470 | 4.1 |

Note that the maximum mining height in the database is 4.1 m.

No formula is offered for multi-seam mining.

## Sensitivity Formulas

The sensitivity of the A-zone height to each of the driving parameters is obtained by differentiation.

The sensitivity formulas for the Ditton Geometry Model are:

$$\frac{\partial A}{\partial H} = 0.600\ H^{-0.729}\ W'^{0.357}\ T^{0.372}$$

$$\frac{\partial A}{\partial T} = 0.824\ T^{-0.628}\ W'^{0.357}\ H^{0.271}$$

$$\frac{\partial A}{\partial W'} = 0.791\ W'^{-0.643}\ H^{0.271}\ T^{0.372}$$

The sensitivity formulas for the Ditton Geology Model are:

$$\frac{\partial A}{\partial H}= 0.813{*}H^{-0.465}\ W'^{0.4}\ T^{0.464}\ t'^{-0.4}$$

$$\frac{\partial A}{\partial T}= 0.705\ T^{-0.536}\ W'^{0.4}\ H^{0.535}\ t'^{-0.4}$$

$$\frac{\partial A}{\partial W'} = 0.608\ W'^{-0.6}\ H^{0.535}\ T^{0.464}\ t'^{-0.4}$$

$$\frac{\partial A}{\partial t\prime} = 0.608\ \ t'^{-1.4}\ W'^{0.4}\ H^{0.535}\ T^{0.464}$$

The Tammetta model sensitivity formulas are:

$$\frac{\partial A}{\partial H} = \frac{0.2\ C1\ E1\ H^{-0.8}}{0.9818 + E1\ H^{0.2}}$$

$$\frac{\partial A}{\partial T} = \frac{1.4\ C1\ E2\ T^{0.4}}{0.9818 + E2\ T^{1.4}}$$

$$\frac{\partial A}{\partial W} = \frac{C1\ E3}{0.9818 + E3\ W}$$

where: $C1 = 1438$

$C2 = 4.315 \times 10^{-5}$

$E1 = C2\ W\ T^{1.4}$

$E2 = C2\ W\ H^{0.2}$

$E3 = C2\ H^{0.2}\ T^{1.4}$

The sensitivities to each causative factor are illustrated in Figure 7 to Figure 9, with comparison between Ditton and Tammetta models.

Figure 7 considers the increase in fractured zone height for an increase of 25 m in either the (effective) panel width or the cover depth. The findings for (effective) panel width are:

- ☐ The Ditton Geometry Model has an A-Zone increase of 3-10 m (12-40% of 25 m increment);
- ☐ The Tammetta (Geometry) Model has an A-Zone increase of 15-19 m (60-76% of 25 m increment); and
- ☐ The Ditton Geology Model has an A-Zone increase of 5-14 m (20-56% of 25 m increment).

The findings for cover depth are:

- ☐ The Ditton Geometry Model has an A-Zone increase of 1.5-8 m (6-32% of 25 m increment);
- ☐ The Tammetta (Geometry) Model has an A-Zone increase of 1.5-10 m (6-40% of 25 m increment); and
- ☐ The Ditton Geology Model has an A-Zone increase of 5-15 m (20-60% of 25 m increment).

Figure 8 considers the increase in fractured zone height for an increase of 0.5 m in mining height. The findings for mining height are:

- ☐ The Ditton Geometry Model has an A-Zone increase of 3.8-8.6 m (10-17 times the 0.5 m increment);
- ☐ The Tammetta (Geometry) Model has an A-Zone increase of 26-37 m (52-74 times the 0.5 m increment), and it trends in the opposite direction; and
- ☐ The Ditton Geology Model has an A-Zone increase of 6.5-14 m (13-27 times the 0.5 m increment).

As the Ditton model has a basis in geotechnical theory, while the Tammetta model is an empirical best-fit procedure, it is expected that the Ditton model would give the more correct sensitivity trend for mining height. The departure of the Tammetta model, in terms of trend and magnitude of its sensitivity to mining height, might be due to database limitations. It has previously been noted that the respective Ditton and Tammetta databases had maximum values of 6.0 m and 4.1 m for mining height. This means that the Tammetta model is uncontrolled for the higher mining heights.

Figure 9 shows the decrease in fractured zone height for an increase of 0.5 m in the effective thickness of a spanning beam. The finding for beam thickness is:

- ❑ The Ditton Geology Model has an A-Zone decrease of 0.3-7 m (0.6-14 times the 0.5 m increment).
- ❑ There is no equivalent parameter in the Tammetta model, but it is noted in Tammetta (2012) that "Host geology appears to play a minor role".

## Database Probability Statistics

Representative statistics for characteristic ratios derived for the Ditton database are listed in Table 4 and Table 5. When applied to the Ditton database for Australian coalfields, the Tammetta formula leads to similar statistics in Table 6.

A common first-order estimate of fractured zone height is afforded by the ratio A/W, which is 0.45 for the Ditton concept at the median (Table 4) and 0.78 for the Tammetta concept at the median (Table 6). The Ditton B-Zone ratio is 0.60 at the median (Table 5).

Another common first-order estimate of fractured zone height is afforded by the ratio A/T, which is 21-37 for the Ditton concept (Table 4) and 33-61 for the Tammetta concept (Table 6). The Tammetta estimates would appear excessive and are likely to include areas of disconnected fractures given that the B-zone range, which does include disconnected fractures, is 27T to 71T.

**Table 4. Exceedance Probabilities for Ditton Continuous Fracture Zone (A-Zone) Height for Australian Coalfields.**

| EXCEEDANCE PROBABILITY | Height of Fracture Zone / Panel Width [A/W] | Height of Fracture Zone / Cover Depth [A/H] | Height of Fracture Zone / Mining Height [A/T] |
|---|---|---|---|
| 20% | 0.38 | 0.23 | 21 |
| 50% | 0.45 | 0.43 | 32 |
| 80% | 0.73 | 0.69 | 37 |

For the parameters W, H and T in turn, the median B-height exceeds the median A-height by 33%, 100% and 34% (Table 5).

**Table 5. Exceedance Probabilities for Ditton Discontinuous Fracture Zone (B-Zone) Height for Australian Coalfields.**

| EXCEEDANCE PROBABILITY | Height of Fracture Zone / Panel Width [B/W] | Height of Fracture Zone / Cover Depth [B/H] | Height of Fracture Zone / Mining Height [B/T] |
|---|---|---|---|
| 20% | 0.47 | 0.60 | 27 |
| 50% | 0.60 | 0.86 | 43 |
| 80% | 1.07 | 0.95 | 71 |

**Table 6. Exceedance Probabilities for Tammetta Desaturated Zone Height for Australian Coalfields. [Derived using Tammetta formula applied to the database of Ditton]**

| EXCEEDANCE PROBABILITY | Height of Desaturated Zone / Panel Width [H/W] | Height of Desaturated Zone / Cover Depth [H/d] | Height of Desaturated Zone / Mining Height [H/t] |
|---|---|---|---|
| 20% | 0.61 | 0.32 | 33 |
| 50% | 0.78 | 0.80 | 48 |
| 80% | 1.02 | 1.13 | 61 |

There is a substantial difference between the Ditton A-height and the Tammetta desaturation-height. Table 7 shows comparative statistics for the Ditton and Tammetta conceptual models. For the parameters W, H and T in turn, the median desaturation-height exceeds the median A-height by 73%, 86% and 50%.

**Table 7. Exceedance Probabilities for Ditton Continuous Fracture Zone (A-Zone) Height and for the Tammetta Desaturated Zone Height for Australian Coalfields.**

| STATISTIC | Height of Fracture Zone / Panel Width [A/W] | | Height of Fracture Zone / Cover Depth [A/H] | | Height of Fracture Zone / Mining Height [A/T] | |
|---|---|---|---|---|---|---|
| | Ditton | Tammetta | Ditton | Tammetta | Ditton | Tammetta |
| **20%** | **0.38** | 0.61 | **0.23** | 0.32 | **21** | 33 |
| **50%** | **0.45** | 0.78 | **0.43** | 0.80 | **32** | 48 |
| **80%** | **0.73** | 1.02 | **0.69** | 1.13 | **37** | 61 |

## Model Probability Distributions

Calculations of A-Zone and B-Zone heights, and associated ratios, for the entries in the Ditton database have been sorted and ranked to give cumulative probability distributions in Figure 10 to Figure 14. The Ditton Geology Model and Geometry Model track each other closely.

Comparative cumulative probability distributions (Ditton and Tammetta models) are shown in Figures 12, 13 and 14 where it appears that the Tammetta formulation agrees better with the B-zone definition. For the parameters W, H and T in turn, the median desaturation-height exceeds the median B-height by -0.4%, 5% and -8%.This suggests that the Tammetta formulation includes zones of disconnected fractures.

## Conclusion

Opinions have been offered in this report on two literature reviews endorsed by the IESC:

A. Commonwealth of Australia 2014, *Temperate Highland Peat Swamps on Sandstone: evaluation of mitigation and remediation techniques, Knowledge report*, prepared by the Water Research Laboratory, University of New South Wales, for the Department of the Environment, Commonwealth of Australia; and

B. Commonwealth of Australia 2014, *Temperate Highland Peat Swamps on Sandstone: longwall mining engineering design—subsidence prediction, buffer distances and mine design options, Knowledge report*, prepared by Coffey Geotechnics for the Department of the Environment, Commonwealth of Australia.

The opinions are restricted to statements on surficial and deep fracturing as a result of underground mining:

1. The treatment of fractured zone algorithms in the literature reviews is inadeqate as the work of Ditton, documented in Ditton and Merrick (2014), is ignored;
2. The Ditton model for fractured zone height is considered superior to the Tammetta algorithm due to a basis in geotechnical theory, a correct trend for sensitivity to mining height, calibration to Australian conditions, and inclusion of a host geology term;

3. The association of the Collapsed Zone in the Tammetta model with complete desaturation is disputed, given the retention of significant volumes of water in the matrix of the rock material in this zone, and statistical correlation of the height of this zone with the B-Zone altitude in the Ditton model, which marks the top of a zone that has disconnected fractures;

4. The treatment of fracture permeabilities in the literature review (in Report A) is inadeqate as the substantial body of work on discrete fracture networks is ignored;

5. The estimates for fracture permeability are simplistic and grossly overstated, due to lack of consideration of fracture connectivity influenced by closure or truncation;

6. The conclusion that "a few small cracks through the swamp substrate can lead to substantial vertical drainage" is invalid, due to over-reliance on the cubic law for relating water flow to aperture size, and lack of consideration of the relative sizing of water-holding cracks and the water stored within intact swamp sediments."

## Historical context

Since 2002, Centennial has conducted extensive research on the effects to groundwater systems and ecosystem resilience of longwall mining under the Newnes Plateau. An extensive groundwater monitoring network (comprising 36 swamp piezometers, 36 open hole aquifer piezometers and 26 multi-level vibrating wire piezometers) has been installed and monitored in current and future mining areas. The geology of the overlying strata has been modelled using data from 501 boreholes on the Newnes Plateau. Hydrogeological characterisation of THPSS on the Newnes Plateau has been conducted for the swamps in the Angus Place and Springvale Mine Extension Project areas.

The COSFLOW groundwater model used by CSIRO, and referenced as Appendix K: CSIRO Numerical Modelling Report to the SVMEP EIS and the APMEP EIS, is arguably the most representative model currently in use (Merrick (2014), Kay (2014)). NSW Office of Water reviewed the EIS' and stated in part: "In general, the impact assessment on aquifers has been carried out to a high standard, including preparation of a large and complex groundwater model by CSIRO. The most sensitive receptors in the area are the protected Temperate Highland Peat Swamps on Sandstone, for which longwall mining has been declared a key threatening process under the Threatened Species Conservation Act 1995. A great deal of attention has been paid in the EIS to demonstrate that the proposed extensions will not significantly harm overlying swamps and no specific shortcomings have been found in this assessment."

The COSFLOW model is able to predict groundwater behaviour as measured by changes in piezometric head in response to mine subsidence, which appear to occur as changes to phreatic surfaces within aquifers, instead of as a "height of complete dewatering". The COSFLOW model uses a "ramp function" to simulate the reduction in changes to permeability higher in the overburden. This ramp function is based on measured A, B and C zone data which is correlated to measured changes in permeability (from actual packer test results). As such this model is more representative of what actually occurs than other groundwater models.

In addition to using a groundwater model for the Angus Place and Springvale MEP's, an empirical model has also been used to characterise changes to groundwater systems caused by longwall mining throughout the overburden lithology. The height of continuous fracturing (HoCF) has been assessed for all longwalls in the proposed MEP areas using the DgS and Hydrosimulations Geology Pi-Term model. A presentation on the new methodology was co-authored by Steve Ditton and Noel

Merrick and presented at the Australian Earth Sciences Convention (AESC) in July 2014. The new methodology recognises the key fracture height driving parameters of panel width (W), cover depth (H), mining thickness (T), and local geology factors (t'), which represents the effective thickness of strata at height of A-Zone to estimate the A-Zone and B-Zone horizons above a given longwall panel. This model is superior to the existing models as it does recognise geology from a geotechnical perspective. The Pi-Term empirical model is based on an extensive database of 34 Case Studies from all NSW and Qld Coalfields.

It has also been calibrated against local data from a number of multi-level extensometers, multi-level vibrating wire piezometers and groundwater level monitoring bores. Microseismic data from overburden monitoring at Longwall 413 also appears to support the modelled height of the A-Zone. The effective delineation of A, B and C Subsidence Zones is critical to understanding effects to groundwater in the overburden.

The process by which the Pi-Term empirical model was calibrated to the geological and hydrogeological conditions and then used to model subsidence zones in future mining areas at Angus Place and Springvale was through:

- Measuring subsidence zones using extensometers
- Measuring groundwater effects within different subsidence zones using vibrating wire piezometers AND water level monitoring piezometers (changes in storage though minor bed separation may change pressures without measurable changes in water level)
- Modelling of subsidence zones using the Pi-Term Model (calibrated to site measured data)
- Use of historical piezometric response within the measured subsidence zones to approximate future groundwater response in the overburden (modelled subsidence zones) throughout the mine extension areas.

It is certainly the case that significant claystone aquitards are present in the overburden lithology and that these have a significant effect on groundwater behaviour in response to longwall mining. The Mt York Claystone (analogous to the Bald Hill Claystone in the Southern Coalfield) is a major claystone unit (average 22m thick and laterally continuous across the historical and proposed mining areas) which lies approximately 200m above the Lithgow Seam. Measurement with multi-level vibrating wire piezometers in 26 different boreholes over up to a 12 year period indicates that desaturation of the AQ3 aquifer which underlies the Mt York Claystone is very significant, compared to a relatively minor response in the AQ4 aquifer which overlies the Mt York Claystone (this is also modelled in the COSFLOW groundwater model).

In addition, there are a number of claystone units (up to 4m in thickness) located in the Burralow Formation, which lies immediately below the surface. These units appear to have a significant influence on retarding downward movement of groundwater flows and causing lateral movement of groundwater into the adjacent valleys, where it represents a significant source of water to the THPSS (GDE's) which lie in those valleys. These do not appear to be significantly affected by longwall mining, as measured in five water level monitoring bores installed in 2005 and subsequently undermined by longwall panels, without measurable response to water levels. This measured lack of change to groundwater levels has been measured at a number of other bores also.

In a Peer Review of Mine Subsidence Induced Height of Fracturing Issues for Angus Place and Springvale Collieries, Kay (2014) wrote: "MSEC has reviewed the above referenced CSIRO and DgS Reports and found that they provide detailed information on the existing environment, the groundwater systems, the overburden and the presence of layers of low permeability for this

Western Coalfields area. The selection and use of both numerical and empirical models which have been calibrated to site data over many years and used for the Angus Place and Springvale Mine Extension Projects, are believed to represent the current "industry best practice".

MSEC has reviewed these reports and, in our opinion, we consider the assessments of the HoCF for the proposed longwalls at Angus Place and Springvale Collieries that are included in these reports are reasonable for this particular geological region.

It is noted that these reports have provided geologically adjusted and calibrated predictions and assessments of the likely HoCF over the proposed longwalls at Angus Place and Springvale Collieries, which, in our opinion, appear to be appropriate for this geological region and, hence, should provide a satisfactory estimate for the impact assessments on the groundwater systems from the proposed mining for this particular geological region. The selection and use of both numerical and empirical models (calibrated to site data over many years) which has been used in the Angus Place and Springvale Mine Extension Projects, represents current industry best practice and provides a satisfactory estimate of the effects to groundwater systems of the proposed mining."

Based on the research undertaken and described above, a site specific hydrogeological model has been developed that is considered by a number of experts in the field as best practice. The level of detail, as well as the calibration with a significant geological and hydrological data set, is unprecedented for longwall mining operations in the Western Coalfield and is superior to the modelling summations made in the IESC Report.

## 7.6 Observed impacts on peat swamps from longwall mining

### 7.6.6 Simulation of groundwater hydrographs

The data and analysis conducted in CoA (2014) contains numerous errors of fact and contradictory arguments. These are summarised below:

**Table 7.4 –Errors of Fact**

The stated mining height of 3.7m is incorrect (116% of actual).

Timing of undermining of WE1 piezometer (Aug 2006) is not correct. WE1 piezometer was outside of the angle of draw of LW411 and lay directly over Angus Place LW960, which undermined the piezometer in 2010.

Licenced Discharge Point 6 is approximately 500m downstream of NS1 and NS2 and thus can't have influenced data.

Data from 2006 to 2009 clearly show periodic waterlogging of swamp (outside of periods influenced by mine water discharges).

At WE2 piezometer, 2 different seam heights have been used (3.2m and 3.7m). Angus Place and Springvale both minethe same seam section, which is approximately 3.2m in height. NB the height of the collapsed zone calculated by Tametta equation varies by 44m (13%) as a result of this change.

The reduced number of spikes in the hydrograph at WE2 piezometer after LW960 occurred because mine water discharges ceased in 2010.

The “Clear impact” at WE2 piezometer in Aug 2006 was due to cessation of MWD

**Analysis of Table 7.4**

Analysis of Table 7.4 on page 129, references WE1 as having the greatest angle of influence at 45 degrees (“From the database, the angle of influence for impacts (defined as the angle whose tangent is the lateral distance to an impact at the surface, divided by the overburden thickness) is a maximum of approximately 45° (WE1 and LW411 Springvale”). In Table 7.4, in the context of WE1 piezometer and Longwall 411, the analysis states “Impact masked by drought effect”. These analyses are contradictory and do not support the stated position.

The text on page 128 states “The impact at piezometer WW1 (and WW2 close by) is interpreted from comparing the deficit cumulative residual (R) to measured WW1 water level, as shown in Figure 7.17. Undermining by LW940 in late 2008 appears to have had negligible impact.”). The analysis continues on page 129 “The responses at …. at WW1 and WW2 (West Wolgan Swamp), suggest that the most severe impact occurs at the edge of the panel, to a minimum distance of half the panel width (0.5w) past the edge of the panel (i.e. a distance of 1 panel width from the centre of the panel).” Does this mean that undermining causes negligible impact and that only subsequent panel extraction causes impact (i.e. negative angle of influence)? The author goes on the say “Impacts were not interpreted to occur at two locations where the angle was approximately 50° (WW1 and LW930) and 45° (WW2 and LW930). The database is too small to draw definite conclusions about the generic extent of off-panel impact; however, the results agree closely with field observation discussed in Ouyang and Elsworth (1993) where a probable angle of influence of 42° was interpreted from a large database of dewatering information for water supply wells.”. This logic fails to acknowledge the earlier statement “ Undermining by LW940 in late 2008 appears to have had negligible impact” in this argument.

Comparison to Tametta’s height of complete dewatering model (incorrectly calculated using 3.7m seam height, then stating “Clear impacts on a swamp groundwater system occurred for ground surfaces as high as 86 m above the top of the collapsed zone (see the model of Tammetta 2012).”.

Data from WW3 and WW4 piezometers was dismissed as “No pre-impact water-level data available”. As per figure below there was at least 6 months pre-mining data for these piezometers.

It is notable that data from only two swamps (4 piezometers) was discussed in the analysis (East Wolgan and West Wolgan) was discussed in the analysis, with data from the other 36 swamp piezometers not used in analysis.

KC1 piezometer is in Table 7.4, but not discussed as impacts were “over panel” with zero degree angle of influence.

Data from NS1 and NS2 piezometers at Narrow Swamp was dismissed as “Impact masked by last discharges at LDP06. Following water levels show impact”. LDP06 is downstream of NS1 and NS2 piezometers by approximately 500m and does not influence water levels at NS1 and NS2.

There is no mention of data from Sunnyside West Swamp, Sunnyside Swamp, Junction Swamp, where monitoring showed no measurable influence in response to mining.

## Review of the IESC Cumulative Residual of Water Deficit ‘R' Method

Below is a critique of the Water Deficit ‘R' Method used for the analysis of hydrographs in the EISC report. The analysis of hydrograph data at West Wolgan Swamp is disputed as concluded by the analysis below.

### Background

The correlation between rainfall and groundwater level has been frequently observed. Bredenkamp et. al. (1995) proposed that the relationship between these two series is explained based on groundwater mass balance. The work by Bredenkamp et. al. was based on case studies in South Africa. Butterworth et. al. (1999) presents a review of this method. Butterworth et. al. note that, with some limitations, water levels in a specific aquifer will fluctuate according to Cumulative Rainfall

Departure (CRD) from the mean, given a proportionality of *a/S*, where *a* is fraction of rainfall that recharges the groundwater system and *S* is storativity.

Application of the method is presented in Butterworth et. al. (1999) and Baalousha (2005) and further discussion of the CRD method is presented in Xu and van Tonder (2001).

A critique of the CRD method is presented by Weber and Stewart (2004). Weber and Stewart note that there are several limitations to the method that require consideration, however, it has valid hydrologic meaning in the short term. Weber and Stewart's criticisms include: the choice of beginning and end points of the data can affect the results, a lack of consideration that above average rainfall can reset the hydrological system without mathematically eliminating the accumulated deficit, and lack of support for the necessary inference that rainfall events and observed groundwater level response that are widely separate in time are related.

The methodology presented by the IESC (Commonwealth of Australia (CoA), 2014) is called Cumulative Residual of Water Deficit, R. The methodology is unorthodox and, as will be presented below, results in an incorrect identification of impact at West Wolgan Swamp in the period 2009/10 and post 2011. This letter presents a critique of the proposed IESC methodology.

Additional discussion of observed simultaneous groundwater level response behaviour in West Wolgan Swamp and Sunnyside West Heath Swamp, spatially separate to LW950, is presented elsewhere in the Response to Submissions.

## Model Approaches

The CRD method, when fully deployed, correlates groundwater level response to rainfall recharge to the groundwater system via a simplified water balance. Rainfall recharge in the CRD method is effective recharge, namely inclusive of the effect of surface water rainfall-runoff processes, evapotranspiration etc. The CRD method does not explicitly incorporate evaporation, rather it is incorporated into the concept of effective recharge.

In general, the CRD method is usually only partially deployed. The typical approach is as per Bredenkamp et. al. (1995), namely calculation of the departure of observed rainfall over a defined interval from the mean. The departure is then added cumulatively. Equation (1) presents the general form, after Xu and van Tonder (2001):

$$ {}_{av}^{1}CRD_i = \sum_{n=1}^{i} R_n - \kappa \sum_{n=1}^{i} R_{av} \quad (i = 0, 1, 2, 3, \ldots N) $$

Equation (1)

where $R_i$ is rainfall in the $i$ th period, usually months; $R_{av}$ is average rainfall; and $K = 1$ when there is no pumping and/or natural net outflow from the groundwater system. As noted by Weber and Stewart (2004), caution should be exercised with respect to calculation of the mean. In general, the mean is calculated outside of the period of interest and normally based on long-term climatic statistics of the relevant BOM station.

The methodology presented by the IESC (CoA, 2014) uses a different approach to Bredenkamp et. al. (1995), namely inclusive of Pan A evaporation to derive a water deficit. CoA (2014) states "*Fortnightly rainfall … and fortnightly average pan evaporation from the Australian Bureau of Meteorology gridded dataset were used to construct a running cumulative residual (R) of the difference between fortnightly rainfall and evaporation (the water deficit). R is calculated by first finding the time series of fortnightly rainfall minus fortnightly pan evaporation, referred to as the fortnightly water deficit. The average of the time series of the fortnightly water deficit is then found. A second time series is then created, comprising the fortnightly deficit minus the average, creating a time series of deficit residuals. These deficit residuals are then cumulatively added to create R. This simple yet powerful formulation tracks the groundwater levels reasonably well.*".

## Critique

To investigate the impact of the inclusion of evaporation to the CRD method, Figure 7.17 of CoA (2014) is presented as Figure 1 below, which includes groundwater level in West Wolgan Swamp, WW1, together with the reconstructed ‘R' model. It is noted that the IESC model was based on the SILO (http://www.longpaddock.qld.gov.au/silo/) gridded datasets (both rainfall and evaporation) whereas the reconstructed ‘R' model was based on observed rainfall on the Newnes Plateau (BOM Station No. 63062) and Lithgow (BOM Station No. 63132). Evaporation in the reconstructed ‘R' model was obtained from the BOM Station at Bathurst (Station No. 63005).

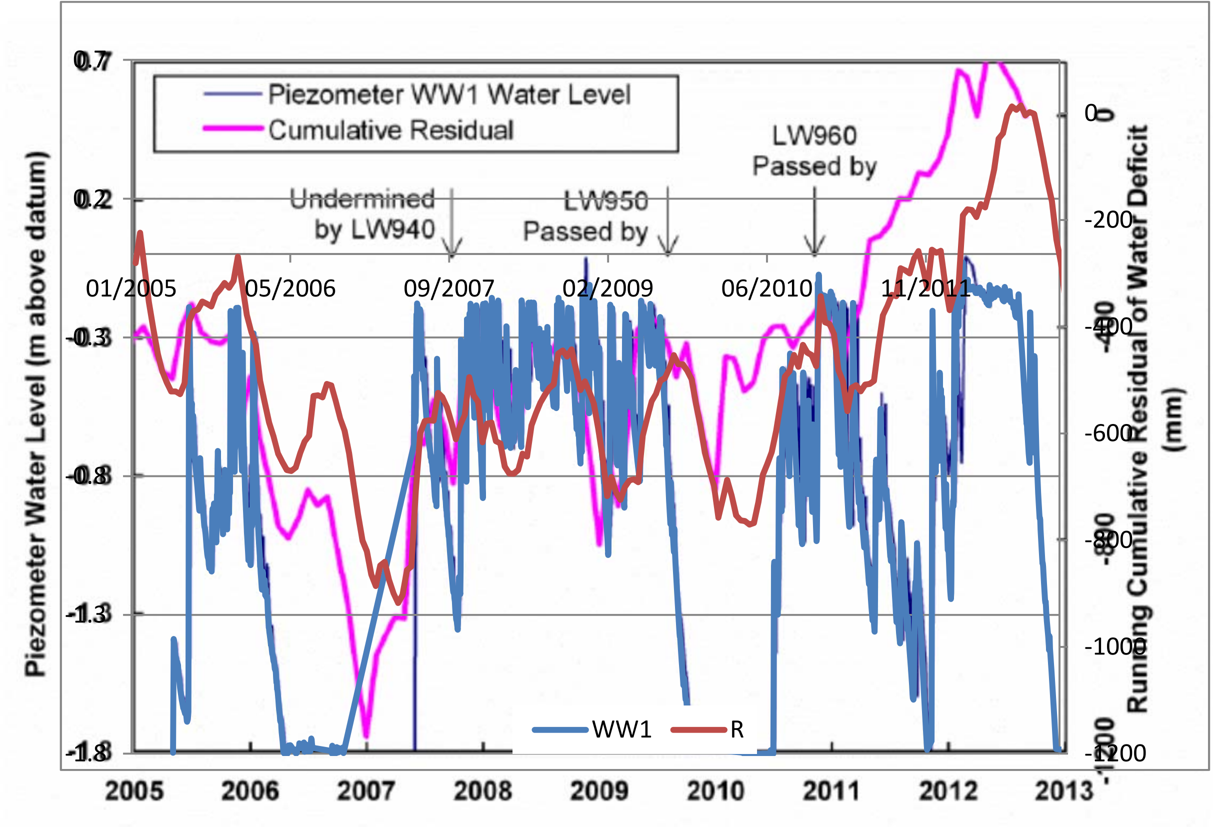

Figure 7.17 Modelled hydrograph for piezometer WW1, West Wolgan Swamp, Angus Place Mine, 2005 to 2013.

**Figure 1: Reconstructed ‘R' model and Groundwater Level Observation in Monitoring Piezometer, WW1 in the West Wolgan Swamp (adapted from CoA, 2014).**

From Figure 1, it is apparent that the reconstructed ‘R' model is based on slightly different rainfall and evaporation data, however, the magnitude of fluctuation and increasing and decreasing trends are reasonably replicated, in particular during the periods of interest between 2009/10 and post 2011.

A conclusion from the IESC study is that in the period of interest in 2009/10 and post 2011 that the trend in ‘R' diverges from observed groundwater level response and thereby implies impact to West Wolgan Swamp. As will be presented below, this conclusion is disputed because ‘R' depends on evaporation and as groundwater level in the swamp drops, the assumption that full Pan A evaporation can occur, despite a groundwater level of more than 1m below ground surface, becomes invalid.

To test the impact of evaporation on the IESC method, the ‘R' model was reconfigured as follows:

fortnightly evaporation was excluded

fortnightly residual was redefined as difference between fortnightly rainfall and average of fortnightly rainfall

cumulative residual was calculated as per normal.

Figure 2 presents the reconfigured IESC model. It is highlighted that the rainfall dataset used in the reconfigured model was the same as adopted in the reconstructed ‘R' model presented in Figure 1.

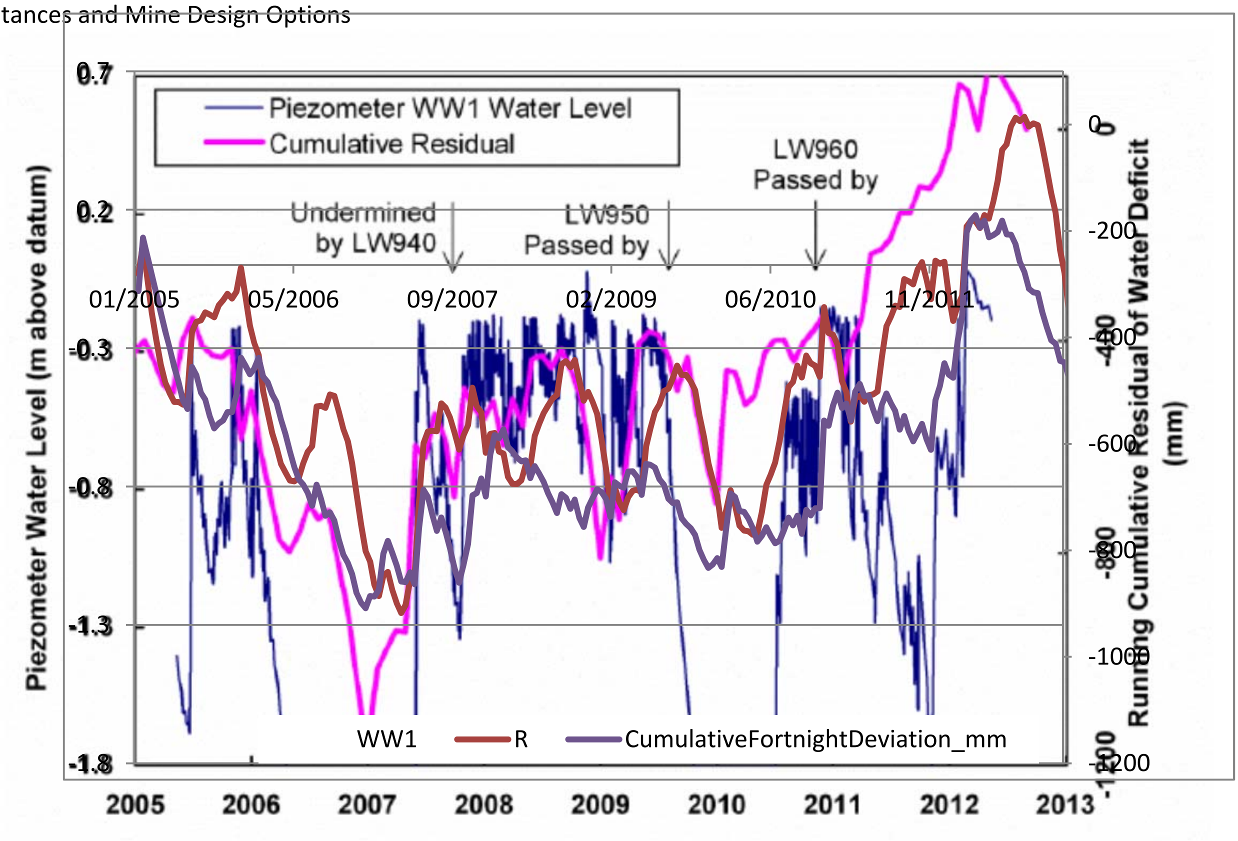

Figure 7.17 Modelled hydrograph for piezometer WW1, West Wolgan Swamp, Angus Place Mine, 2005 to 2013.

**Figure 2: Reconfigured IESC model without evaporation (adapted from CoA, 2014).**

From Figure 2, in the period of interest in 2009/10 and post 2011, the reconfigured IESC model illustrates either a stationary or declining trend rather than an increasing trend. The analysis indicates that during dry periods, evaporation dominates the ‘R' model, however, the assumption that full Pan A evaporation can occur from the naturally declining water table is not valid.

Weber and Stewart (2004) do comment, however, that the link between observed change in groundwater level and average can be problematic when the CRD method is applied over the long term. It is considered that the presented period of 10 years is at the upper limit of validity and it is likely that there have been ‘hydrologic' resets.

The influence of the assumption of a single and internal mean instead of an externally derived, month to month varying, mean was investigated and the results are presented in Figure 3. This model comprised:

fortnightly rainfall as per the reconstructed ‘R' model

fortnightly departure from mean obtained from long-term climatic statistics, varying dependent on month cumulative departure calculated as per normal.

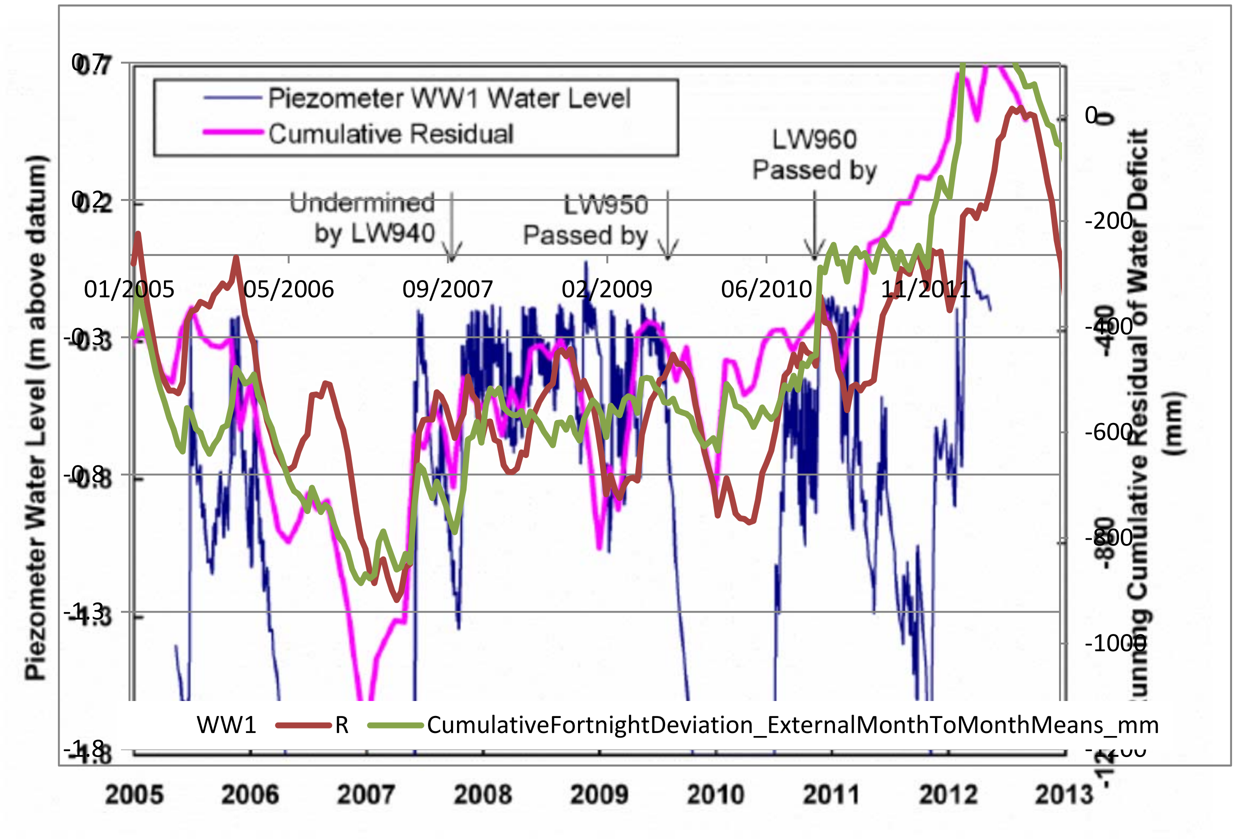

Figure 7.17 Modelled hydrograph for piezometer WW1, West Wolgan Swamp, Angus Place Mine, 2005 to 2013.

**Figure 3: Reconfigured IESC model without evaporation but including external month to month 'mean' (adapted from CoA, 2014).**

From Figure 3, in the period of interest in 2009/10 and post 2011, month to month 'mean' improves the correlation between observed decline in groundwater level and 'static' cumulative rainfall departure. The results imply that seasonal variation in mean rainfall is a useful consideration in the CRD method.

## Conclusion

A technical summary of the origin of the CRD method is presented, which does not include evaporation or the concept of water deficit. The CRD methodology is typically only partially deployed, however, is based on a simplified groundwater mass balance. Issues such as effect of surface rainfall-runoff processes and evapotranspiration are incorporated via the concept of effective recharge in the full method.

It is presented that the assumption in the IESC 'R' model that full Pan A evaporation occurs during naturally declining groundwater levels, to a maximum of 1.8m below ground surface, is not valid. It is demonstrated that reconfiguration of the IESC model to correct this assumption, as well as incorporation of an externally derived month to month varying mean, leads to an improved correlation between groundwater response and climatic conditions.

It is concluded that there was no impact to West Wolgan Swamp, as is asserted in the EISs of the Angus Place and Springvale Mine Extension Projects, and the identified divergence between the IESC 'R' model and observed groundwater level can be explained by assumptions made in the 'R' model.

## References

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Bredenkamp D.B., Botha L.J, van Tonder, G.J. and H.J. van Rensburg, 1995. *Manual on Quantitative Estimation of Groundwater Recharge and Aquifer Storativity*. Reference No. WRC Report TT73/95.

Butterworth, J.A., Schulze, R.E., Simmonds, L.P., Moriaty, P. and F. Mugabe, 1999. *Hydrological processes and water resources management in a dryland environment IV: Long-term groundwater level fluctuation due to variation in rainfall.* Hydrology and Earth System Sciences, 3(3): 353-361.

Commonwealth of Australia, 2014a. *Temperate Highland Peat Swamps on Sandstone: longwall mining engineering design – subsidence prediction, buffer distances and mine design options*. Reference No. N/A, dated August 2014.

Weber, K. and M. Stewart, 2004. *A Critical Analysis of the Cumulative Rainfall Departure Concept*. Groundwater, 42(6): 935-938.

Xu, Y. and G.J. van Tonder, 2001. *Estimation of recharge using a revised CRD method*. Water SA, 27(3): 341-343.

The following analysis was conducted on the hydrographs from Sunnyside West Swamp Heath and West Wolgan Swamp and also does not reach the same conclusions as those reached in CoA (2014).

### Sunnyside West Swamp Heath and West Wolgan Swamp

The Sunnyside West Swamp Heath is located upstream of the Sunnyside Swamp over Springvale Colliery, and West Wolgan Swamp is located over Angus Place Colliery. While these swamps have been classified as different botanical types, both are located at higher elevations, where the groundwater table beneath the low flanking ridges is situated well below the base of the swamps. As a result, these swamps are not fed by the main aquifer in this area, but rely to a large extent on rainfall to contribute to the groundwater. The swamps have probably formed in these areas due to the presence of a perched water table on a high-level aquitard.

Sunnyside West Swamp Heath is located over the pillar between LW412 and 413 at 10 cut-through at Springvale Colliery (Figure 9). West Wolgan Swamp is located over LW 940 and LW 950 at 17 cut-through at Angus Place Colliery (Figure 10). Both swamps are periodically waterlogged swamps in which the groundwater level varies significantly with rainfall.

Groundwater monitoring commenced at West Wolgan Swamp in two piezometers (WW1 and WW2) in May 2005, while monitoring in one piezometer (SW1) at the Sunnyside West Swamp Heath commenced in July 2007. Monitoring data are shown in Figure 11. West Wolgan Swamp was undermined by LW 940 in November 2007, while LW 950 passed the site in July 2009. At the Sunnyside West Swamp Heath, LW 912 passed beneath the swamp in January 2009 and LW 413 passed the site in July 2010. Groundwater monitoring results are presented in Figure 11, and discussed in detail in the following section.

These two swamps are discussed together as they display almost identical hydrogeological behaviour (even though they are separated by about 4 km), and the data from the piezometers in one swamp can be compared with data from the piezometers in the alternate swamp, to check for mining-related impacts. There is no flow monitoring at either of these swamps as they are both periodically waterlogged and flow from the downstream ends of these swamps occurs very rarely.

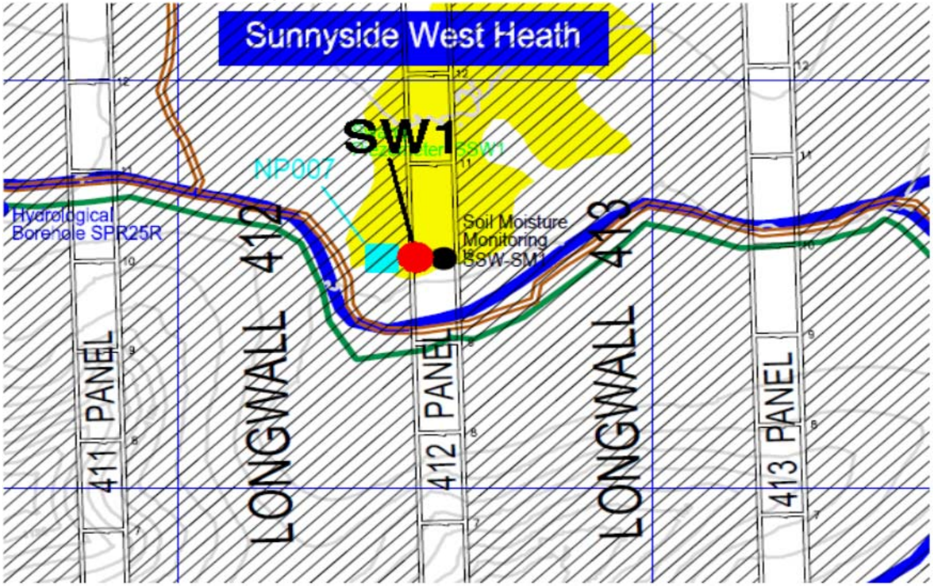


**Figure 9 - Sunnyside West Swamp Heath - location of piezometer**

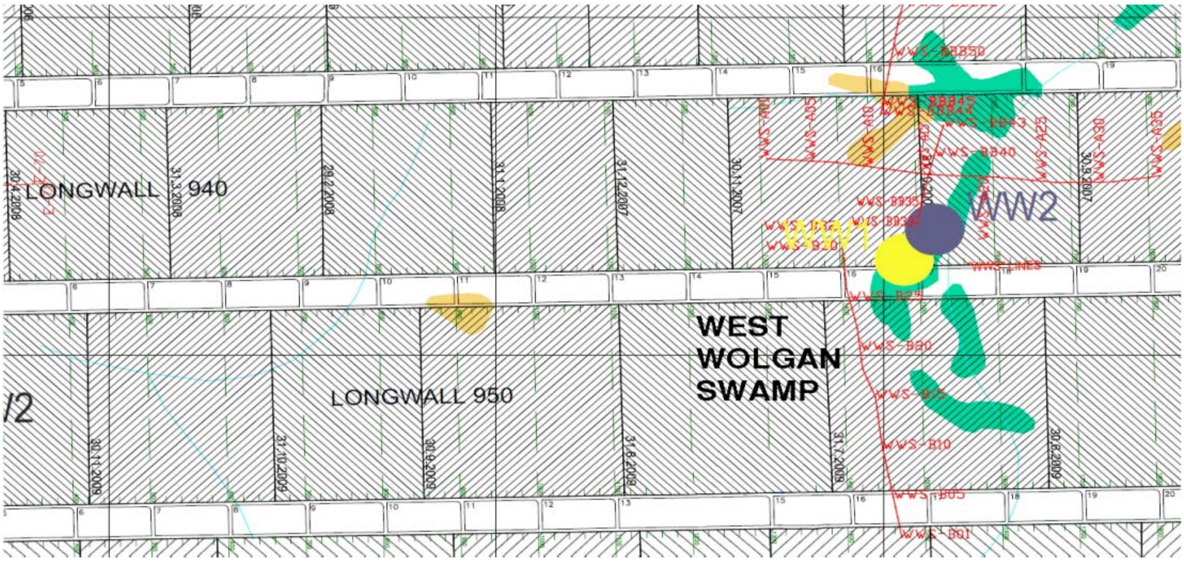


**Figure 10 - West Wolgan Swamp - location of piezometers**

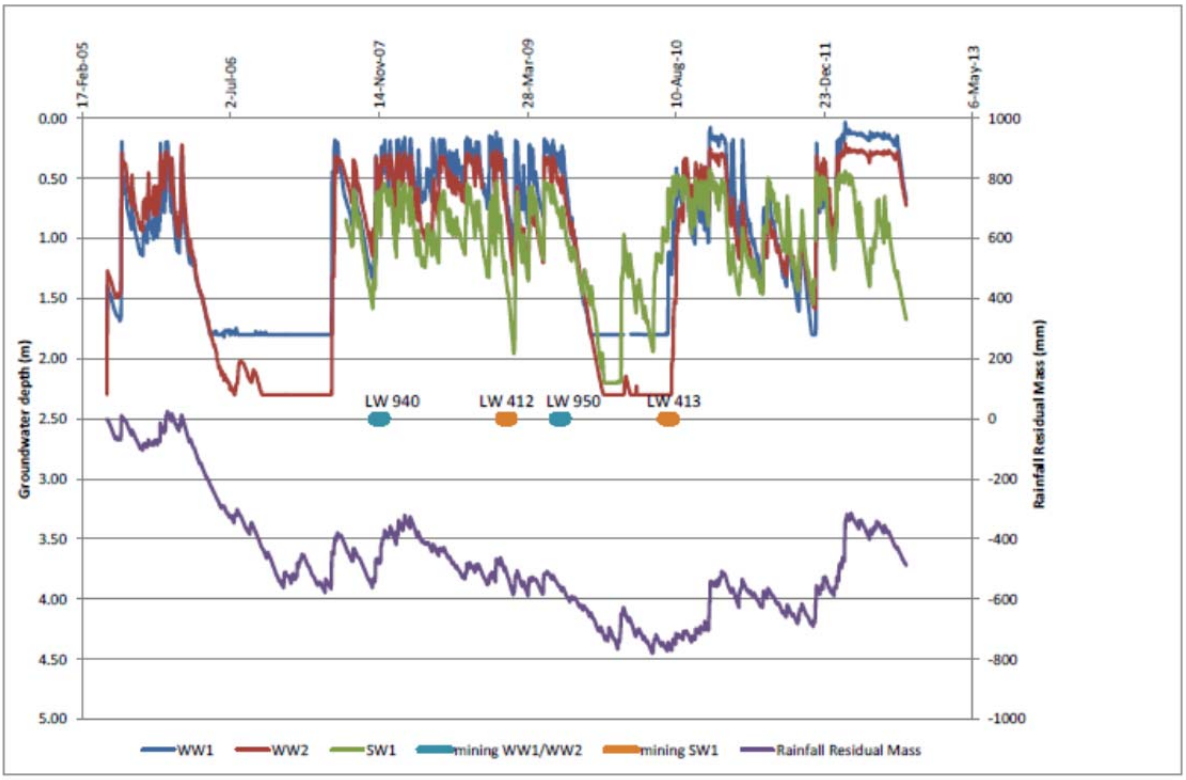


**Figure 11 – West Wolgan Swamp and Sunnyside West Swamp Heath – groundwater levels**

## Monitoring results and analysis

The monitoring results for WW1 and WW2 (Figure 11) in the West Wolgan Swamp show groundwater level movements which are typical of a periodically waterlogged swamp, where the groundwater level rises rapidly, then declines more gradually following rainfall events. The low groundwater level in both WW1 and WW2 in 2006/2007 (pre-mining) was due to the severe drought conditions at the time. This drought period is also evident on the rainfall residual mass plot shown in Figure 11. Above average rainfall in the latter half of 2007 raised the groundwater to pre-drought levels prior to the swamp being undermined by LW 940 in November 2007.

Following the undermining, the monitoring shows no change in the groundwater level behaviour in WW1 and WW2 to that observed prior to mining, with the same pattern of rapid rise followed by gradual decline after rainfall events. It is also clearly evident from Figure 11 that the post-mining groundwater level behavior in WW1 and WW2 is identical to the pre-mining behavior in SW1 in the Sunnyside West Swamp Heath, which at that time had not been undermined. This provides further evidence for a lack of mining-related impacts at the West Wolgan Swamp.

An identical pattern of groundwater movements is also evident after the undermining of SW1 in January 2009. These patterns are very similar to the patterns in WW1 and WW2 at the same time, and there is no discernible difference in the pre- and post-mining patterns or in the SW1 data and the WW1/WW2 data.

WW1 and WW1 showed a decline in groundwater level following the passage of LW 950 past the site in July 2009, but this was not due to mining. The low groundwater levels between September 2009 and early 2010 were due to abnormally low rainfall over this period, as there was a similar decline in the level in SW1. This again is evident in the decline of the rainfall residual mass during this period. Additionally, during this time, the data logger in WW1 malfunctioned and had to be replaced. These below average rainfall conditions reversed in late 2010 about the time that LW 413 passed SW1, and the groundwater level patterns returned to normal in both swamps. Again, there was no material difference between the groundwater level behaviour in the swamp after the passage of this longwall panel.

## Conclusions

The recent pattern of groundwater level movements in piezometer SW1 in the Sunnyside West Swamp Heath is consistent with the response measured prior to undermining by LW 412 in March 2009 (and almost identical to the movements in WW1 and WW2). The data indicate conclusively that there has been no impact from the mining in LW 412 or LW 413 on the hydrogeological conditions recorded within the swamp at SW1. No mining-related impacts are evident from the hydrogeological data, even though this swamp experienced near-maximum subsidence for the panel, which would have been of the order of 1.2 metres.

Similar analyses have also confirmed that mining at Angus Place has had no impact on the West Wolgan Swamp, where the post-mining groundwater level patterns have been compared to patterns in the Sunnyside West Swamp Heath and found to be near-identical. The groundwater level movements in both swamps are closely related to the rainfall residual mass, which reinforces the fact that both swamps are periodically waterlogged swamps.

### Hydrology of East Wolgan and Narrow Swamps (Baseline and Post-Mining)

Detailed analysis was conducted in the context of establishing the baseline hydrology of East Wolgan and Narrow Swamps was conducted Springvale Coal Pty Ltd (2013) EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau – Supplementary Data Volume 1. This analysis is summarised in Corbett et al (2014) and an extract presented below:

Groundwater levels at East Wolgan Swamp began to decline rapidly in February 2006 when Centennial commissioned the Water Transfer Scheme (WTS), which transferred water pumped from the mine via a pipeline off the Newnes Plateau for use by industrial water users (Wallerawang Power Station).

Hydrographs of East Wolgan Swamp piezometers WE1 and WE2, presented with the timing of mine water discharge and longwall mining as well as the cumulative rainfall deviation trend show strong correlations between groundwater levels and mine water discharges prior to mining. Following the cessation of mine water discharges, the hydrograph trends can be seen to be strongly influenced by rainfall.

There are periods (in excess of two years) during which pre-mining data for WE1 piezometer was not influenced by mine water discharge (March 2006 to March 2008), which may be used to characterise the pre-mining hydrology of East Wolgan Swamp. It is important to note that, at both piezometer locations, the data shows that the standing water level was at or below the WE1 piezometer instrument (indicated by discontinuities in the hydrograph trend) for most of the periods not influenced by mine water discharge. The standing water levels rise in response to rainfall events which are in excess of the long-term average trends and fall in response to less than average rainfall trends. The responses are typically immediate and of short duration, indicated by the “spikes” in the hydrograph trends. When the data recorded during mine water discharged is removed, the same trend can be seen in the pre-mining baseline data at WE1 piezometer (March 2006 to March 2008). Based on this baseline data it is concluded that East Wolgan Swamp was a periodically waterlogged swamp before commencement of mining activities.

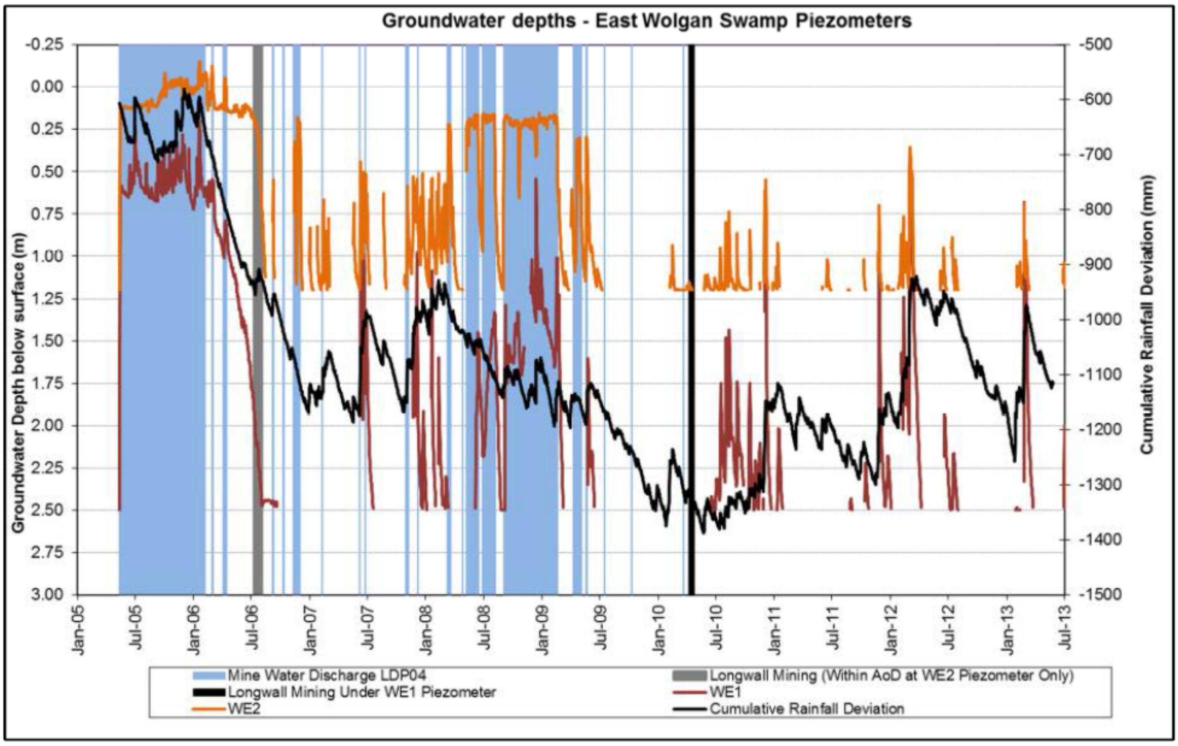


**Figure 8 Hydrographs of East Wolgan Swamp Piezometers WE1 and WE2 showing the timing of mine water discharge and longwall mining and the cumulative rainfall deviation trend**

### Narrow Swamp baseline hydrology

Figure 18 is a hydrograph of Narrow Swamp piezometers NS1, NS2, NS3 and NS4 showing the timing of mine water discharge and longwall mining as well as the cumulative rainfall deviation trend. The timing of mining was similar to that of the cessation of mine water discharges at LDP05 in February 2009, but the dominant influencing factor can be seen to be mine water discharges. Following the cessation of mine water discharges, the hydrograph trends can be seen to be strongly influenced by rainfall. The standing water levels rise in response to rainfall events that are in excess of the long term average trends and fall in response to less than average rainfall trends. The responses are typically immediate and of short duration, indicated by the ‘spikes’ in the hydrograph trends. When the data recorded during mine water discharged is removed, the same trend can be seen in the pre-mining baseline data. There is approximately 12 months pre-mining data (between March 2007 and March 2008) that is not affected by mine water discharge, which clearly shows that the swamp was periodically waterlogged prior to mining. It remains periodically waterlogged following mining.

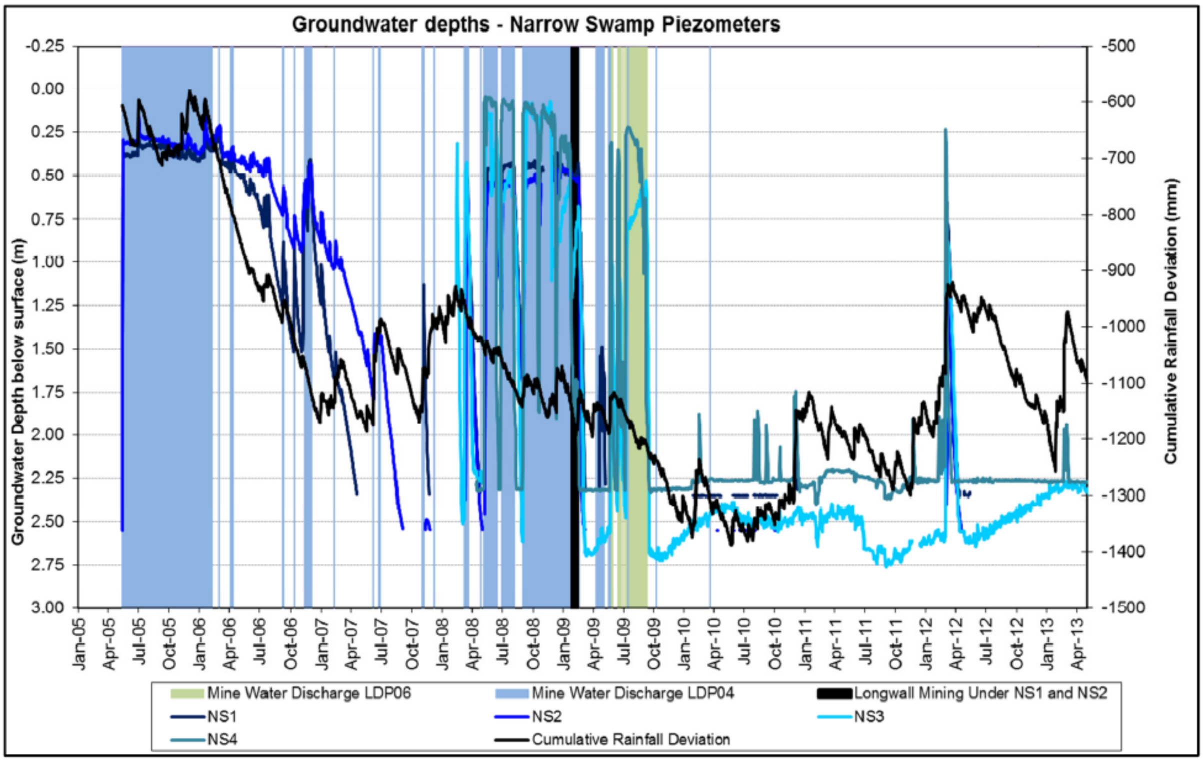


**Figure 18 Hydrographs of the four piezometers in Narrow Swamp, together with timing of mine water discharges and cumulative rainfall deviation**

### 7.6.6.1 Baal Bone Colliery

There are six piezometers installed in the vicinity of the Coxs River Swamp at Baal Bone Colliery. Of these, there are two installed into the swamp itself, BBP5 and BBP6. Piezometer BBP1 is identified in Figure 7.18 of CoA (2014) as being topographically up-gradient of piezometer BBP2 and both BBP1 and BBp2 reside within a mapped structural stress zone. Piezometer BBP3 lies approximately 1km southwest of LW29, again within a mapped structural stress zone. Piezometer BBP4 is located on the western side of the Coxs River Swamp.

As identified in CoA (2014), from Figure 7.19, a drop in groundwater level is observed in BBP1, BBP2 and BBP6 from July 2009. For BBP6, the monitoring piezometer is dry between October 2009 to July 2010. At BBP2, the groundwater level declines from ~952mAHD to a low of 945mAHD before recovering to 952mAHD in October 2010. The monitored water level at BBP1 shows a sharp decline until August 2009 and then abruptly stabilises and essentially remains static through to the end of the monitoring record. The water level response in BBP1 is unusual for two reasons, firstly the abrupt change in trend from declining to flat at about August/September 2009 that does not appear to correspond with a large recharge event, and secondly, the subdued magnitude of variation in response since that time. It is suspected that piezometer BBP1 has been damaged by ground deformation or the logger has malfunctioned. An alternative explanation is there has been a change in hydraulic properties induced by subsidence at that location, as proposed by CoA (2014).

In terms of the longer term impact of mining at Baal Bone Colliery on the Coxs River Swamp, groundwater level response in BBP2, located topographically down-gradient of BBP1, has recovered to pre-mining levels from the potential mining induced change in storage by July 2010, as has BBP, which is located in the swamp itself. At the end of the monitoring record, aside from BBP1, the absolute groundwater level of all monitoring piezometers equals or exceeds pre-mining levels and the magnitude of variation in level post-mining is indiscernible from pre-mining. If mining of LW29 lead to permanent decline in inflows to Coxs River Swamp then this would be reflected in observed water level response of BBP2 and BBP6, given they are topographically and hydrogeologically down-gradient. The temporary decline in observed water level in BBP2 is explained by a local change in storage, potentially limited to the structural stress zone, with no long term consequence.

# 8 Subsidence impacts on peat swamps and valleys

The case studies and analysis presented in Section 8 are from the Southern Coalfield of NSW and do not necessarily represent the scale of impacts in other Australian Coalfields for reasons related to geology, topography and in-situ stress regimes. Below are presented relevant data related to subsidence impacts to groundwater systems at Angus Place and Springvale mines in the Western Coalfield of NSW.

## 8.4 Impacts on peat swamps

The following case studies are provided as examples of monitoring results and interpretation in terms of longwall mining effects to swamps on the Newnes Plateau. They are provided in terms of the general headings in the IESC report.

**General lowering of groundwater table**

The following excerpt is copied from Corbett et al (2014), and describes monitoring results of groundwater levels between valleys in undermined areas of the Newnes Plateau.

**"Water level data from ridges between valleys containing Newnes Plateau Shrub Swamps**

Five water level monitoring boreholes were drilled in 2005 from the topographic ridges that lie between the valleys containing the following shrub swamps: West Wolgan Swamp, Narrow Swamp, East Wolgan Swamp, Sunnyside Swamp, Sunnyside East Swamp, Carne West Swamp and Gang Gang Swamp. Figure 14 is a plan showing the location of each of these bores (along the transect marked in red). Figure 15 shows the hydrographs of each of these boreholes since monitoring commenced in December 2005. The vertical lines on the hydrographs show the timing of mining beneath the borehole locations (in colours corresponding to the hydrographs). The black dashed line indicates the measured cumulative rainfall deviation. Figure 16 shows a cross section though the strata between the Lithgow Seam and the surface (along the transect indicated on Figure 14), including the location of mined longwall panels and the height of connected fracturing above them. The piezometer locations are also shown with the minimum and maximum standing water levels monitored at each location over the life of the monitoring installation. Monitoring of standing water levels at bores installed from the ridges between the shrub swamps indicates that there is no apparent change in response to mine subsidence and that observed minor fluctuations correspond with the cumulative rainfall deviation trend. This trend is the same for the ridges on either side of East Wolgan Swamp. The data indicates that the Burralow Formation (perched aquifer system) has not been significantly affected by mining over the period since 2005. The effect of the Mount York Claystone is evident in Figure 16, where mine design limits the height of connective fracturing to well below this stratigraphic unit. The objective of the mine design is to eliminate the potential for direct connectivity between the mine workings and the aquifer system above the Mt York Claystone."

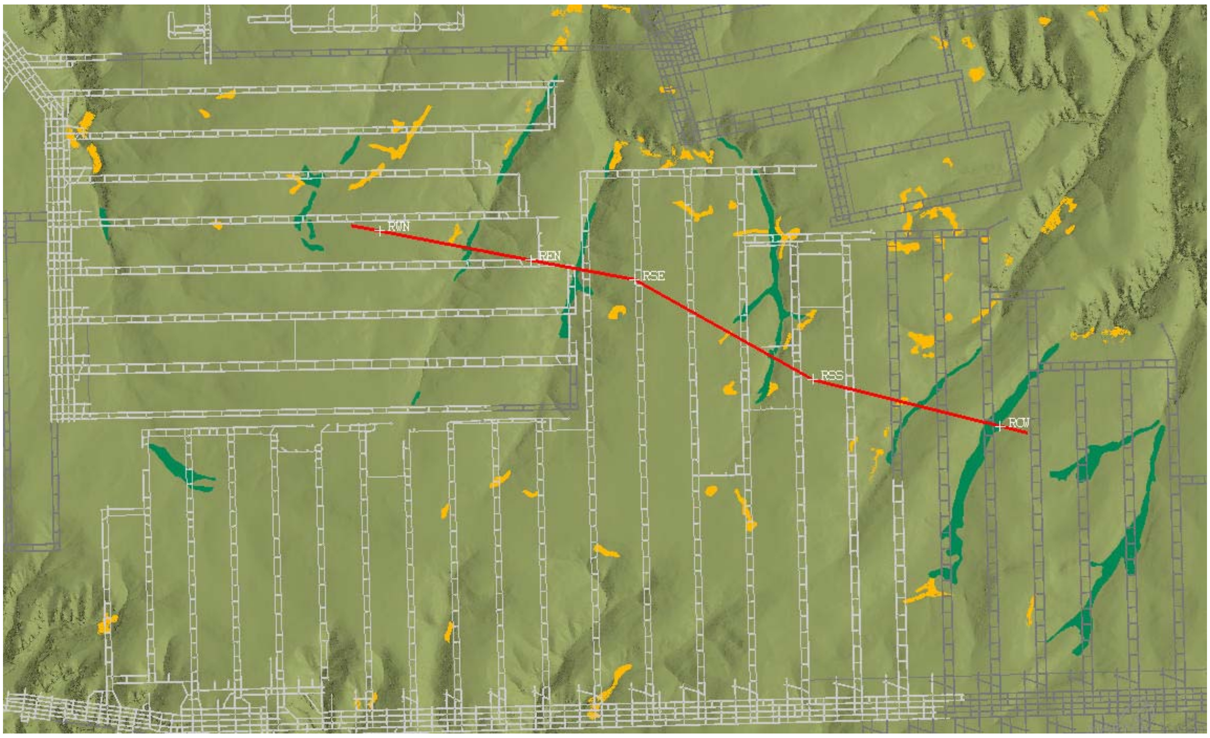


**Figure 14 Plan view of transect through ridge water level monitoring bores**

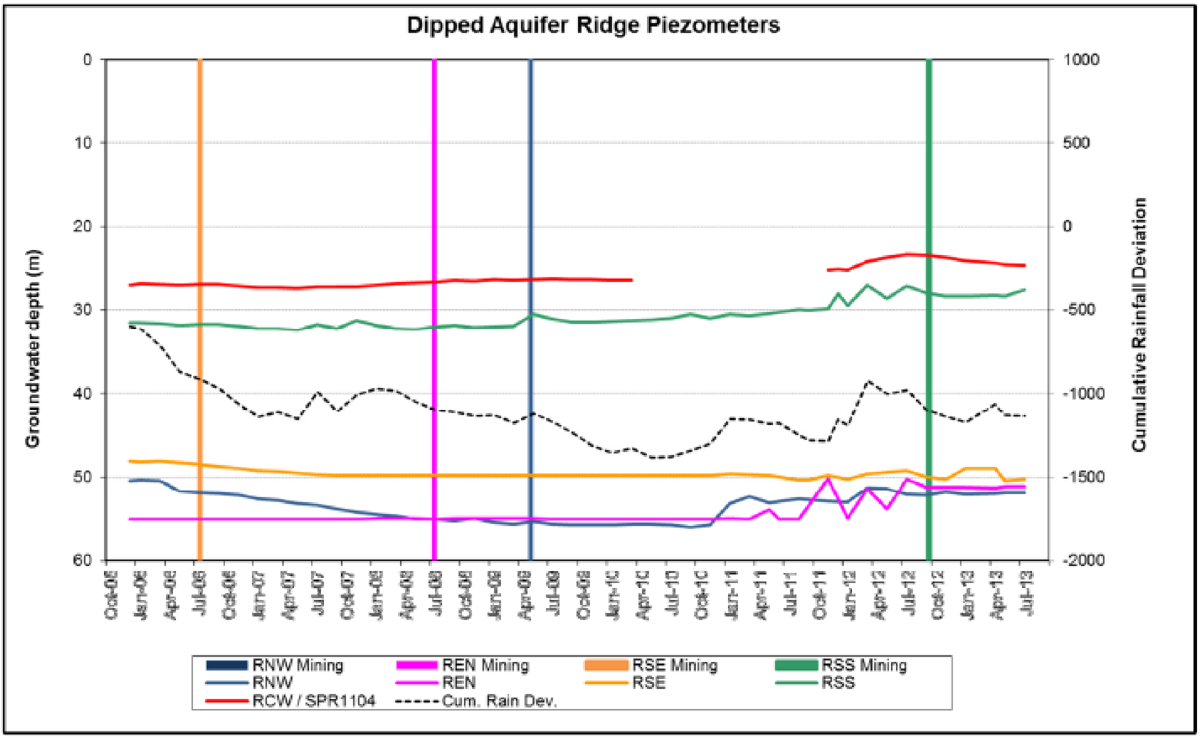


**Figure 15 Hydrographs of ridge water level monitoring bores related to timing of mining**

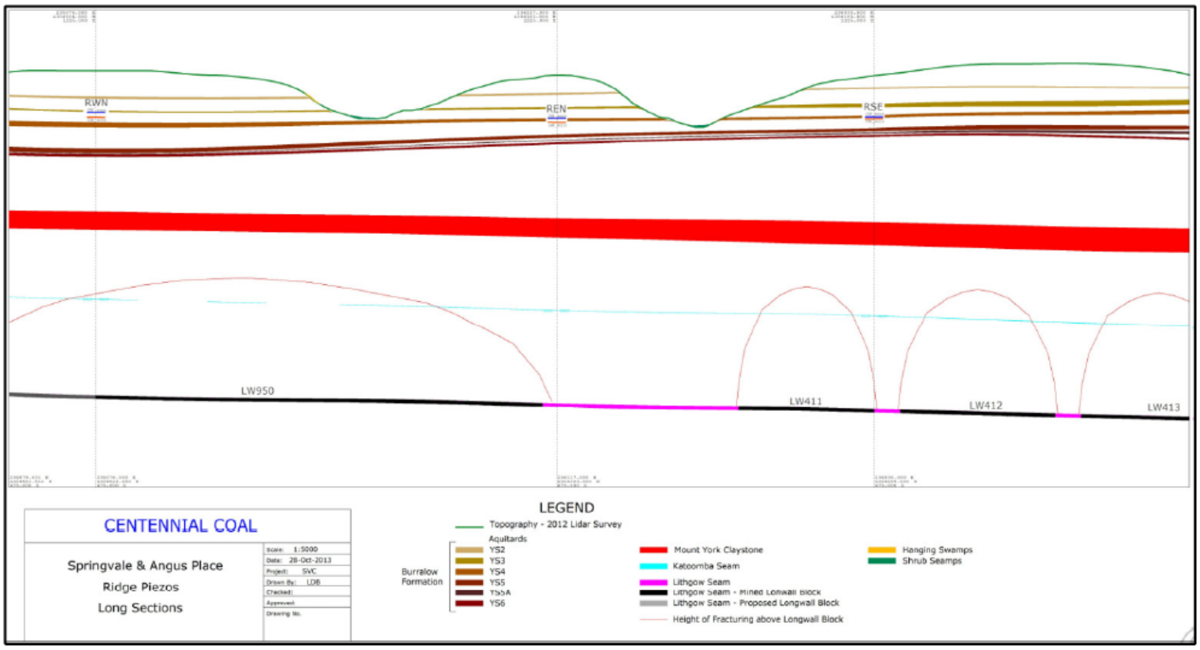


**Figure 16 Cross-section through Narrow Swamp (left) and East Wolgan Swamp (right) showing topography, geology, mining areas and related height of connected fracturing**

## Fracturing of hydraulic control and local groundwater drawdown and Fracturing of underlying sandstone strata

The following excerpt is copied from Corbett et al (2014), and describes monitoring results of groundwater levels in West Wolgan Swamp and Sunnyside West Swamp on the Newnes Plateau.

### "5. Longwall mining under Newnes Plateau Shrub Swamps

Monitoring of West Wolgan Swamp and Sunnyside West Swamp, which have been directly undermined by longwalls at Springvale and Angus Place, has not detected changes to swamp hydrology in response to mining related activities.

### 5.1 West Wolgan Swamp

West Wolgan Swamp was undermined by Angus Place Longwalls 930 and 940 in 2006 and 2007. The hydrographs on Figure 6 show four West Wolgan Swamp piezometers. Other data related to this case study are tabulated in Table 1. Figure 6 shows hydrographs of the four swamp piezometers installed at West Wolgan Swamp together with the time of longwall mining beneath the piezometers (indicated by the vertical black lines) and the Cumulative Rainfall Deviation (CRD) which is indicated by the black trendline. Note that there is a very strong correlation between the trendline of standing water level beneath the swamp and the CRD trendline for the four West Wolgan Swamp piezometers over the eight years of monitoring at this location. These data indicate that the swamp is periodically waterlogged (standing water levels respond to rainfall). The data also indicate that there has been no significant impact to swamp hydrology in response to longwall mining.

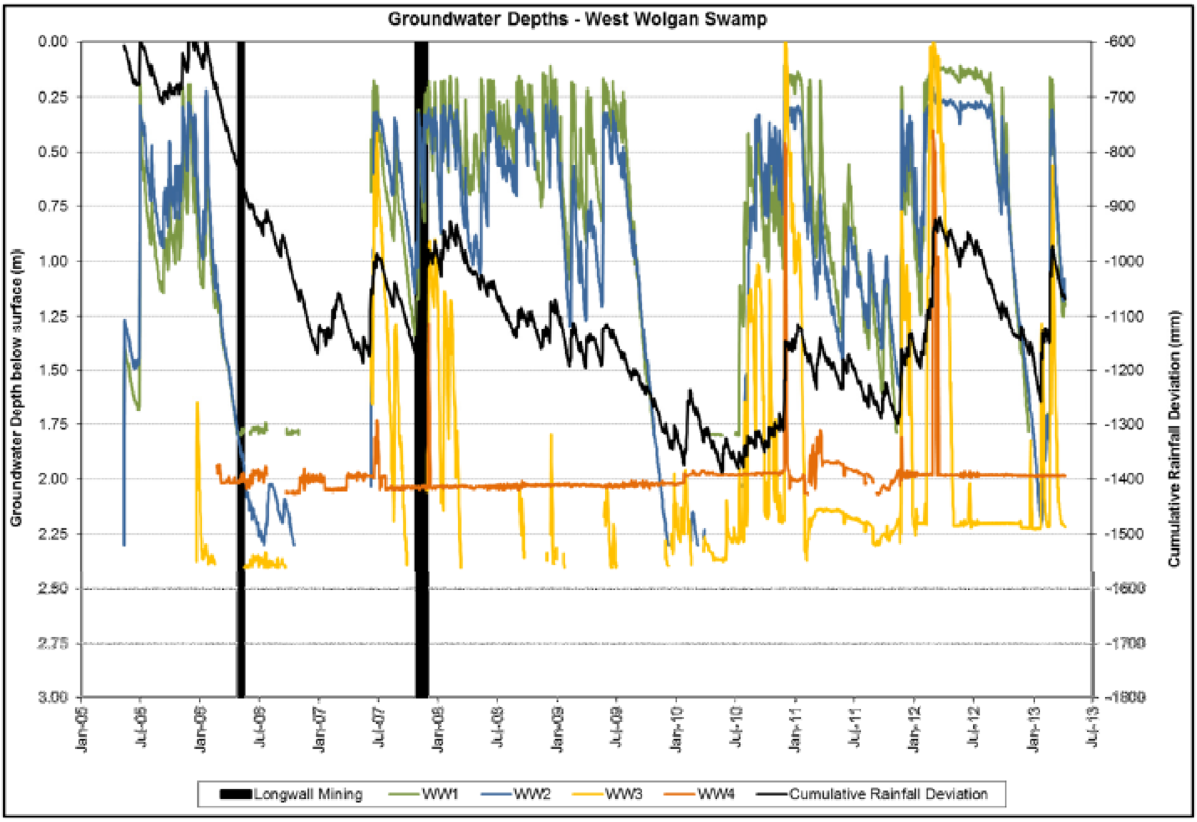


**Figure 6 Hydrographs of West Wolgan Swamp piezometers**

## 5.2 Sunnyside West Swamp

Sunnyside West Swamp was undermined by Springvale Longwalls 412 and 413 in 2009 and 2010. The hydrographs on Figure 7 show one Sunnyside West Swamp piezometer. Other data related to this case study is tabulated in Table 1. Figure 7 shows hydrographs of the swamp piezometer installed at Sunnyside West Swamp, together with the time of longwall mining adjacent to the piezometer. Mining within the angle of draw is indicated by the vertical grey lines and the Cumulative Rainfall Deviation (CRD) is indicated by the black trendline. Note that there is a very strong correlation between the trendline of standing water level beneath the swamp and the CRD trendline for the SW1 swamp piezometer over the six years of monitoring at this location. This data indicates that the swamp is periodically waterlogged (standing water levels respond to rainfall). The data also indicates that there have been no significant impacts to swamp hydrology in response to longwall mining.

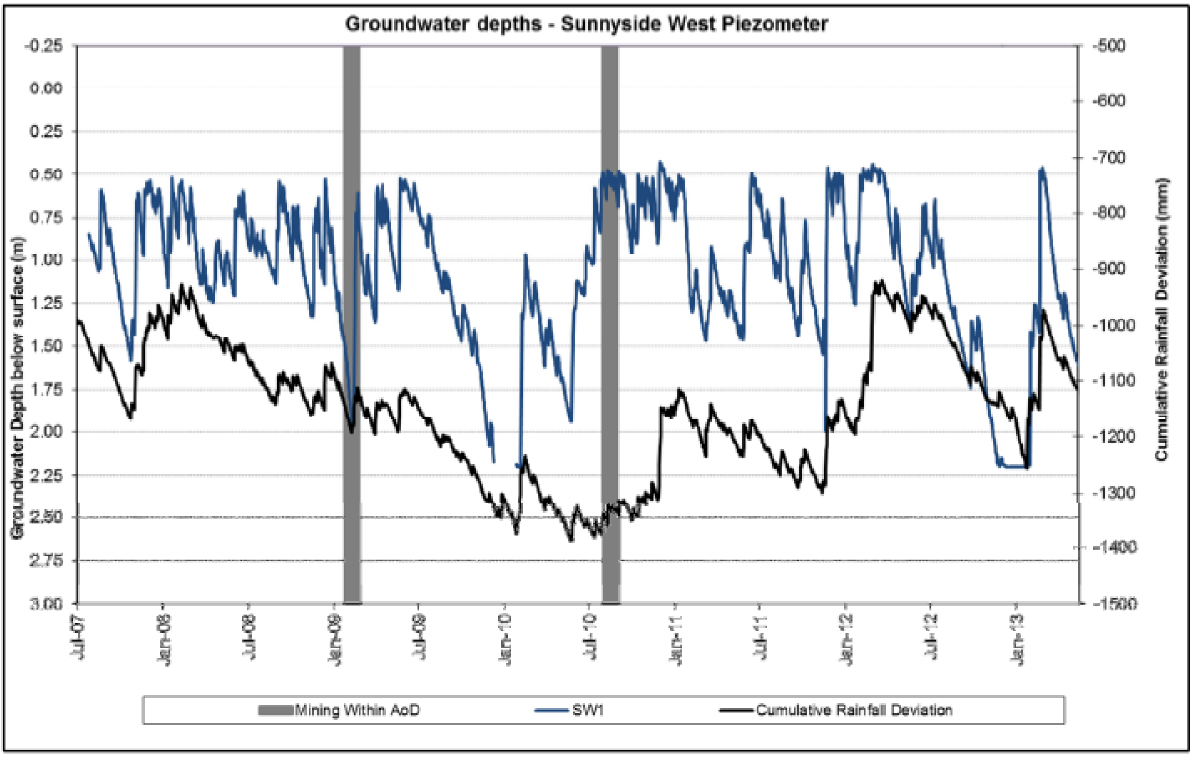


**Figure 7 Hydrographs of Sunnyside West Swamp piezometer"**

## East Wolgan Swamp, Newnes Plateau (Western Coalfield)

Goldney et al (2010) concluded the following with regard to East Wolgan Swamp: 'Site 10 (East Wolgan Samples a and b): There has been a significant and catastrophic impact on this swamp, where ecological and geomorphic thresholds have been exceeded.
Shrub components had disappeared, a significant thickness of peat had been washed away and a heavy deposit of patchy sand of unknown origin was deposited over what remains of the swamp bed. We attributed this swamp's destruction principally to mine water discharge. However, we are unable to determine the role of longwall mining as a contributing factor since mine water discharge impacts have very likely masked the longwall mining impacts. We have determined that these impacts were very likely significant."

The findings of the Goldney et al (2010) report are supported by further research by University of Queensland. An extract from ACARP Project - C20046 Report (Monitoring surface condition of upland swamps subject to mining subsidence with very high-resolution imagery) is included below:

"Imagery collected by the small-UAS clearly show spatially discrete impacts on the vegetation within a shrub swamp associated with mine discharge flow channel (Fig. 21a,d), including slumping and scouring of peat and underlying sand (Fig. 21b) and trampling as a result of subsidence monitoring (Fig 21e). Mine water discharge rates were as high as 240l.sec-1 which, combined with a continuous slope of 1.53 degrees along the length of the shrub swamp (25m decline over 960m), resulted in a channel up to 28m wide. Vegetation outside the flow path of the mine associated water is still intact present (Fig. 22). As imagery was collected in mid-June (late autumn) condition is difficult to assess from imagery.

To allow classification of shrub swamp impacts a 15cm GSD orthophoto product was segmented using multi-resolution segmentation algorithm (eCognition Developer v8.7 scale 30, shape 20, compactness 30) resulting in recognizable features in the image. The segments were converted to polygon features and exported to ArcGIS (v10.1, ESRI, CA, U.S.A.). Manual interpretation was then applied to each segment to assign a class of shrub vegetation, bare ground/dead vegetation or other. Dead vegetation was characterized by high reflectance while bare peat in eroded areas was dark in colour. Shrub vegetation was defined by a combination of colour, surface elevation and texture. The imagery detected both live vegetation and areas of bare ground allowing the spatial extent of disturbance to be classified in two categories (Fig. 22). Waypoints (Fig. 22; e.g., 14 and 15) could be separated in two categories even if they had similar estimates of bare ground (10-25 percent), high estimates of leaf litter (55-80%), and differed only in low percentage cover estimates of vegetation. For example, waypoint 14 had cover from a common shrub swamp species Leptospermum obovatum (7%), while waypoint 15 had small low growing species, including Baumea rubiginosa (6%) and Centella asiatica (5%). In contrast to ground surveys, the classification process utilized surrounding information to quantify natural breaks in shrub swamp habitat and disturbed areas over a broad geographic area. The utility of small UAS can bridge the gap between data collected from the ground (local) and information captured using remote sensing tools (regional), to provide broad landform assessments covering key conservation concerns in protected and threatened ecosystems (Kerr and Ostrovsky, 2003; Turner et al., 2003).

The primary cause for vegetation loss appears to be the flow path of mine discharge water through the studied shrub swamp community. This conclusion is supported by the presence of shrub swamp species surrounding impacted areas caused by discharge events which ended in March 2010. The extensive areas of dead vegetation and bare ground remaining more than three years later demonstrates a sustained and extensive degradation of this community. UAS imagery combined with field survey demonstrates the capacity for assessment of impacts at an actionable scale by applying ground derived knowledge to spatial extents.

Manual delimitation of extent and context of spatially discrete impacts to vegetation is not necessarily quantitative but provides coverage of entire shrub swamp communities at a known date without impact to the community.

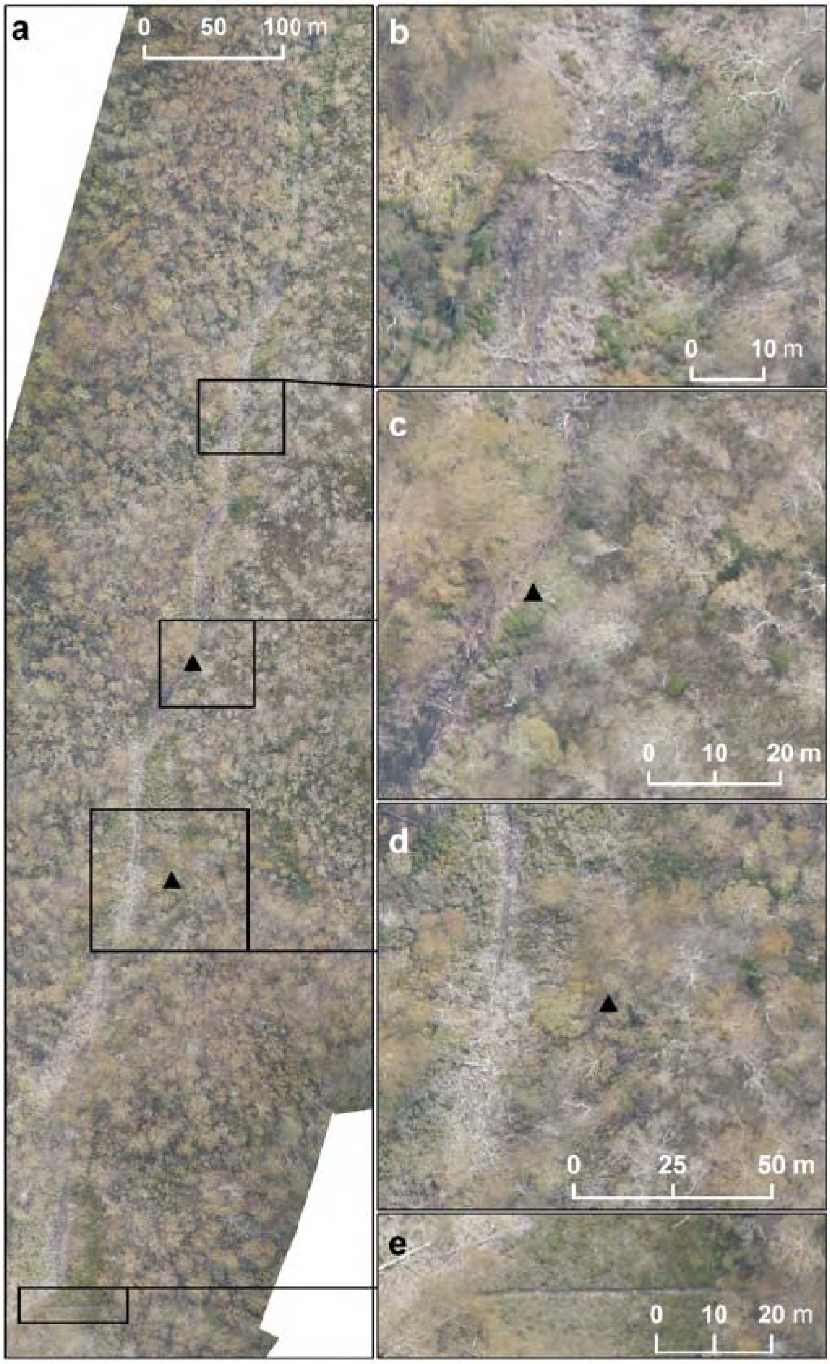


Figure 21: (a) UAS orthophoto mosaic of a shrub swamp collected in June 2013 showing outline of community as described in VISmap 2231 by New South Wales Office of Environment and Heritage. (b). Detail of slump towards downstream end of swamp caused by preferential flow of mine discharge water to below ground strata. (c) Detail image of location of monitoring plot EW01. (d) Detail image of location of EW02 monitoring plot. (e) Upstream end of shrub swamp community showing trampling impact of subsidence monitoring line.

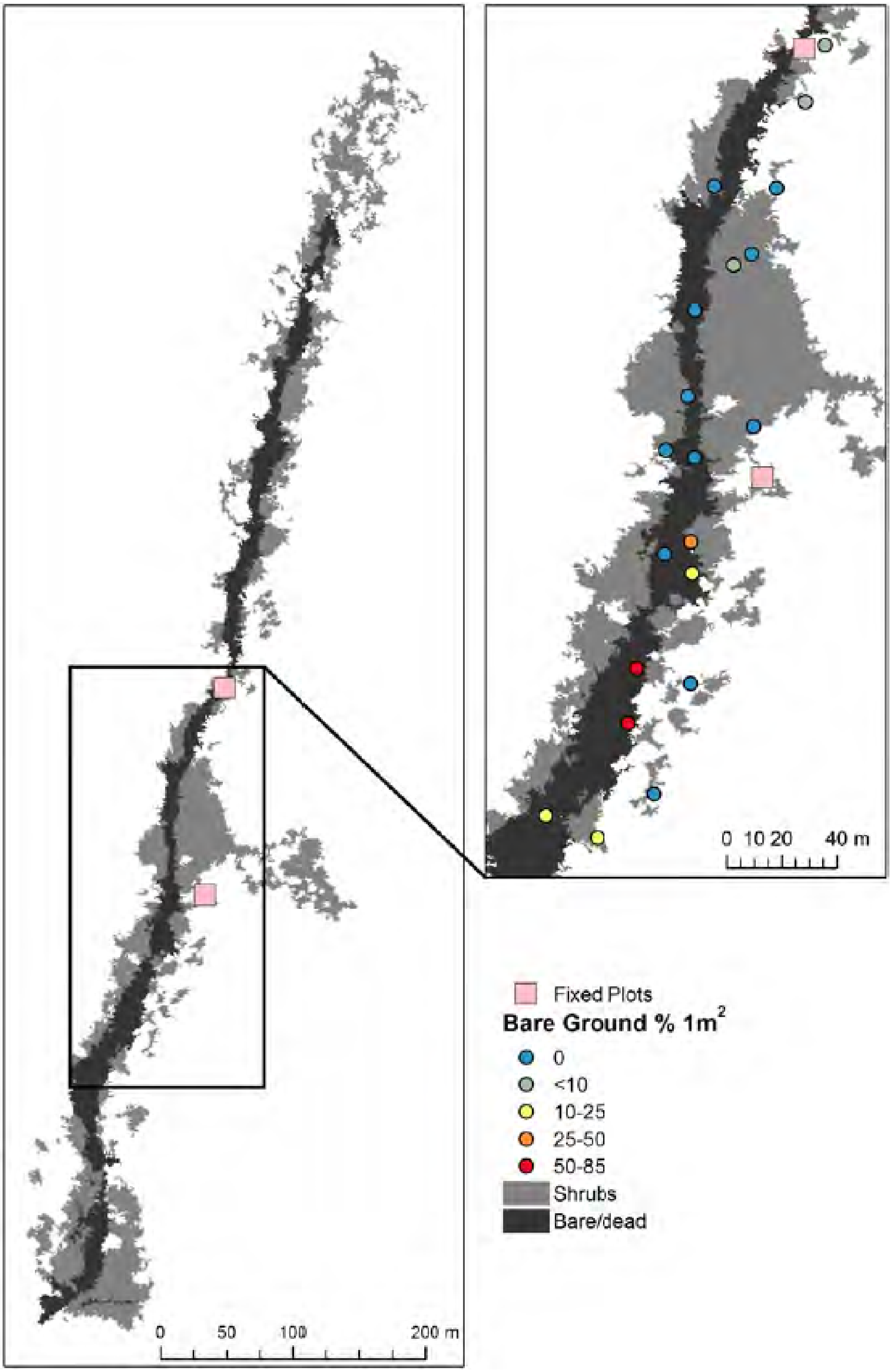


Figure 22: (main) Thematic map of a shrub swamp describing shrub vegetation and dead or bare ground. (inset) Area of mini-plot vegetation assessment ranked by proportion of bare ground identified in 1m2 plot."

The key co-incident factors related to cavity formation at East Wolgan Swamp (into which water discharge flowed and erosion / peat slumping occurred) are listed below:

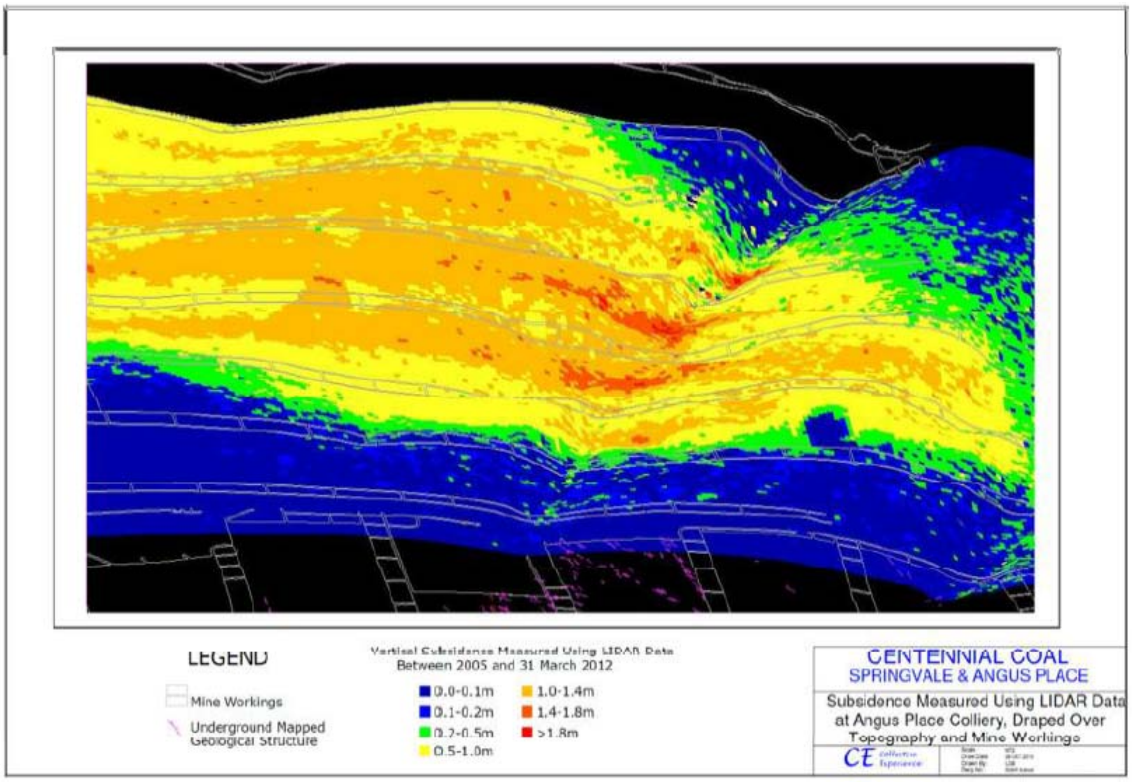
- licensed mine water discharge at rates of up to 12Ml/day;
- intersection of major geological fault structures;
- orientation of the longwall panel subparallel to the major structures;
- steepness and depth of East Wolgan Swamp valley at northern end;
- prevailing in-situ stress direction and magnitude (Springvale longwalls sub-perpendicular to principal horizontal stress direction);
- critical width longwall panel design;
- location of the geological structure close to the permanent barrier pillar (at cavity location); and
- interaction of Angus Place and Springvale mine workings and subsidence effects due to close proximity (at cavity location).

There is no data to validate the assertion of pre-mining flows. Evidence of return of natural flows to East Wolgan Swamp in the period since 2010 is discussed in EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau – Supplementary Data Volume 1 (2013).

### Narrow Swamp, Newnes Plateau (Western Coalfield)

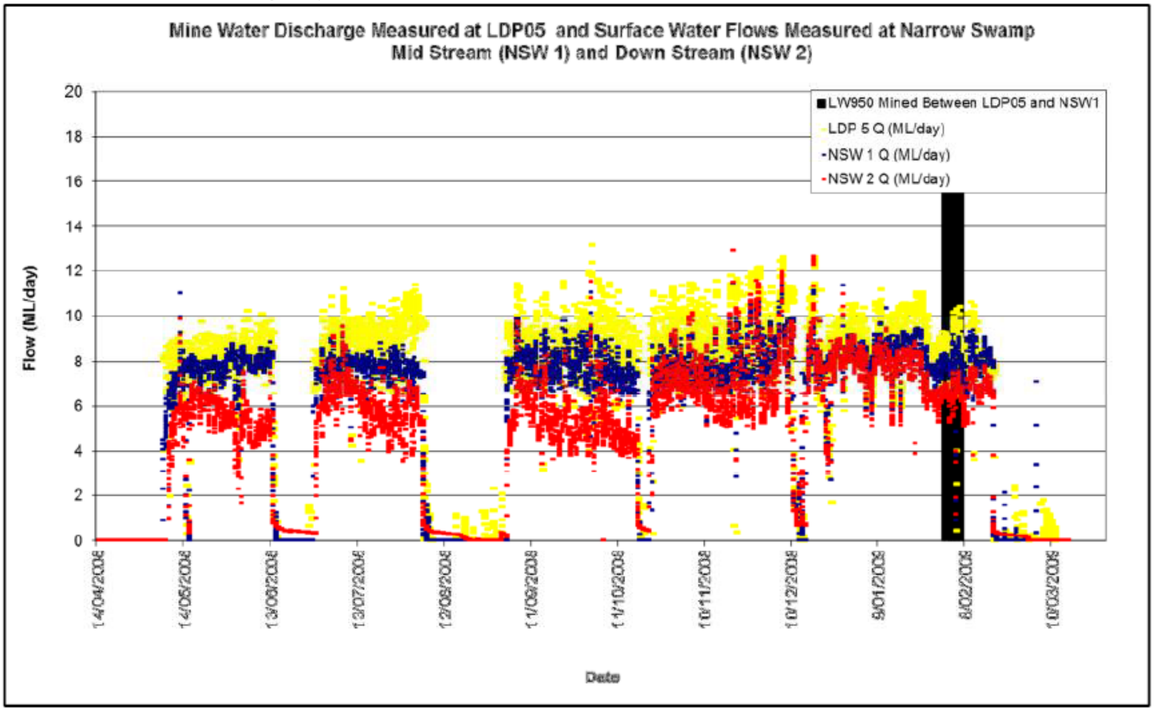
Narrow Swamp was undermined by Longwall 920 in March 2004, Longwall 940 in May 2007 and Longwall 950 in February 2009.

Subsidence monitoring from Angus Place A and F subsidence monitoring lines across the surface valleys associated with the Wolgan River Lineament (which contain Narrow Swamp and East Wolgan Swamp) has identified greater subsidence levels (up to 1.75m) compared to previous predictions. Further analysis of subsidence associated with major geological structures was conducted using LiDAR data (from pre-mining survey in 2005 compared with post-mining data from 2012). LiDAR subsidence data draped over topography from the Digital Terrain Model and mine workings shows subsidence levels in excess of previously predicted values (>1.4 m) can be clearly seen to be concentrated around the valley that contains Narrow Swamp (and identifies the western flank of the Wolgan River Lineament major geological structure zone). These elevated levels of subsidence did not cause changes to swamp hydrology at Narrow Swamp.



A graph of mine water discharge at Angus Place Colliery's Licensed Discharge Point 5 (upstream of Narrow Swamp) compared to two downstream flow monitoring stations at Narrow Swamp shows that there is a similarity of the trend of mine water discharge volumes compared to upstream and downstream flow monitoring (similar losses through the monitoring period from pre-mining to post-mining period). The monitoring data shows that the three longwall panels which have passed under Narrow Swamp during the period of licensed mine water discharge (i.e. Angus Place LW920 in 2004, LW940 in 2007 and LW950 in February 2009) have caused no significant loss of flow in the watercourse.

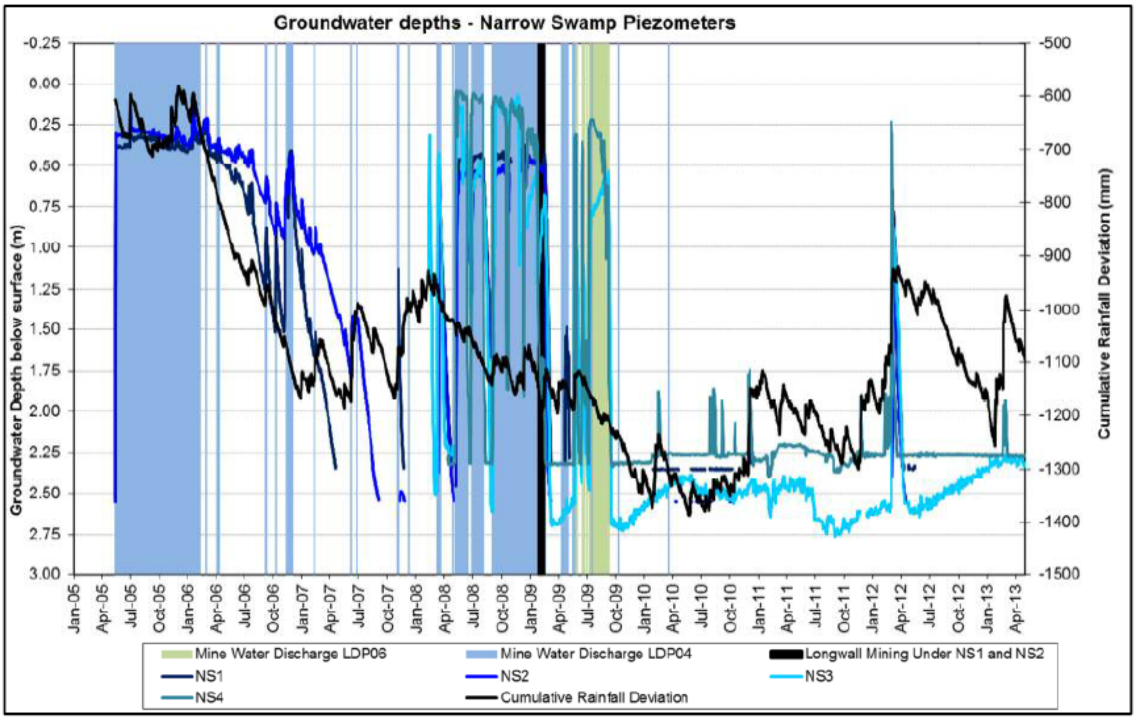
Flow monitoring carried out in this swamp prior to the extraction of LW950 has shown that approximately 91% of the discharge from Angus Place Colliery LDP005 reached a weir (NSW1) in the centre of the Narrow Swamp. After undermining by LW950 in February 2009, the monitoring indicated no change in the percentage of the discharge that reached NSW1. In addition, the percentage of discharge from NSW1, which reached a weir at the northern end of the Narrow Swamp (NSW2), was also 91%. Two longwall panels have undermined the Narrow Swamp in the section of the watercourse between NSW1 and NSW2, and so the flow monitoring indicates that the mining to date has not resulted in any significant cracking in the base of the swamp.



A hydrograph of Narrow Swamp piezometers NS1, NS2, NS3 and NS4 presented with the timing of mine water discharge and longwall mining as well as the cumulative rainfall deviation trend shows that the timing of mining was similar to that of the cessation of mine water discharges at LDP05 in February 2009, but the dominant influencing factor can be seen to be mine water discharges.

Following the cessation of mine water discharges, the hydrograph trends can be seen to be strongly influenced by rainfall. The standing water levels rise in response to rainfall events that are in excess of the long term average trends and fall in response to less than average rainfall trends. The responses are typically immediate and of short duration, indicated by the ‘spikes’ in the hydrograph trends.

When the data recorded during mine water discharged is removed, the same trend can be seen in the pre-mining baseline data. There is approximately 12 months pre-mining data (between March 2007 nd March 2008) that is not affected by mine water discharge, which clearly shows that the swamp was periodically waterlogged prior to mining. It remains periodically waterlogged following mining.



Goldney et al (2010) reported the following in terms of Narrow Swamp: ‘Site 5 (Narrow Swamp South): A significantly impacted THPS which we attributed to a combination of mine discharge and sediment movement. Lack of baseline data pre-LWM made it difficult to assess this site. As argued above we have ruled out drought as a likely explanation. Any other minor impacts due to LWM would be completely masked by the greater impacts.

‘Site 9 (Narrow Swamp North): There has been a significant and catastrophic impact on this swamp, where ecological and geomorphic thresholds have been exceeded. Based on snagged clumps of vegetation we were able to ascertain that at times the depth of water has reached up to 1 m across a 75 m wide bed. That represents a very considerable flow and one potentially very destructive. Shrub components had disappeared (no mean feat), a significant thickness of peat had been washed away and a heavy deposit of patchy sand of unknown origin was deposited over what remains of the swamp bed. We attributed this swamp’s destruction to mine water discharge, since this appears to be the only viable explanation.’.

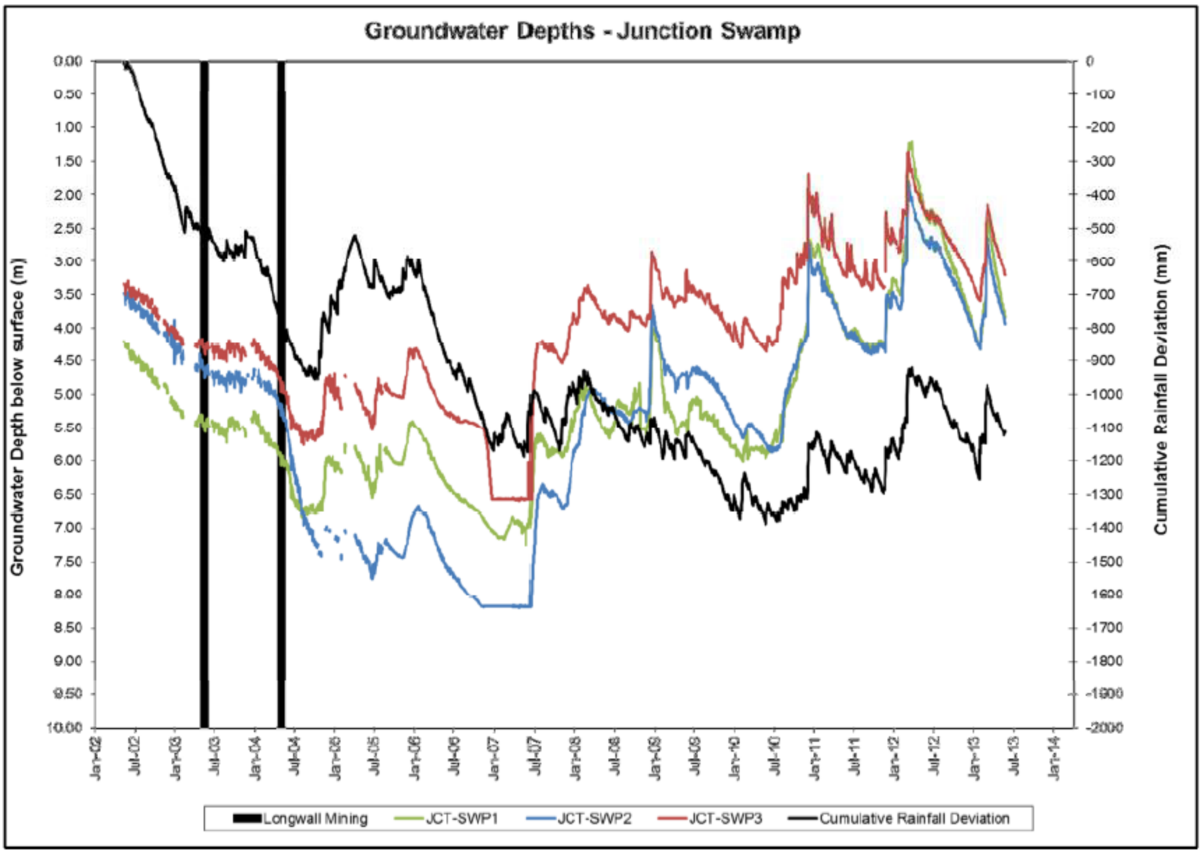
OEH approved the undertaking restoration actions at East Wolgan Swamp and Narrow Swamp, and issued a certificate under Section 95 of the TSC Act on 25 November 2013. Approved remediation works have been carried out since January 2014 in East Wolgan Swamp and will also be conducted in 2014 in Narrow Swamp.

### Junction Swamp, Newnes Plateau (Western Coalfield)

Surface water flow from the swamp was unaffected by LW 408, but ceased after the passage of this panel due to the ongoing rainfall residual mass deficit and the reduced downstream groundwater gradient. The flow from the swamp did not recommence until December 2010, even though the downstream groundwater gradient was above the threshold gradient for a period of two months. This suggests that there has been some tilting of the unconfined aquifer that has possibly changed the subsurface flow direction.

There is a very strong correlation between the trendlines of standing water levels beneath the swamp and the cumulative rainfall deviation trendline for all swamp piezometers over the eleven years of monitoring at this location.

This data indicates that the swamp is periodically waterlogged (standing water levels respond to rainfall). The data also indicates that there has been no significant vertical drainage of groundwater from the aquifer supporting the swamp (i.e. no significant impacts to swamp hydrology) in response to longwall mining as the standing water levels now are similar to pre-mining levels (Corbett et al 2014).



**Kangaroo Creek Swamp**

Kangaroo Creek Dam monitoring conducted in the period 2009 -2012 shows that the dam has contained water on 22 out of 24 monitoring occasions (conducted monthly or bi-monthly). This dam lies downstream of Kangaroo Creek (upper) Swamp, which was undermined by Springvale Longwall 401 in 1996.

In the Save Our Swamps - Newnes Plateau Shrub Swamp Aerial Assessment Project Report (2010), Kangaroo Creek Swamp (upper) was assessed to be in "Good" condition (no visible impact) in all categories (channelisation, desiccation, erosion, swamp crossing, access track, blackberry) except pine wildings, where a minor impact assessment was made. This swamp was undermined by Springvale Mine Longwall 401 in 1996. In the absence of data, this information suggests either:

1. No significant impact from longwall mining

2. Recovery of the swamp system over time

Either way, no long term impacts from longwall mining were detected.

The photo above is the mapped Kangaroo Creek (mid) Swamp in July 2013. Flora monitoring at Kangaroo Creek Shrub Swamp indicated no trend of decreasing condition and that species abundance is not declining.

**Kangaroo Creek (Mid) Swamp**

Figure 1 shows Kangaroo Creek Piezometer Monitoring Data (KC1 and KC2) and Cumulative Rainfall Deviation over the period between 2006 and 2014. It shows hydrographs of the swamp piezometers installed at Kangaroo Creek Swamp, together with the cumulative rainfall deviation, which is indicated by the black trendline. Note that there is a very strong correlation between the trendline of standing water level beneath the swamp and the cumulative rainfall deviation trendline for the KC2 piezometer over the eight years of monitoring at this location. This data indicated that the swamp is periodically waterlogged at this location (standing water levels respond to rainfall). The data also indicates that there have been no significant impacts to swamp hydrology in response to longwall mining at KC2. Groundwater levels at KC1 appear to have been affected by the longwall mining of Angus Place LW940, which was below the lower reaches of the swamp, as there was a sudden reduction in groundwater levels in June 2008, unrelated to rainfall.

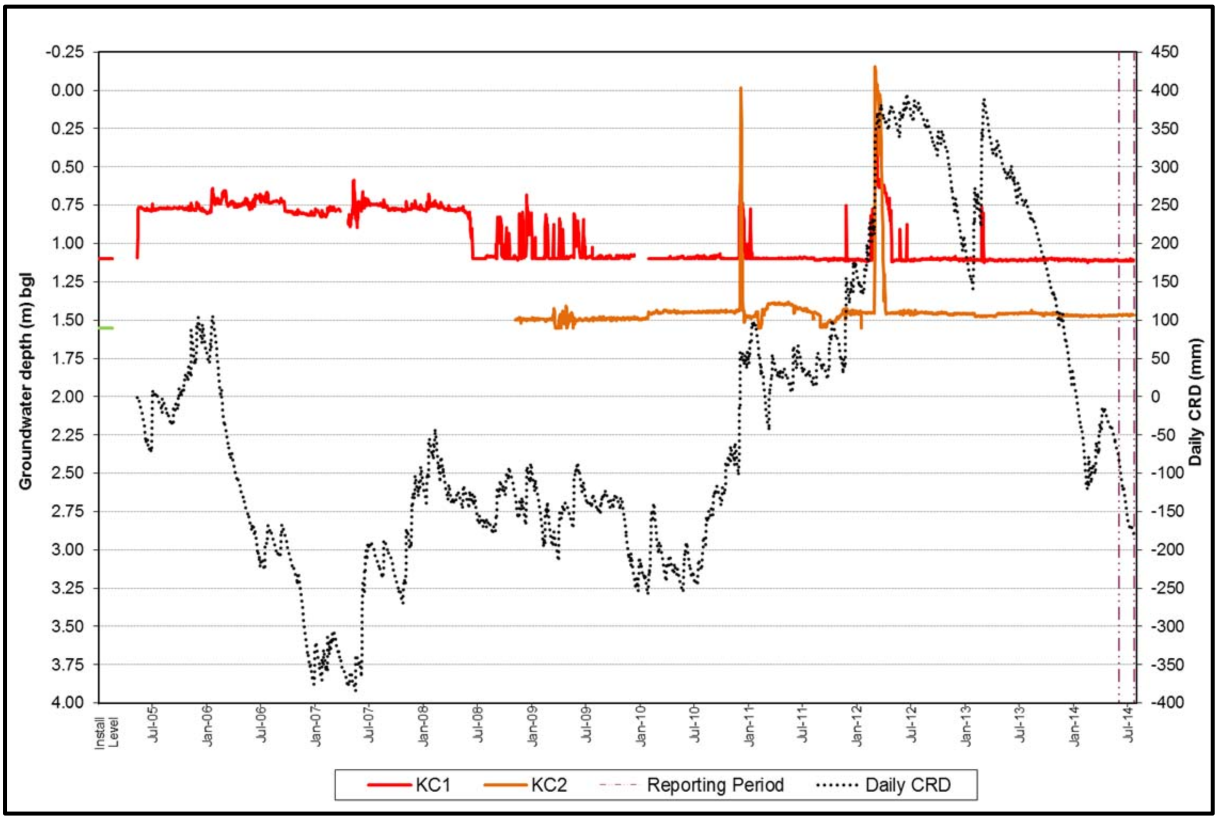


Figure 1 – Kangaroo Creek Piezometer Monitoring Data and Cumulative Rainfall Deviation

Kangaroo Creek Shrub Swamp is fed by a perennial spring. This spring, which in turn is fed by the aquifer-aquitard systems within the Burralow Formation, was unaffected by mining and the creek remained permanently wet below the spring. This, together with the presence of healthy hanging swamps along the valley walls surrounding Kangaroo Creek Shrub Swamp, indicates that the water supply from the spring and valley wall seepage has not been interrupted by longwall mining and that groundwater inputs to the swamp hydrological system remain intact.

**Plate 5** **(2013) Spring (left) and hanging swamp (right) at Kangaroo Creek Shrub Swamp**

**Plate 6** **(2013) Waterhole upstream of Kangaroo Creek Shrub Swamp (left) and Kangaroo Creek Shrub Swamp (right)**

Plates 5 and 6 illustrate that the Burralow Formation aquifer/ aquitard system has not been affected by longwall mining, as evidenced by the Spring, Waterhole and Hanging Swamps surrounding Kangaroo Creek Shrub Swamp. Flora monitoring at Kangaroo Creek Shrub Swamp indicated no trend of decreasing condition and that species abundance is not declining. The available evidence indicates that underground mining has not resulted in any negative effects on Kangaroo Creek Shrub Swamp. Investigation of mining related impacts at Kangaroo Creek Swamp showed that high levels of differential subsidence movements were measured, including strains (up to 6 mm/m tensile and 26mm/m compressive) and tilts (up to 13mm/m). The reasons for the high levels of differential movement are as follows.

- Mine Design: Longwall Void Width (w) to Depth of Cover (H) ratio of 0.94 to 1.04 (Critical Width). NB These are the highest w/H ratios of any of the longwalls at Angus Place and Springvale.

- Major Geological Structure Zone: Kangaroo Creek is located within the Kangaroo Creek Lineament, which has been identified as a ‘Type 1’ Geological Structure Zone.

- Topography: Valley slope angles >18 degrees.

- Location of Kangaroo Creek Swamp being near the western end of Angus Place Colliery’s LW940 and LW950 (adjacent to permanent barrier pillar).

Investigations have concluded that for the Kangaroo Creek Swamp, the presence of major fault zones and incised valleys in combination with mine design factors caused localised hydrological impacts.

The CRD trend also helps to understand changes in presence and flows of surface water. Since March 2013, there has been rainfall deficit in excess of 550mm (a significant proportion of the annual average Newnes Plateau rainfall of 1092mm). The rainfall deficit in the past 18 months is greater than any period since the end of 2005 (including the drought of 2006-2007). This helps to explain the lack of surface water present in recent monitoring periods e.g. February, June and August 2014 (and photos taken in May 2014 for the purpose of community submissions to the Angus Place and Springvale Mine Extension Project EISs). The photo used in the EIS was taken on 16 July 2013 and can be seen to be consistent with monitoring photos in prior and subsequent periods. In the five years of photographic monitoring since the measured reduction in groundwater levels at KC1 piezometer, there have only been three monitoring events out of 41 monthly or bi-monthly monitoring events where water has not been present in the waterhole (February 2014, June 2014 and August 2014). On these occasions groundwater seeps from upstream can still be seen to be present.

#### 8.4.3.1 Fracturing of underlying sandstone base

Centennial is in agreement with the following statement copied from pp164 of the IESC report, as it is consistent with monitoring data from the Newnes Plateau.

*"In general, when the overburden depth to the mining horizon is greater than about 400 m, maximum systematic tilts are expected to be less than 5 mm/m and systematic strains are expected to be less than 1 to 2 mm/m. At these levels, surface cracking and changes in gradient are likely to be imperceptible and impacts associated with mine subsidence are expected to be slight."*

# 9 Subsidence models and prediction methods

The subsidence prediction methods identified in Section 9 are accepted by Centennial, however, it is observed that the majority of the research work has been conducted in the Southern Coalfield and that differences in geology, topography and stress regimes result in different behaviour in other coalfields. Details are discussed in Section 5 (above).

## 9.1 Introduction

The use of the Tametta (2012) model for groundwater effect of longwall mining is discussed in Section 7 (above).

## 9.5 Prediction of mining impacts on peat swamps

Centennial has used industry best practice methods to predict subsidence and groundwater effects of longwall mining under the Newnes Plateau, detailed in Section 7 and 8 (above). Investigations into historical impacts of mining related activities to THPSS on the Newnes Plateau have identified causative factors. Future planned mining activities mitigate identified causative factors.

# 10 Monitoring

Centennial agrees with methods nominated for monitoring of subsidence and groundwater and has used all of the techniques nominated with the exception of the following:

- Interferometric Synthetic Aperture Radar (InSAR) – due to issues related to resolution of vertical and horizontal movement vectors. This may become a viable method in the future.
- Borehole inclinometers – lateral strata movement has been measured using conventional survey technicques.

- Time domain reflectometry – as this is related monitoring infrastructure and not environmental effects.

# 11 Management strategies

### 11.4 Setback or buffer distances

Springvale's EPBC2011/5949 approval required buffer zones to be defined. Initially these were approved based on 26.5 degree angle of draw. Subsequently, based on the information gained from extensive studies conducted by Centennial Coal, the buffer zones were were modified for the purposes of EPBC2011/5949 approval for Springvale Mine, when permission to mine within approved buffer zones and directly mine beneath THPSS on the Newnes Plateau was granted by DotE on 21 October 2013.

### 11.4.1.1 General guidelines

The magnitudes of 0.5 mm/m tensile and 2 mm/m compressive are guides to the potential for fracturing in bedrock due to conventional subsidence movements. The basis for these values is that fracturing is rarely seen in the Southern Coalfield as a result of conventional subsidence movements, i.e. away from valley bases, where the maximum ground strains are typically in this order. These strain values should not be used as an indicator of the potential for environmental consequence (i.e. impact) on surface features, as fractures at these magnitudes tend to be minor and isolated. This is supported by the PAC review (2010) for the Bulli Seam Operations which stated that *"As already noted, it is based on MSEC's advice that fracturing of sandstone has generally been observed in the Southern Coalfield once systematic compressive strain has exceeded 2 mm/m. This concurs with the Panel's experience. However, based on the Panel's own inquiries, field inspections and experience, total diversion of surface flow into a subsidence-induced subsurface fracture system requires higher total compressive strains that are very dependent on geological factors such as strata composition, thickness and bedding laminations. Limited measurements suggest a threshold total compressive strain[156] value for total diversion of flow in sandstone environments of the order of 7 mm/m, however the database is too small to be reliable at this point in time."*

### 11.4.1.2 Additional considerations for valley infill swamps and hanging swamps

An extensive groundwater monitoring network has been established on the Newnes Plateau, with monitoring commencing in 2002.

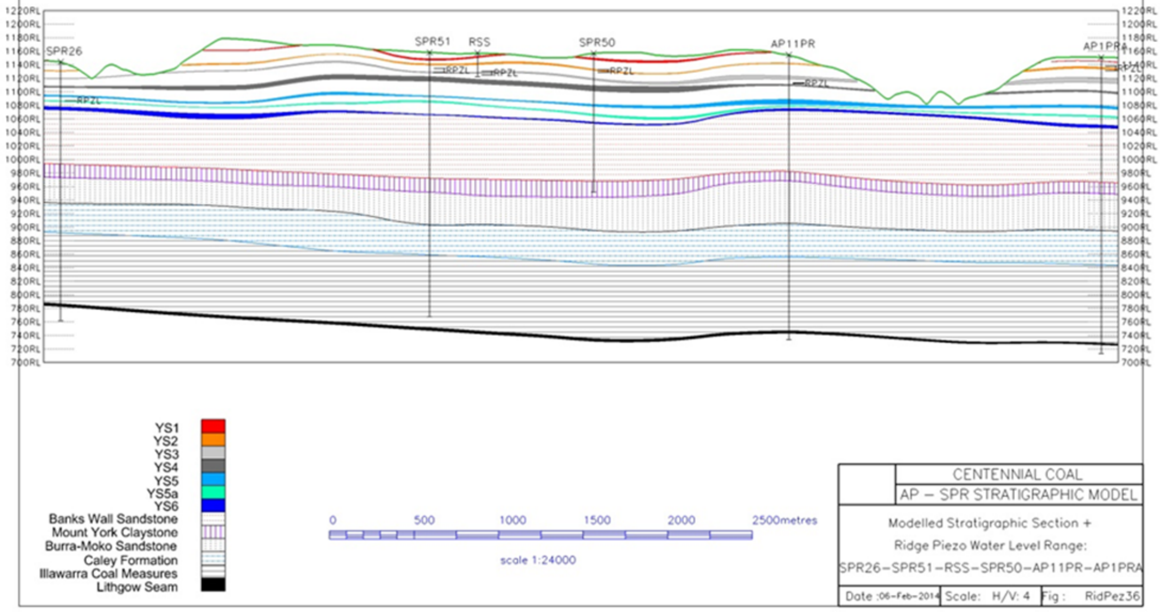
Groundwater monitoring has been used in mining areas at Springvale and Angus Place mines since 2005 (e.g.Junction Swamp, Kangaroo Creek Swamp, West Wolgan Swamp, Narrow Swamp, East Wolgan Swamp, Sunnyside Swamp, Sunnyside East Swamp, Carne West Swamp and Gang Gang Swamp). Each of these swamps has multiple piezometers installed within the swamp and aquifer piezometers installed in the ridges between the swamps.

All other Newnes Plateau Shrub Swamps (NPSS) in the Angus Place and Springvale Mine Extension Project areas have at least one piezometer installed in them, with a minimum of two years baseline data.

Due to potential impacts to THPSS associated with using truck mounted drill rigs required to drill into the rock underlying the swamps (to allow for installation of multi-level piezometers), it was decided to use a combination of piezometers as follows:

- Swamp Piezometers, which monitor water level every three hours using a datalogger and are installed in hand augered holes within the peat / soil profile of the swamp (bottom of monitoring bore at or near bedrock)
- Aquifer Piezometers, which monitor water levels every three hours using a datalogger and are installed in boreholes drilled from the top of the ridges adjacent to Newnes Plateau Shrub Swamps (NPSS) using truck mounted drill rigs. They monitor standing water levels in the Burralow Formation aquifers (AQ5 and AQ6), which supply water through the valley floor / wall seepage mechanism.
- Multi-Level Vibrating Wire Piezometers, which monitor water pressure at different levels within the strata every two hours using a datalogger and are installed in boreholes drilled from the top of the ridges adjacent to Newnes Plateau Shrub Swamps (NPSS) using truck mounted drill rigs. They monitor groundwater pressure in aquifers between the surface and the Lithgow Seam (AQ1 to AQ6),

The close proximity of instruments in the piezometer network has been used in conjunction with a three dimensional topographic and stratigraphic model to enable an understanding of groundwater levels and their interaction with swamps. The figure below shows a cross section of topography, stratigraphy, groundwater levels along a transect between a number of monitoring bores. EIS Section 2.6.2.6 Figures 2.24 to 2.26 shows a similar transect between ridge piezometer bores installed in 2005.



Despite the statement CoA (2014) “Hanging swamps are expected to be more vulnerable to subsidence impacts than headwater and valley infill swamps, due to their location in steep topography where natural stresses are highest”, there are no documented cases of impacts to Newnes Plateau Hanging Swamps in the history of mining at Angus Place and Springvale since 1979.

#### 11.4.1.3 Monitoring

The peer reviewed THPSS Monitoring and Management Plan (THPSS MMP) which has been approved by the Federal Department of the Environment (DotE) is aligned with **Before-After/Control-Impact (BACI)** design. It incorporates monitoring of subsidence, groundwater levels and quality, surface water flows and quality, flora and fauna. It is based on studies of individual swamp geology, hydrogeology and hydrology in the EPBC2011/5949 Controlled Action Area. A similar baseline characterisation and monitoring approach has been adopted for the following swamps in the Angus Place and Springvale Mine Extension Project areas: Trail 6 Swamp, Twin Gully Swamp, Tri-Star Swamp, Crocodile Swamp, Carne West Swamp, Gang Gang Southwest Swamp, Gang Gang East Swamp, Carne Central Swamp, Barrier Swamp, Nine Mile Swamp, Pine Swamp, Upper Pine Swamp, Paddy’s Creek Swamp, Paddy’s Creek East Swamp, Marrangaroo Swamp.

#### 11.4.1.4 Trigger action response plans

The THPSS Monitoring and Management Plan (THPSS MMP) is based on a **Before-After/Control-Impact (BACI)** design and incorporates TARPs with triggers for subsidence, groundwater levels and quality, surface water flows and quality and flora.

## 11.5 Remediation

As indicated in section 2.6.2.6 of the EIS, OEH approved the undertaking restoration actions at East Wolgan Swamp, and issued a certificate under Section 95 of the TSC Act on 25 November 2013. Approved remediation works have been carried out since January 2014 and are ongoing.

# 12 Future work

Centennial has conducted extensive investigations in order to determine the hydrogeological characteristics of THPSS’. The purpose of these investigations was to ascertain the coincident characteristics which lead to THPSS formation and to understand the sensitivity of those characteristics to mine subsidence behaviour.

Centennial Coal has Conducted extensive investigations to determine the factors which caused historical impacts at East Wolgan Swamp, Kangaroo Creek Swamp, Narrow Swamp and Junction Swamp.

The results of investigations have allowed Centennial Coal to understand the multiple co-incident factors that have led to historical mining-related impacts and implement management practices to ensure mining impacts will be avoided in the future or can be managed appropriately.

Mine water management and mine design were the key controllable factors by Centennial management and Springvale’s mine design was changed in 2011 following the investigations in order to mitigate potential impacts to THPSS on the Newnes Plateau.

Since the investigations were conducted, Centennial Coal has been proactive in avoiding or minimising potential subsidence impacts to the geodiversity and biodiversity of the mining area using a comprehensive multi-disciplinary risk-based approach to mine planning and mine design in conjunction with a rigorous monitoring program.

The monitoring techniques employed are wide-ranging and complementary and the combined results provide insights into roles that factors such as geology, hydrogeology, topography play in THPSS formation and the effects of mine subsidence on THPSS.

The extensive monitoring and investigation process employed by Centennial Coal, which utilised multiple lines of evidence to support the management decisions, created the foundations for an adaptive management outcome. Mine design changes (in the form of reduced longwall void width and increased chain pillar width) were implemented in 2011 and are planned in all MEP areas where NPSS are present.

The following shows how Centennial has responded to the points raised in Section 12 of the IESC report.

- Determine how peat swamps fail due to being undermined, based on field measurements of ground deformations, groundwater levels, and changes in flora and fauna in the undermined swamp and using a control swamp. Detailed case studies have been conducted on West Wolgan Swamp, Sunnyside West Swamp, Sunnyside Swamp, East Wolgan Swamp, Kangaroo Creek Swamp, Narrow Swamp and Junction Swamp on the Newnes Plateau, in terms of geology, hydrogeology, hydrology, ground deformations, groundwater levels, and changes in flora and fauna. Control swamps used for comparison were Trail 6 Swamp, Twin Gully Swamp, Tri-Star Swamp, Crocodile Swamp, Carne West Swamp, Gang Gang Southwest Swamp, Gang Gang East Swamp, Carne Central Swamp, Barrier Swamp, Nine Mile Swamp, Pine Swamp, Upper Pine Swamp, Paddy’s Creek Swamp, Paddy’s Creek East Swamp, Marrangaroo Swamp.
- Study damaged swamps. Detailed studies have been conducted at East Wolgan Swamp, Kangaroo Creek Swamp, Narrow Swamp and Junction Swamp on the Newnes Plateau.
- Perform trial remediation projects on damaged swamps and monitor the swamp to assess if improvement of the swamp occurs over time. Remediation work is currently underway at East Wolgan Swamp.
- Improve predictive capability to assess impacts on peat swamps based on a revised understanding of deformation and peat swamp function. Predictive modelling of mine subsidence effects to groundwater systems associated with the THPSS on the Newnes Plateau has been conducted by CSIRO and DgS as described in Sections 7 and 8 above
- Monitor, simultaneously, groundwater levels in a peat swamp and the sealing layer beneath a swamp before, during and after mining. Monitoring ground movement (strain) must also be conducted simultaneously with the water-level monitoring, so that any relationship between hydraulic head behaviour and ground deformation can be investigated.
- Monitor the long-term hydraulic head behaviour in the peat following mining (this can be conducted at some of the swamps analysed in this report). Monitoring has been conducted of hydraulic head behaviour at THPSS on the Newnes Plateau for up to 10 years post-mining.

- Monitor long-term changes in groundwater levels and chemistry to develop a database for the coalfields for comparison with predictive models. Monitoring has been conducted of groundwater levels and chemistry THPSS on the Newnes Plateau for up to 8 years post-mining.
- Modify the preliminary guidelines for setback criteria, based on the information gained from the above activities. Setback criteria, based on the information gained from the above activities, were modified for the purposes of EPBC2011/5949 approval for Springvale Mine, when permission to mine within approved buffer zones and directly mine beneath THPSS on the Newnes Plateau was granted by DotE on 21 October 2013.

## Appendix A-1

It is noted that all case studies presented in Appendix A-1 are from the Southern Coalfield.

## Appendix A-2

It is noted that all case studies presented in Appendix A-2 are from the Southern Coalfield.

## Appendix B

The work done by CSIRO in “Hydrological response to longwall mining—ACARP project C14033” built upon and superseded the models identified in the literature survey referenced in Table 1.

## Appendix C

It is noted that the example of application of general guidelines using the ACARP1 method IN Appendix C is an example from the Southern Coalfield and that differences in geology, topography and stress regimes result in different behaviour in other coalfields. Case studies of undermining THPSS in the Western Coalfield experiences on the Newnes Plateau are discussed in Section 7and 8 (above).

## Appendix D

The extract presented in Appendix D is generalised and does not reflect measured response of groundwater systems to subsidence in the Western Coalfield experiences on the Newnes Plateau are discussed in Section 7and 8 (above).

# References

A number of relevant publicly available references were not used in the preparation of these reports. These include:

Forster, I., (2009) Aurecon Report Ref: 7049-010 Newnes Plateau Shrub Swamp Management Plan Investigation of Irregular Surface Movement in East Wolgan Swamp

Goldney, D., Mactaggart B., and Merrick, N. (2010) Determining Whether Or Not A Significant Impact Has Occurred On Temperate Highland Peat Swamps On Sandstone Within The Angus Place Colliery Lease On The Newnes Plateau

Forster, I., (2011) Aurecon Report Ref: 208354, Geotechnical Investigation Report Wolgan East Investigation

Speer, J., (2011) Alpha GeoScience Report, Final Report: AG-293 Geophysical Survey Ground Penetrating Radar And Resistivity Investigation Of East Wolgan Swamp On The Newnes Plateau

Ditton, S., (2013) DgS Report No. SPV-003/6 Further Discussion on the Potential Impacts to Sunnyside East and Carne West Temperate Highland Peat Swamps on Sandstone due to the Proposed Springvale LWs 416 to 418

McHugh, E., (2013) The Geology of the Shrub Swamps within Angus Place/Springvale Collieries

Fletcher, A., Brownstein, G., Blick, R., Johns, C., Erskine, P. (2013) Assessment of Flora Impacts Associated with Subsidence

Helensurgh Coal Pty Ltd (2008) Waratah Rivulet Remediation Trial Activities – Completion Report

Gilbert and Associates (2012) Metropolitan Collieries - Assessment of the Success of WRS3 Remediation Works in Re-Establishing Surface Flow.

Springvale Coal Pty Ltd (2013) EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau – Supplementary Data Volume 1 – 3 and Appendices

Brassington, G., Wood, J., Walsh, R., Coleman, S., Jamieson, M. (2006) BHP Billiton West Cliff Mine Environmental Management System Georges River Report, Assessment of Georges River Remediation Longwalls 5A1-4

Good, R., Hope, G., Blunden, B. (2010) Dendrobium Area 3A Swamp Impact, Monitoring, Management and Contingency Plan

DP&I (2008). Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield – Strategic Review. Department of Planning NSW, July 2008. Proceedings of the Australian Geomechanics Society - Engineering Geology of the Newcastle-Gosford Region, The University of Newcastle, February 1995.

Tomkins and Humphreys (2006). Evaluating the Effects of Fire and Other Catastrophic Events on Sediment and Nutrient Transfer within SCA Special Areas. Humphreys, G., S., and Tomkins; M. Sydney Catchment Authority - Macquarie University collaborative research project. Technical Report 2.

Fletcher, A. and Erskine, P. (2014) Monitoring surface condition of upland swamps subject to mining subsidence with very high-resolution imagery (ACARP Project - C20046)

DgS Report No. SPV-003/7b (2014) Subsurface Fracture Zone Assessment above the Proposed Springvale and Angus Place Mine Extension Project Area Longwalls

Corbett, P., White, E., Kirsch, B., (2014) Hydrogeological Characterisation of Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau

Corbett, P., White, E., Kirsch, B., (2014) Case Studies of Groundwater Response to Mine Subsidence in the Western Coalfields of NSW

Brownstein, G., Johns, C., Blick, R., Fletcher, A., Erskine, P., (2014) Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps

PAC (2010). *Bulli Seam Operations - PAC Report*. NSW Planning and Assessment Commission, July 2010.

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

Nagindar Singh
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Locked Bag 1002
WALLERAWANG
NSW 2845

Dear Nagindar,

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

## 1. Introduction

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

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

## 2. Proposed Response

The IESC advice is divided into two sections:

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

### 2.1 Assessment against Information Guidelines

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

*Relevant data and information*

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

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

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

*Application of appropriate methodologies*

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

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

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

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

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

*Reasonable values and parameters in calculation*

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

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

## 2.2 Response to Specific Questions nominated by the Referrer

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

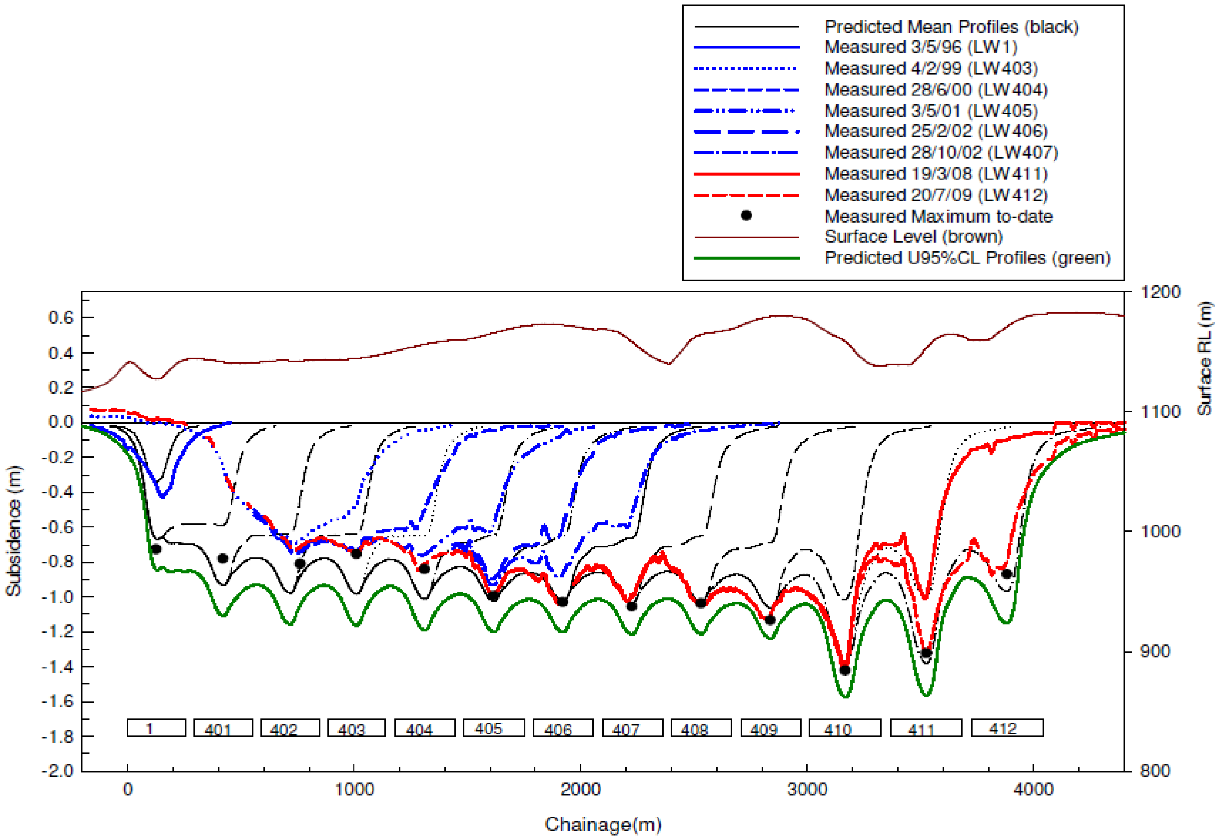

**Figure 1: Subsidence Profile of Extracted LW1 and LW401-LW412 at Springvale Mine**

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

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

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

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

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

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

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

- *"Narrow Swamp South (Site 5): A significantly impacted THPS which we attributed to a combination of mine water discharge and sediment movement. … Any other minor impacts due to LWM may be masked by the greater impacts".*

- *"Narrow Swamp North (Site 9): There has been a significant and catastrophic impact on this swamp, where ecological and geomorphic thresholds have been exceeded. … We attributed this swamp's destruction to mine water discharge, since this appears to be the only viable explanation."*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Further detail is presented in RPS (2014e).

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

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

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

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

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

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

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## 4. Closing

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

Yours sincerely
RPS Water

*Justin*

Dr Justin Bell
Principal Environmental Engineer

cc:
enc:

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DATE: 21 September 2014

TO: Peter Corbett
Technical Services Manager
Centennial Coal Angus Place

FROM: Dr Noel Merrick

RE: **Springvale/Angus Place Response to IESC - Fractured Zone Estimation**

OUR REF: HC2014/28

## 1 Background

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) was requested by the Australian Government Department of the Environment and the New South Wales (NSW) Department of Planning and Environment to provide advice on both the Centennial Angus Place Pty Ltd, Angus Place Mine Extension Project (APMEP) and the Springvale Coal Pty Ltd, Springvale Mine Extension Project (SMEP). Centennial Coal Company Limited (CCCL) has been invited to respond to these Advices.

In addition, the Office of Water Science (OWS) in the Commonwealth Department of the Environment has released three research reports (endorsed by the IESC) relevant to the Angus Place and Springvale operations[1]:

1. Commonwealth of Australia 2014, *Temperate Highland Peat Swamps on Sandstone: ecological characteristics, sensitivities to change, and monitoring and reporting techniques, Knowledge report*, prepared by Jacobs SKM for the Department of the Environment, Commonwealth of Australia;

2. Commonwealth of Australia 2014, *Temperate Highland Peat Swamps on Sandstone: evaluation of mitigation and remediation techniques, Knowledge report*, prepared by the Water Research Laboratory, University of New South Wales, for the Department of the Environment, Commonwealth of Australia; and

3. Commonwealth of Australia 2014, *Temperate Highland Peat Swamps on Sandstone: longwall mining engineering design—subsidence prediction, buffer distances and mine design options, Knowledge report*, prepared by Coffey Geotechnics for the Department of the Environment, Commonwealth of Australia.

The three projects involved literature reviews collating available information on peat swamps, and analysis of the significance of other relevant information to the ecological community. In summary the reports conclude (according to the OWS): "that swamps in

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[1] Website iesc.environment.gov.au/publications.html

steeper terrain and with groundwater connection are most vulnerable to damage from subsidence; that more extensive monitoring of swamps is required prior to and during mining to understand ecological impacts; that quantifying horizontal ground movements associated with subsidence is key to understanding potential impacts; altering mine layout is the only mitigation measure to avoid damage to peat swamps; and that there are no successful examples of existing remediation techniques being used in peat swamps".[2]

Heritage Computing Pty Ltd, trading under the name HydroSimulations (HS), has been engaged to provide an opinion on the so-called "Tammetta model"[3] for ground deformation above a caved longwall panel. This model is featured in Report #2 at pages 118-119 and in Report #3 at pages 36-37. It should be noted that neither report makes any reference to an alternative conceptualisation and formulation known as the "Ditton model"[4].

## 2 Research Report #2

### *Research Report Extract 1*

A key section of Report #2 is extracted here:

"Tammetta (2013) highlighted that, from a hydrogeological perspective, longwall mining and the associated caving process create two distinct zones above the panel: the unsaturated collapsed zone and the saturated disturbed zone (Figure 3.7)[5].

The extent of the collapsed and disturbed zones (Figure 3.7) depends on several factors, including the depth and width of the longwall panels, and the geology. Subsidence-induced cracks beneath water bodies may result in the loss of water to near-surface groundwater flows. If the water body is located in an area where the coal seam is less than 100 to 120 m below the surface, longwall mining can cause the water body to permanently lose flow (NSW Scientific Committee 2005a). If the coal seam is deeper than approximately 150 m, the water loss may be temporary unless the area is affected by severe geological disturbances, such as strong faulting. In most cases, surface waters lost to the subsurface re-emerge downstream via lateral faults (NSW Scientific Committee 2005a)."

### *Comment on Research Report Extract 1*

Rather than the two zones in the Tammetta conceptual model, it is generally accepted in literature (e.g. Forster, 1995[6]) that there is a sequence of deformational zones illustrated in Figure 1(b) and usually described as:

- ☐ the caved zone;
- ☐ the fractured zone, consisting of:
    - o a lower zone of connective-cracking; and
    - o an upper zone of disconnected-cracking;
- ☐ the constrained zone; and
- ☐ the surface zone.

Ditton and Merrick (2014) describe four zones with different terminology but essentially the

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[2] Email from Anthony Swirepik (OWS) to Centennial Coal dated 14 August 2014

[3] Tammetta, P. , 2012, Estimation of the Height of Complete Groundwater Drainage Above Mined Longwall Panels. Ground Water, online article 10.1111/gwat.12003, Blackwell Publishing Ltd, 12p.

[4] Ditton, S. and Merrick, N, 2014, A New Subsurface Fracture Height Prediction Model for Longwall Mines in the NSW Coalfields. Geological Society of Australia, 2014 Australian Earth Sciences Convention (AESC), Sustainable Australia. Abstract No 03EGE-03 of the 22nd Australian Geological Convention, Newcastle City Hall and Civic Theatre, Newcastle, New South Wales. July 7 - 10. Page 136.

[5] Figure 2(b) in this report.

[6] Forster, I.R., 1995. Impact of underground mining on the hydrogeological regime, Central Coast NSW. In: Sloan, S W and Allman, M.A. (Ed.), Engineering Geology of the Newcastle-Gosford Region, pp156-168.

same conceptualisation (Figure 1(a)):

- ☐ the A-Zone or "Continuous Cracking" zone - equivalent to the caved zone plus the connective-cracking part of the fractured zone;
- ☐ the B-Zone or "Lower Dilated" zone - equivalent to the disconnected-cracking part of the fractured zone, or the lower part of the constrained zone;
- ☐ the C-Zone or " Upper Dilated" zone - equivalent to the upper part of the constrained zone; and
- ☐ the D-Zone or "Surface Cracking" zone - equivalent to the surface zone.

It will be shown in a later section of this report that the "Collapsed Zone" of the Tammetta model corresponds with the A-Zone plus the B-Zone. As the B-Zone has disconnected fractures, it is not appropriate to ascribe complete collapse to this zone. Nor is it appropriate to infer unsaturated conditions for the entire zone. Unsaturated conditions would occur in the A-Zone, but need not necessarily occur throughout the entire A-Zone.

The rocks in the A-Zone would have a substantially higher vertical permeability than the undisturbed host rocks. This will encourage groundwater to move out of rock storage downwards towards the goaf. In the B-Zone, where disconnected-cracking occurs, the vertical movement of groundwater should not be significantly greater than under natural conditions, but horizontal permeability would be expected to be enhanced through dilation of bedding planes.

Depending on the width of the longwall panels and the depth of mining, and the presence of low permeability lithologies, there would be a constrained zone in the overburden that acts as a bridge. Rock layers are likely to sag without breaking, and bedding planes are also likely to dilate. As a result, some increase in horizontal permeability can be expected.

In the surface zone, near-surface fracturing can occur due to horizontal tension at the edges of a subsidence trough. Fracturing would be shallow (<20 m), often transitory, and any loss of water into the cracks would not continue downwards towards the goaf. The extract from Report #2 agrees that "surface waters lost to the subsurface re-emerge downstream via lateral faults". As "lateral faults" is a strange concept, are dilated bedding planes or opened joints intended as the mechanism?

The strata movements and deformation that accompany subsidence will alter the hydraulic and storage characteristics of aquifers and aquitards. As there would be an overall increase in rock permeability, groundwater levels will be reduced either due to actual drainage of water into the goaf or by a flattening of the hydraulic gradient without drainage of water (in accordance with Darcy’s Law).

## *Research Report Extract 2*

Another key section of Report #2 is extracted here:

"To understand the changes to subsurface flow, it is important to consider the preferential flow path process. Darcy’s Law cannot be used to describe flow through discrete fractures at local scales. Instead, flow in discrete fractures can be described using the cubic law, with the general assumption that fracture walls are analogous to parallel plates separated by a constant aperture (Witherspoon et al. 1980; Bear 1993; Lapcevic et al. 1999). Consequently, for a given gradient, flow through a fracture is proportional to the cube of the fracture aperture, as expressed in equation 3.1 (Lapcevic et al. 1999).

$$Q=C(2b)^3\Delta h \qquad (3.1)$$

where:
$Q$ = volumetric flow rate
$C$ = constant related to the properties of the fluid and the geometry of the flow domain
$b$ = aperture of the fracture
$\Delta h$ = change in hydraulic head

Flows through a fracture flow path are often significantly higher than flow through intact media. Figure

3.8 demonstrates this for a range of hydraulic conductivities. Figure 3.8 shows the thickness of a porous medium that would be equivalent to a single fracture of a given aperture. For example, under the same hydraulic gradient, the flow through a single fracture with an aperture of 1 mm is equivalent to the flow through a 10-m-thick layer of intact media with a hydraulic conductivity of 10 m/day (~$10^{-4}$ m/s) (Lapcevic et al. 1999). The influence of fracture surface roughness can be accounted for by the inclusion of an additional factor, *f*, in equation 3.1. Witherspoon et al. (1980) conducted experimental studies using both radial and straight flow geometries and fractures of various rock types, with apertures ranging from 4 to 250 μm. In these experiments, *f* was observed to vary from 1.04 to 1.65. Consequently, a more generalised form of the cubic law exists (Witherspoon et al. 1980) (equation 3.2):

$$Q=(C/f)(2b)^3\Delta h \qquad (3.2)$$

where:
$f$=1 for smooth walls and $f$>1 for rough surfaces

Hence, predictions of groundwater flow based on the cubic law, where *f* = 1, are generally adequate for most conditions (Lapcevic et al. 1999). Flow velocities through discrete fractures (often measured in m/day) are substantially higher than flow velocities through porous media (typically between 1 and 100 m/year) (Cook 2003). The water velocity in the fracture is proportional to the square of the fracture aperture (Cook 2003).

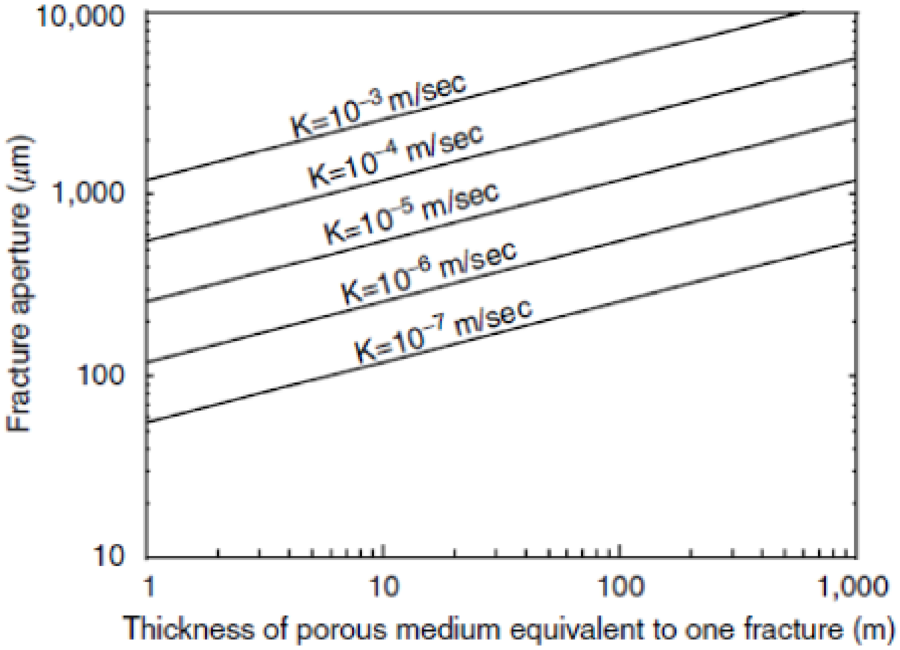

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Figure 3.8 Comparison of aperture of a single fracture with equivalent thickness of porous media.

This summary and explanation of the physics of groundwater flow demonstrate that a few small cracks through the swamp substrate can lead to substantial vertical drainage. The cracks can have an aperture of millimetres, making them hard to detect through overlying sediment and vegetation. The increased flow volume and flow velocity through the fractures can have implications for remediation, as discussed in Section 5.1.

The ability of a swamp water body to recover depends on the width of the crack, the surface gradient, the substrate composition and the presence of organic matter (NSW Scientific Committee 2005a). An already-reduced flow rate due to drought conditions, or an upstream dam or weir, will increase the impact of water loss through cracking. The potential for self-closure of surface cracks is greater at sites with a low surface gradient; however, even temporary cracking, leading to loss of flow, may have long-term effects on ecological function in localised areas (NSW Scientific Committee 2005a). In general, the steeper the gradient, the more likely it is that suspended solids will be transported downstream, allowing the void to remain open, and the more likely is potential loss of flows to the subsurface (NSW Scientific Committee 2005a)."

### Comment on Research Report Extract 2

The literature review in this report extract is inadequate because it ignores the substantial field of discrete fracture networks (e.g. Xu and Dowd, 2010)[7]. The review considers only continuous (infinite) fractures characterised by aperture and roughness, and the impression is given that very large effective permeabilities would result from fracturing by application of an unmodified cubic law.

The argument is flawed for a couple of reasons. First, the application of the cubic law is an assumption that ignores the most important feature of a fracture - its continuity. Crimping or closure or truncation of a fracture would terminate the flow path and reduce the flow rate to zero, unless the discrete fracture intersects another fracture. Nullification of flow could be achieved with equation 3.2 by use of a large *f* factor (for roughness). However, the chart in Figure 3.8 is restricted to a unit value for *f*, a most unlikely condition. Second, the application of an unmodified cubic law leads to hydraulic conductivities that this author has found to be 4-6 orders of magnitude greater than required to match observed mine inflows, using an equivalent porous medium approach to modelling. This suggests that the admittedly high permeabilities in individual fractures are modified by weighted averaging with the deformed rock mass in the fractured zone, or the fractures lack sufficient continuity to transmit large volumes of water.

A better model of fracture flow should be based on stochastic representations of discrete fracture networks, such as offered by discrete fracture ellipses in the FracSim3D code of Wu and Dowd (2010).

Without proper consideration of fracture continuity, and fracture density in the case of surficial cracking, the claim is not substantiated that "a few small cracks through the swamp substrate can lead to substantial vertical drainage". For observed field fracture densities, the cracks themselves would have very small water storage capacity compared to the volume of water held within the bulk of the swamp sediments. A weighted average of the void water and matrix water is appropriate to assess whether the loss of water through surficial fractures might be significant. The fracture density would have to be much higher than generally observed for the loss of water to be significant.

## 3 Research Report #3

### Research Report Extract 3

A key section of Report #3 is extracted here:

"Tammetta (2012) estimated the height of complete groundwater drainage above subsided longwall panels (referred to as H) using a database of hydraulic head measurements made with multiple devices down the depth profile at a number of sites worldwide. H was shown to be relatively independent of most parameters except the geometry of the mined width and the overburden thickness. An empirical equation linking H (in metres) over a centre panel to these parameters was developed and is given by:

$$H = 1438 \ln(4.315 \times 10^{-5} u + 0.9818) + 26$$

where w is the mined width (equal to the panel width plus the adjacent heading widths), d is the overburden thickness, t is the mined height, and $u = w\, t^{1.4}\, d^{0.2}$. All dimensions are in metres.
In the equation, H depends only on the geometry of the mine opening and the overburden thickness. The equation applies to a variety of strata types and is considered a reliable tool for making predictive estimates of H. Host geology appears to play a minor role.

Tammetta also presents a ground deformation conceptual model from a groundwater perspective, shown in Figure 7.10[5].

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[7] C. Xu and P. Dowd. A new computer code for discrete fracture network modelling. Computers & Geosciences, 36(3):292-301, Mar. 2010.

From a groundwater perspective, longwall caving creates two distinct zones above a continuously sheared panel (Tammetta 2012):

- the collapsed zone
- the disturbed zone.

These zones are illustrated in Figure 7.10. The collapsed zone is parabolic in cross-section, and reaches from the mined seam to a maximum height equal to H over the centre panel. This zone is severely disturbed and is completely drained of groundwater during caving. It is subsequently unable to maintain a positive pressure head. It will behave as a drain while the mine is kept dewatered. Within this zone, the matrix of rock blocks may continue draining for extended periods; however, the defects will immediately transport this water downward to the mine. Groundwater flow will not be laminar, and Darcy's equation is unlikely to be obeyed.

The disturbed zone overlies the collapsed zone. Positive groundwater pressure heads are maintained over most of the zone. Limited data for long-term groundwater behaviour in this zone suggest that hydraulic heads remain relatively stable, except for immediate lowering associated with drainage of lower strata and minor increases in void space after caving. Groundwater flow will be laminar, and Darcy's equation is likely to be obeyed. Desaturation in the disturbed zone occurs above the chain pillars. Here, H is smaller than over the centre panel, and may reduce to zero if the pillar is flanked by only one panel. H above the pillars is likely to be more strongly dependent on d than for the centre panel, and will probably also be dependent on the pillar width (see note 2 at the end of the chapter)."

Note 2: "*Ross Seedsman* believes that some of the larger figures for complete height of groundwater drainage (CHGD) provided in Tammetta (2012) should be considered in relation to a paper by Guo et al. (2007), which provides a different interpretation. Ross suggests that the representation of the collapsed zone in Figure 7.10 is questionable and also that there is a fundamental difficulty in using complete groundwater drainage as a measure of impact as it is difficult to allow for the time factor. The dilated zones in the current models allow for a temporary drop in piezometric level, which may take an extended period of time to recover if the pre-mining hydraulic conductivities are low."

### *Comment on Research Report Extract 3*

Comments on the Tammetta conceptual model have been made earlier in "*Comment on Research Report Extract 1*". Additional comments are made in the following sections when comparing the Ditton and Tammetta conceptual models and analytical formulas.

There is agreement with the concept of an arched collapsed zone, but there is disagreement as to the height of this zone and also the requirement that it be fully unsaturated, that it "is completely drained of groundwater during caving" to the height H given by the cited formula. It is agreed that "Darcy's equation is unlikely to be obeyed" at local scale, but at the scale of numerical models an equivalent porous medium is a practical surrogate for characterising the fractured zone and accommodating the water throughput. As the fractured zone permeabilities required to match mine inflows are very much lower than would be expected for pure fracture flow, it is likely that weighted averaging with the fractured zone matrix is appropriate, or the fractures lack sufficient continuity to transmit large volumes of water. In the report extract, it is recognised that the matrix still contains water - "the matrix of rock blocks may continue draining for extended periods". Although the water pressure in the fractures is likely to be atmospheric, when combined with the water pressure in the matrix in an equivalent porous medium, it is likely that a net positive pressure would occur in the modelled representation of the upper part of a fractured zone.

HydroSimulations (2014)[8] conducted a peer review of the groundwater assessment by CSIRO (Adhikary and Wilkins, 2013)[9] for the Angus Place and Springvale Colliery Operations in which this statement was made: " Of particular interest are the resulting pressure head distributions above mined longwall panels (see Figures 62, 63, 76, 77, 78). The results show alternating zones of saturation and desaturation which significantly advances our conceptualisation of the saturation field associated with underground mining - a matter currently under debate in the

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[8] HydroSimulations, 2014, Peer Review - Angus Place and Springvale Colliery Operations Groundwater Assessment. Letter Report HC2014/11 prepared for Centennial Angus Place Pty Ltd.

[9] Adhikary, D. P. and Wilkins, A., 2013, Angus Place and Springvale Colliery Operations Groundwater Assessment. CSIRO Report No EP132799 for Angus Place Colliery and Springvale Colliery. May 2013.

hydrogeology profession". Figures 63 and 77 are reproduced below for a North-South cross-section.

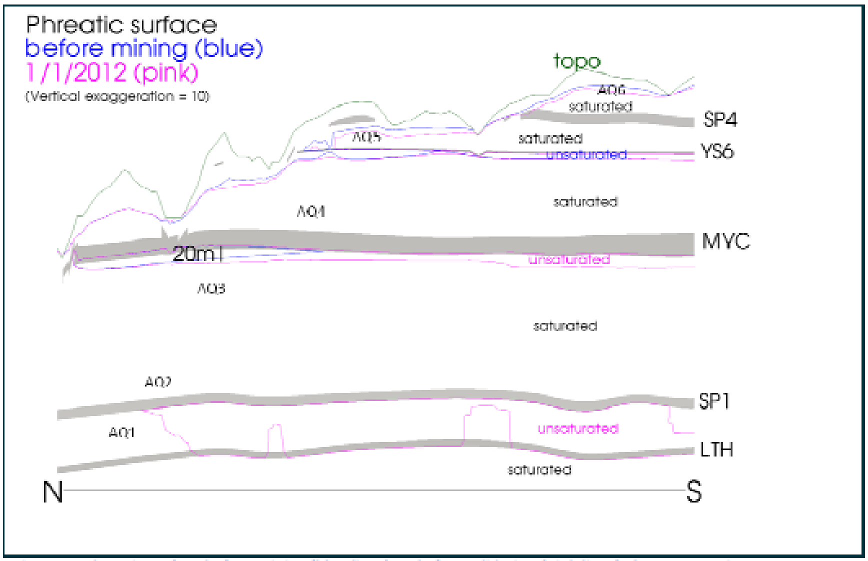

Figure 63 Phreatic surface before mining (blue lines) and after validation (pink lines) along N-S section

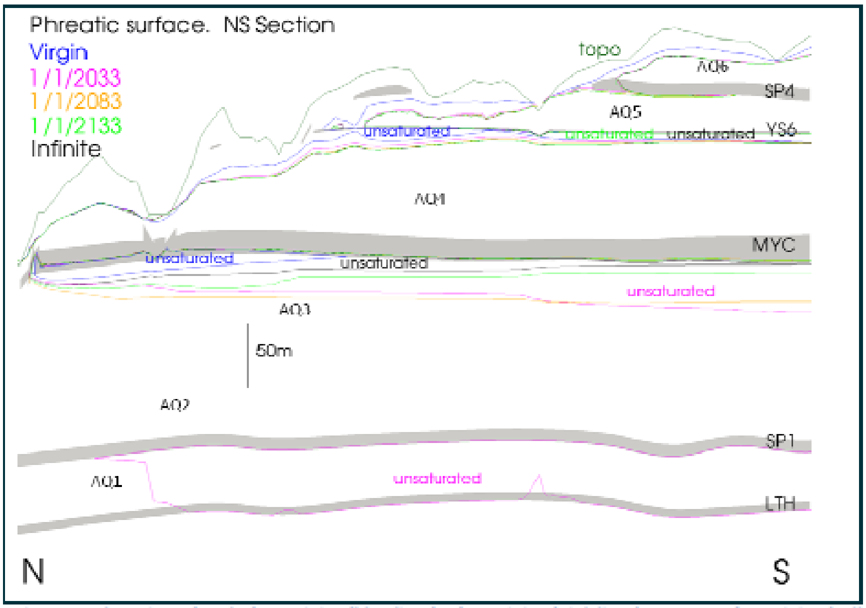

Figure 77 Phreatic surface before mining (blue lines), after mining (pink lines), 50 years after mining (yellow lines), 100 years after mining (green lines) and steady-state after mining (black lines) along N-S section

## 4 Alternative Fractured Zone Algorithms

There are only two known algorithms that aim to estimate the altitude of the deformed zone above an underground mine in terms of more than one causative factor.

The algorithms have been put forward in consulting reports by Steve Ditton of Ditton Geotechnical Services Pty Ltd (DGS) and in a journal paper by Paul Tammetta of Coffey Geosciences Pty Ltd[3]. Their formulas have been differentiated by Noel Merrick and Chris Nicol of HydroSimulations (not previously published) to reveal the sensitivity of fractured zone height to each causative factor. The two approaches have similar sensitivities for cover depth but differ for panel width and mining height. For mining height they are very different and trend in different directions.

The latest formulation of the Ditton model was presented at the Australian Earth Sciences Convention in Newcastle NSW in July 2014 (Ditton and Merrick, 2014)[4].

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

- Mining height [T (Ditton) or t (Tammetta)];
- Cover depth [H (Ditton) or h (Tammetta)]; and
- Longwall panel width [W (both authors)].

In addition, the Ditton model includes effective stratum thickness [t'] as a surrogate for roof rock integrity in one of his two developed models. The second model that uses only mining geometry, with no geology term, is directly comparable to the Tammetta model.

In this report, the underlying formulas for fractured zone height and sensitivity are presented, and then used to compare and contrast the predicted effects for varying panel width (for face widening), cover depth or mining height (for top coal caving).

## 5 Ditton Model Formulas

The Ditton conceptual model is illustrated in Figure 1.

The new Ditton model includes the key fracture height driving parameters of panel width (W), cover depth (H), mining height (T) and local geology factors to estimate the A-Zone and B-Zone horizons above a given longwall panel. Segregation between the A-Zone and B-Zone is based on a threshold vertical strain of 8 mm/m.

Formulas are offered for two models:

Geometry Model, which depends on W, H and T; and

Geology Model, which depends on W, H, T and t' (where t' is the effective thickness[10] of the stratum where the A-Zone height occurs).

The formulas for fractured zone height (A) for single-seam mining are:

Geometry Model: $A = 2.215\ W'^{0.357}\ H^{0.271}\ T^{0.372}\quad \pm [0.16 - 0.1\ W']$ (metres)

Geology Model: $A = 1.52\ W'^{0.4}\ H^{0.535}\ T^{0.464}\ t'^{-0.4}\quad \pm [0.15 - 0.1\ W']$ (metres)

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

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

The models have been validated to 34 measured Australian case-studies (including West Wallsend, Mandalong, Springvale, Able, Ashton, Austar, Berrima, Metropolitan and Wollemi/North Wambo Mines) with a broad range of mining geometries and geological conditions included. The database also includes three cases in which connective cracking reached the surface (South Bulga, Homestead and Invincible Collieries). Statistics for the database are presented in Table 1, and best-fit back-calculated effective beam thicknesses for different coalfields are listed in Table 2.

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[10] Typically 15-20 m in the Gunnedah Coalfield.

**Table 1. Statistics for the Ditton Model Database for Australian Coalfields.**

| STATISTIC | Panel Width [W (m)] | Cover Depth [H (m)] | Mining Height [T (m)] |
|---|---|---|---|
| **Mean** | 191 | 254 | 3.0 |
| **Standard Deviation** | 65 | 138 | 0.8 |
| **Minimum** | 110 | 75 | 1.9 |
| **Median** | 179 | 213 | 2.8 |
| **Maximum** | 355 | 500 | 6.0 |

Note that the maximum mining height in the database is 6.0 m.

**Table 2. Minimum Effective Thickness of a Spanning Stratum.**

| COALFIELD | SOUTHERN | WESTERN | NEWCASTLE | HUNTER | GUNNEDAH |
|---|---|---|---|---|---|
| **Normal Condition [t'(m)]** | 20 - 40 | 20 - 30 | 15 - 20 | 15 - 20 | 15 - 20 |
| **Adverse Condition [t'(m)]** | 15 | 10 | 10 | 10 | 10 |

The variation of the A-Zone height for each factor is illustrated in Figure 3 to Figure 6. In each figure, the other three parameters are held constant at their database median values.

Ditton (2014, pers. comm.) has a procedure for estimating the increased fractured zone height for multi-seam mining, in which the mining height (T) in the above formulas is replaced by an effective mining height (T') for the upper mined seam that accounts for the additional subsidence caused by mining other seams. This relies on theoretical estimates of subsidence for single or multiple seams. The ratio of the increase in subsidence (due to mining another seam) to the subsidence for a single seam is taken to apply also to the increase in the effective mining height[11].

## 6 Tammetta Model Formula

The Tammetta conceptual model is illustrated in Figure 2.

The Tammetta model includes the key fracture height driving parameters of panel width (W), cover depth (h), and mining height (t) to estimate the height of "complete groundwater drainage", which corresponds with the height of the zero-pressure region, an unsaturated "collapsed zone". The model relies on the same parameters as the Ditton Geometry Model. There is no geology factor corresponding to the effective thickness of Ditton's Geology Model.

The formula for collapsed zone height (H) for single-seam mining is:

Geometry Model: $H = 1438 \ln[(4.315 \times 10^{-5})\, h^{0.2}\, t^{1.4}\, W + 0.9818] + 26$ (metres)

Using Ditton's notation to avoid confusion, the formula for collapsed zone height (A) for single-seam mining is equivalent to:

Geometry Model: $A = 1438 \ln[(4.315 \times 10^{-5})\, H^{0.2}\, T^{1.4}\, W + 0.9818] + 26$ (metres)

The 95th percentile (maximum) A-height is estimated by adding 37 m.

The model has been validated to Australian and international case-studies, using hydraulic head and ground movement (extensometer) data. An important assumption is that "*H* is taken as being

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[11] One unpublished case study in the Hunter Coalfield showed an increase in the effective mining height of about 70%. This had the effect of increasing the A-height by 27%.

equal to the top of the zone of large downward movement". This level is said to correspond with zero groundwater pressure, according to the examined head database. Statistics for the database are presented in Table 3.

**Table 3. Statistics for the Tammetta Model Database for Australian and International Coalfields.**

| STATISTIC | Panel Width [W (m)] | Cover Depth [H (m)] | Mining Height [T (m)] |
|---|---|---|---|
| **Minimum** | 110 | 64 | 1.2 |
| **Mean** | 179 | 243 | 2.5 |
| **Maximum** | 260 | 470 | 4.1 |

Note that the maximum mining height in the database is 4.1 m.

No formula is offered for multi-seam mining.

## 7 Sensitivity Formulas

The sensitivity of the A-zone height to each of the driving parameters is obtained by differentiation.

The sensitivity formulas for the Ditton Geometry Model are:

$$\frac{\partial A}{\partial H} = 0.600\ H^{-0.729}\ W'^{0.357}\ T^{0.372}$$

$$\frac{\partial A}{\partial T} = 0.824\ T^{-0.628}\ W'^{0.357}\ H^{0.271}$$

$$\frac{\partial A}{\partial W'} = 0.791\ W'^{-0.643}\ H^{0.271}\ T^{0.372}$$

The sensitivity formulas for the Ditton Geology Model are:

$$\frac{\partial A}{\partial H} = 0.813 * H^{-0.465}\ W'^{0.4}\ T^{0.464}\ t'^{-0.4}$$

$$\frac{\partial A}{\partial T} = 0.705\ T^{-0.536}\ W'^{0.4}\ H^{0.535}\ t'^{-0.4}$$

$$\frac{\partial A}{\partial W'} = 0.608\ W'^{-0.6}\ H^{0.535}\ T^{0.464}\ t'^{-0.4}$$

$$\frac{\partial A}{\partial t'} = 0.608\ t'^{-1.4}\ W'^{0.4}\ H^{0.535}\ T^{0.464}$$

The Tammetta model sensitivity formulas are:

$$\frac{\partial A}{\partial H} = \frac{0.2\ C1\ E1\ H^{-0.8}}{0.9818 + E1\ H^{0.2}}$$

$$\frac{\partial A}{\partial T} = \frac{1.4\ C1\ E2\ T^{0.4}}{0.9818 + E2\ T^{1.4}}$$

$$\frac{\partial A}{\partial W} = \frac{C1\ E3}{0.9818 + E3\ W}$$

where: $C1 = 1438$
$C2 = 4.315 \times 10^{-5}$
$E1 = C2\ W\ T^{1.4}$

$E2 = C2\ W\ H^{0.2}$
$E3 = C2\ H^{0.2}\ T^{1.4}$

The sensitivities to each causative factor are illustrated in Figure 7 to Figure 9, with comparison between Ditton and Tammetta models.

Figure 7 considers the increase in fractured zone height for an increase of 25 m in either the (effective) panel width or the cover depth. The findings for (effective) panel width are:

- ❑ The Ditton Geometry Model has an A-Zone increase of 3-10 m (12-40% of 25 m increment);
- ❑ The Tammetta (Geometry) Model has an A-Zone increase of 15-19 m (60-76% of 25 m increment); and
- ❑ The Ditton Geology Model has an A-Zone increase of 5-14 m (20-56% of 25 m increment).

The findings for cover depth are:

- ❑ The Ditton Geometry Model has an A-Zone increase of 1.5-8 m (6-32% of 25 m increment);
- ❑ The Tammetta (Geometry) Model has an A-Zone increase of 1.5-10 m (6-40% of 25 m increment); and
- ❑ The Ditton Geology Model has an A-Zone increase of 5-15 m (20-60% of 25 m increment).

Figure 8 considers the increase in fractured zone height for an increase of 0.5 m in mining height. The findings for mining height are:

- ❑ The Ditton Geometry Model has an A-Zone increase of 3.8-8.6 m (10-17 times the 0.5 m increment);
- ❑ The Tammetta (Geometry) Model has an A-Zone increase of 26-37 m (52-74 times the 0.5 m increment), and it trends in the opposite direction; and
- ❑ The Ditton Geology Model has an A-Zone increase of 6.5-14 m (13-27 times the 0.5 m increment).

As the Ditton model has a basis in geotechnical theory, while the Tammetta model is an empirical best-fit procedure, it is expected that the Ditton model would give the more correct sensitivity trend for mining height. The departure of the Tammetta model, in terms of trend and magnitude of its sensitivity to mining height, might be due to database limitations. It has previously been noted that the respective Ditton and Tammetta databases had maximum values of 6.0 m and 4.1 m for mining height. This means that the Tammetta model is uncontrolled for the higher mining heights.

Figure 9 shows the decrease in fractured zone height for an increase of 0.5 m in the effective thickness of a spanning beam. The finding for beam thickness is:

- ❑ The Ditton Geology Model has an A-Zone decrease of 0.3-7 m (0.6-14 times the 0.5 m increment).
- ❑ There is no equivalent parameter in the Tammetta model, but it is noted in Tammetta (2012) that "Host geology appears to play a minor role".

## 8 Database Probability Statistics

Representative statistics for characteristic ratios derived for the Ditton database are listed in Table 4 and Table 5. When applied to the Ditton database for Australian coalfields, the Tammetta formula leads to similar statistics in Table 6.

A common first-order estimate of fractured zone height is afforded by the ratio A/W, which is 0.45 for the Ditton concept at the median (Table 4) and 0.78 for the Tammetta concept at the median (Table 6). The Ditton B-Zone ratio is 0.60 at the median (Table 5).

Another common first-order estimate of fractured zone height is afforded by the ratio A/T, which is 21-37 for the Ditton concept (Table 4) and 33-61 for the Tammetta concept (Table 6). The Tammetta estimates would appear excessive and are likely to include areas of disconnected fractures given that the B-zone range, which does include disconnected fractures, is 27T to 71T.

**Table 4. Exceedance Probabilities for Ditton Continuous Fracture Zone (A-Zone) Height for Australian Coalfields.**

| EXCEEDANCE PROBABILITY | Height of Fracture Zone / Panel Width [A/W] | Height of Fracture Zone / Cover Depth [A/H] | Height of Fracture Zone / Mining Height [A/T] |
|---|---|---|---|
| 20% | 0.38 | 0.23 | 21 |
| 50% | 0.45 | 0.43 | 32 |
| 80% | 0.73 | 0.69 | 37 |

For the parameters W, H and T in turn, the median B-height exceeds the median A-height by 33%, 100% and 34% (Table 5).

**Table 5. Exceedance Probabilities for Ditton Discontinuous Fracture Zone (B-Zone) Height for Australian Coalfields.**

| EXCEEDANCE PROBABILITY | Height of Fracture Zone / Panel Width [B/W] | Height of Fracture Zone / Cover Depth [B/H] | Height of Fracture Zone / Mining Height [B/T] |
|---|---|---|---|
| 20% | 0.47 | 0.60 | 27 |
| 50% | 0.60 | 0.86 | 43 |
| 80% | 1.07 | 0.95 | 71 |

**Table 6. Exceedance Probabilities for Tammetta Desaturated Zone Height for Australian Coalfields. [Derived using Tammetta formula applied to the database of Ditton]**

| EXCEEDANCE PROBABILITY | Height of Desaturated Zone / Panel Width [H/W] | Height of Desaturated Zone / Cover Depth [H/d] | Height of Desaturated Zone / Mining Height [H/t] |
|---|---|---|---|
| 20% | 0.61 | 0.32 | 33 |
| 50% | 0.78 | 0.80 | 48 |
| 80% | 1.02 | 1.13 | 61 |

There is a substantial difference between the Ditton A-height and the Tammetta desaturation-height. Table 7 shows comparative statistics for the Ditton and Tammetta conceptual models. For the parameters W, H and T in turn, the median desaturation-height exceeds the median A-height by 73%, 86% and 50%.

**Table 7. Exceedance Probabilities for Ditton Continuous Fracture Zone (A-Zone) Height and for the Tammetta Desaturated Zone Height for Australian Coalfields.**

| STATISTIC | Height of Fracture Zone / Panel Width [A/W] | | Height of Fracture Zone / Cover Depth [A/H] | | Height of Fracture Zone / Mining Height [A/T] | |
|---|---|---|---|---|---|---|
| | Ditton | Tammetta | Ditton | Tammetta | Ditton | Tammetta |
| **20%** | **0.38** | 0.61 | **0.23** | 0.32 | **21** | 33 |
| **50%** | **0.45** | 0.78 | **0.43** | 0.80 | **32** | 48 |
| **80%** | **0.73** | 1.02 | **0.69** | 1.13 | **37** | 61 |

## 9 Model Probability Distributions

Calculations of A-Zone and B-Zone heights, and associated ratios, for the entries in the Ditton database have been sorted and ranked to give cumulative probability distributions in Figure 10 to Figure 14. The Ditton Geology Model and Geometry Model track each other closely.

Comparative cumulative probability distributions (Ditton and Tammetta models) are shown in Figures 12, 13 and 14 where it appears that the Tammetta formulation agrees better with the B-zone definition. For the parameters W, H and T in turn, the median desaturation-height exceeds the median B-height by -0.4%, 5% and -8%.This suggests that the Tammetta formulation includes zones of disconnected fractures.

## 10 Conclusion

Opinions have been offered in this report on two literature reviews endorsed by the IESC:

A. Commonwealth of Australia 2014, *Temperate Highland Peat Swamps on Sandstone: evaluation of mitigation and remediation techniques, Knowledge report*, prepared by the Water Research Laboratory, University of New South Wales, for the Department of the Environment, Commonwealth of Australia; and

B. Commonwealth of Australia 2014, *Temperate Highland Peat Swamps on Sandstone: longwall mining engineering design—subsidence prediction, buffer distances and mine design options, Knowledge report*, prepared by Coffey Geotechnics for the Department of the Environment, Commonwealth of Australia.

The opinions are restricted to statements on surficial and deep fracturing as a result of underground mining:

1. The treatment of fractured zone algorithms in the literature reviews is inadeqate as the work of Ditton, documented in Ditton and Merrick (2014), is ignored;

2. The Ditton model for fractured zone height is considered superior to the Tammetta algorithm due to a basis in geotechnical theory, a correct trend for sensitivity to mining height, calibration to Australian conditions, and inclusion of a host geology term;

3. The association of the Collapsed Zone in the Tammetta model with complete desaturation is disputed, given the retention of significant volumes of water in the matrix of the rock material in this zone, and statistical correlation of the height of this

zone with the B-Zone altitude in the Ditton model, which marks the top of a zone that has disconnected fractures;

4. The treatment of fracture permeabilities in the literature review (in Report A) is inadeqate as the substantial body of work on discrete fracture networks is ignored;

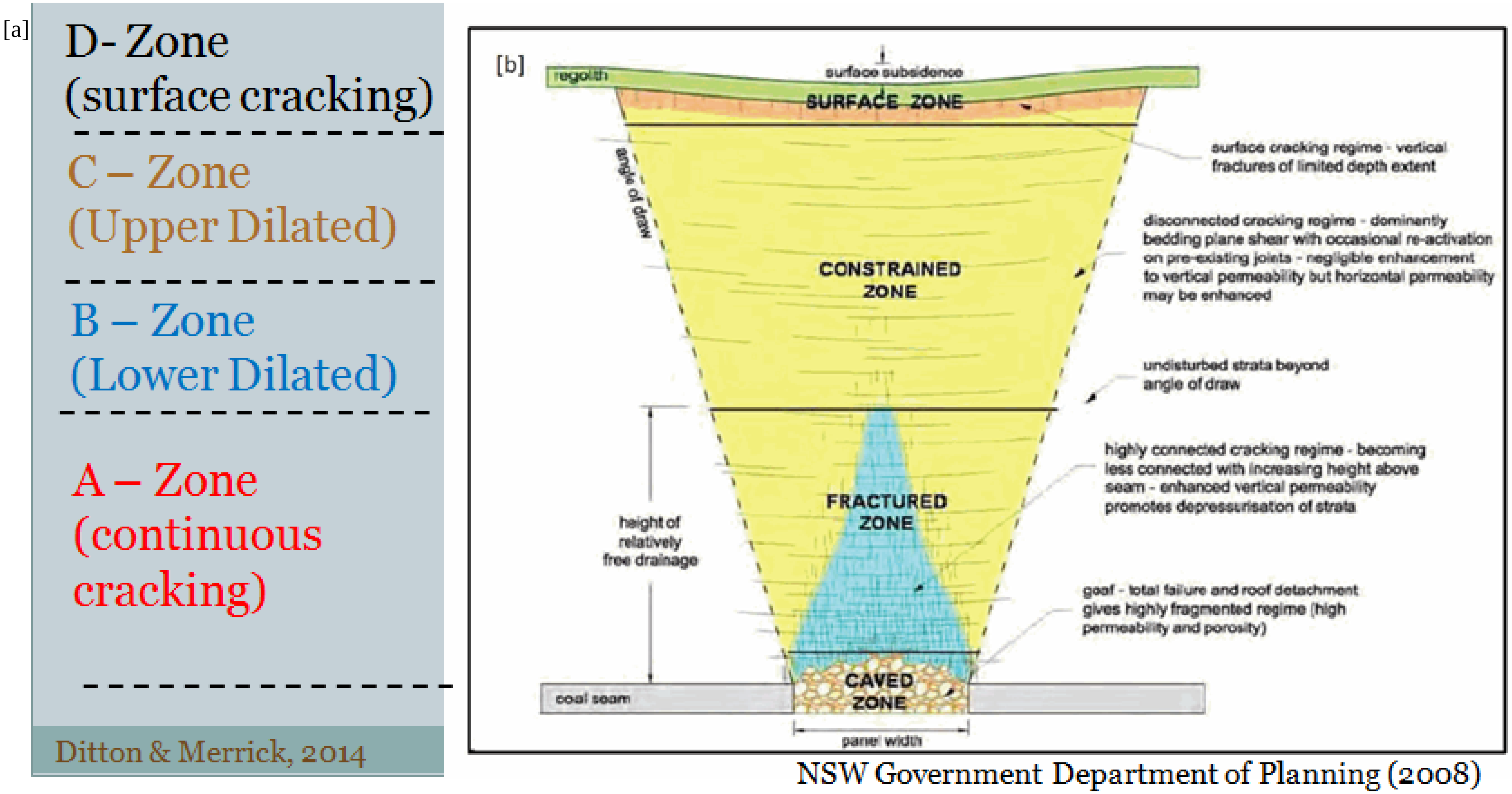
5. The estimates for fracture permeability are simplistic and grossly overstated, due to lack of consideration of fracture connectivity influenced by closure or truncation;

6. The conclusion that "a few small cracks through the swamp substrate can lead to substantial vertical drainage" is invalid, due to over-reliance on the cubic law for relating water flow to aperture size, and lack of consideration of the relative sizing of water-holding cracks and the water stored within intact swamp sediments.

Yours sincerely

N P Merrick

Dr Noel Merrick
Director



Ditton & Merrick, 2014

NSW Government Department of Planning (2008)

Figure 1. The Ditton Conceptual Model

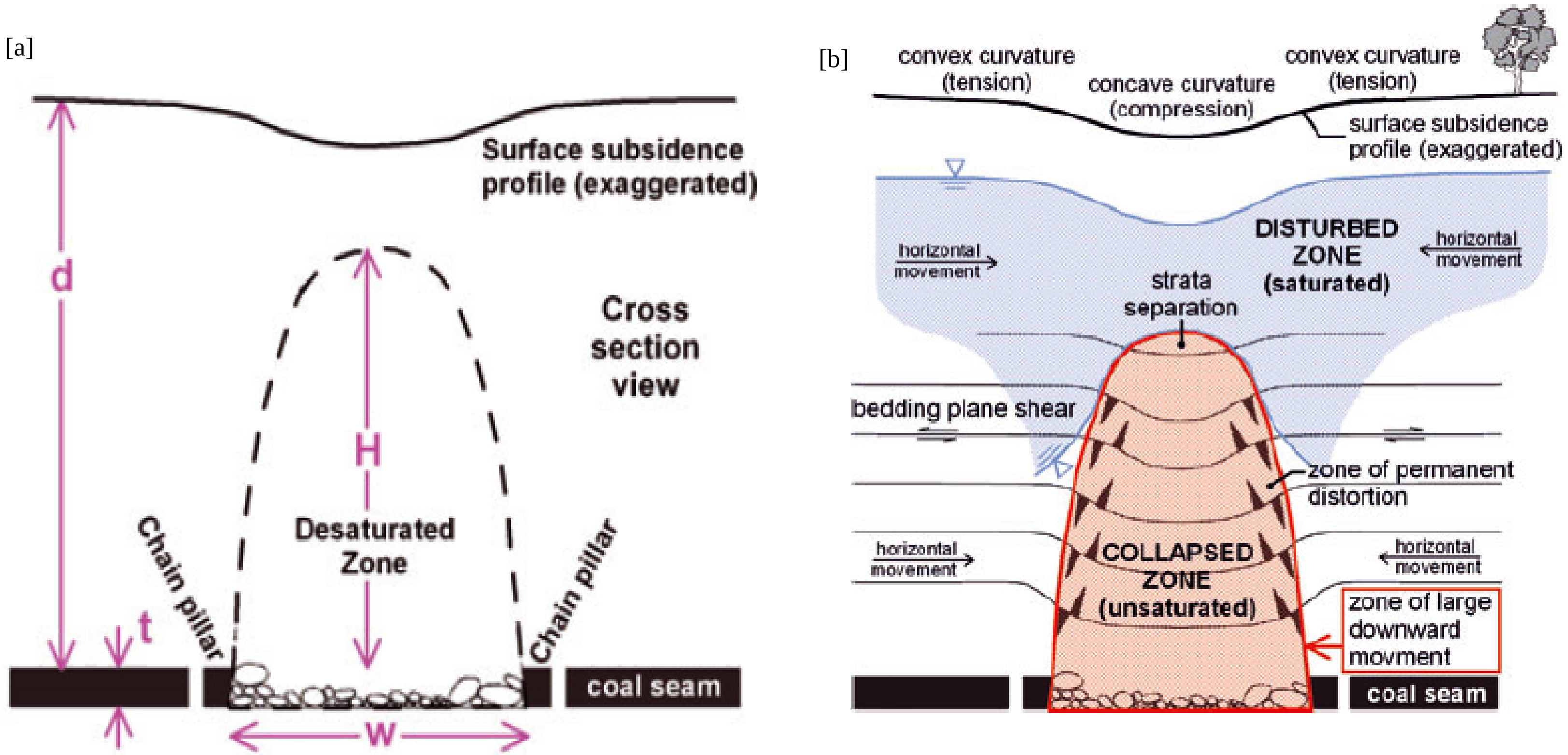


Figure 2. The Tammetta Conceptual Model [Figure 1b and Figure 10 from Tammetta (2012)]

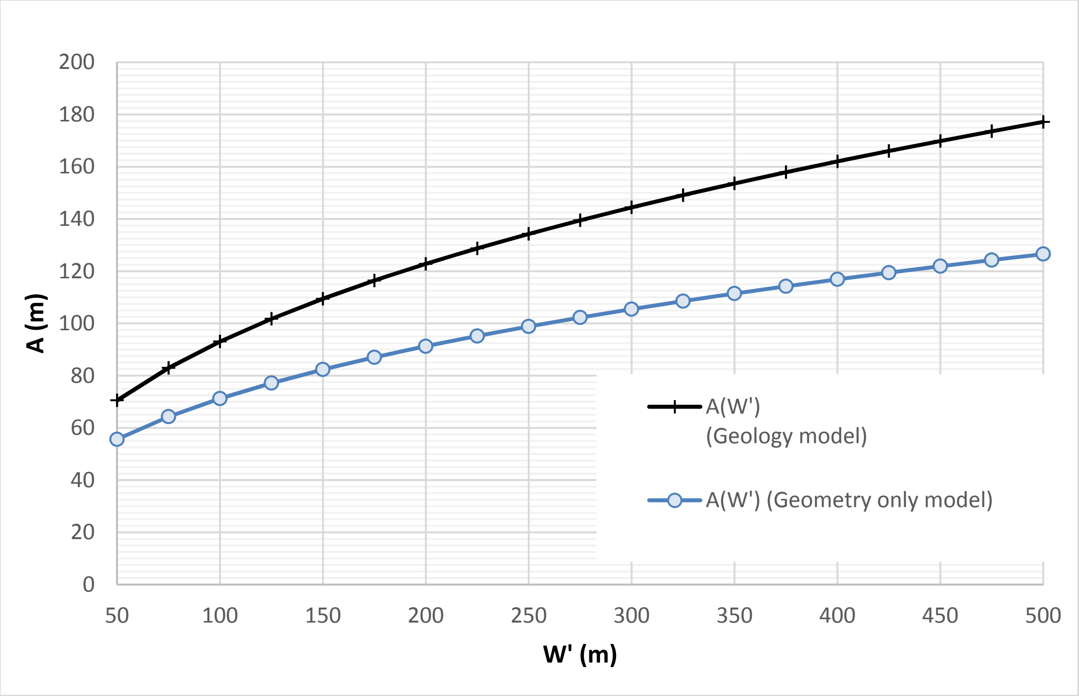


Figure 3. Variation of A-Zone Height for Varying Effective Panel Width for the Ditton Models [H, T and t' held constant at database median values]

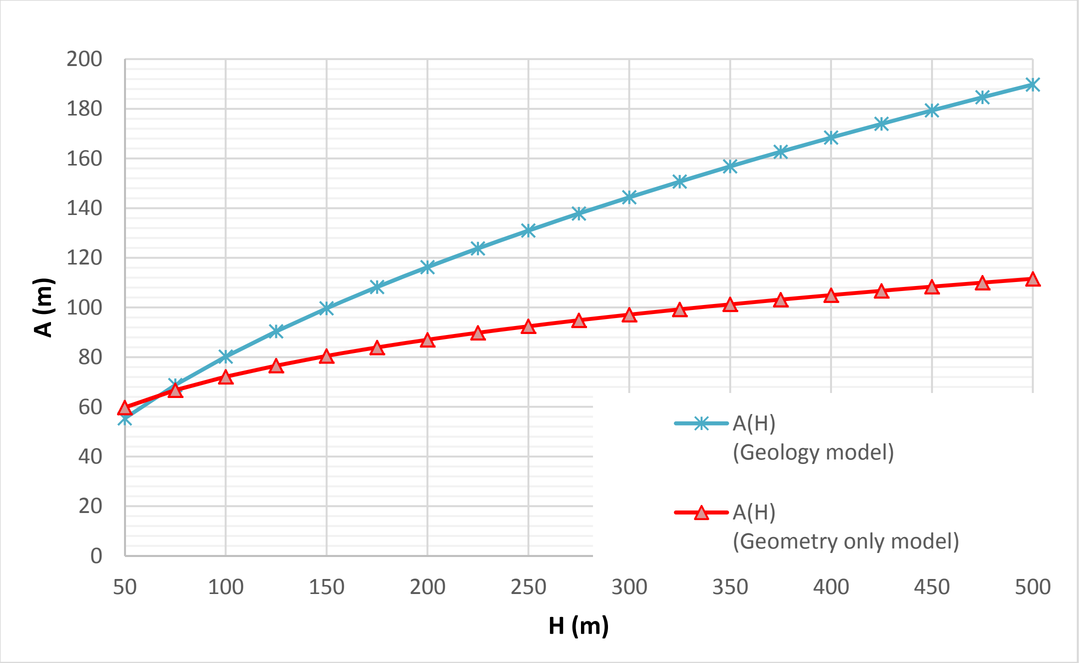


Figure 4. Variation of A-Zone Height for Varying Cover Depth for the Ditton Models [W', T and t' held constant at database median values]

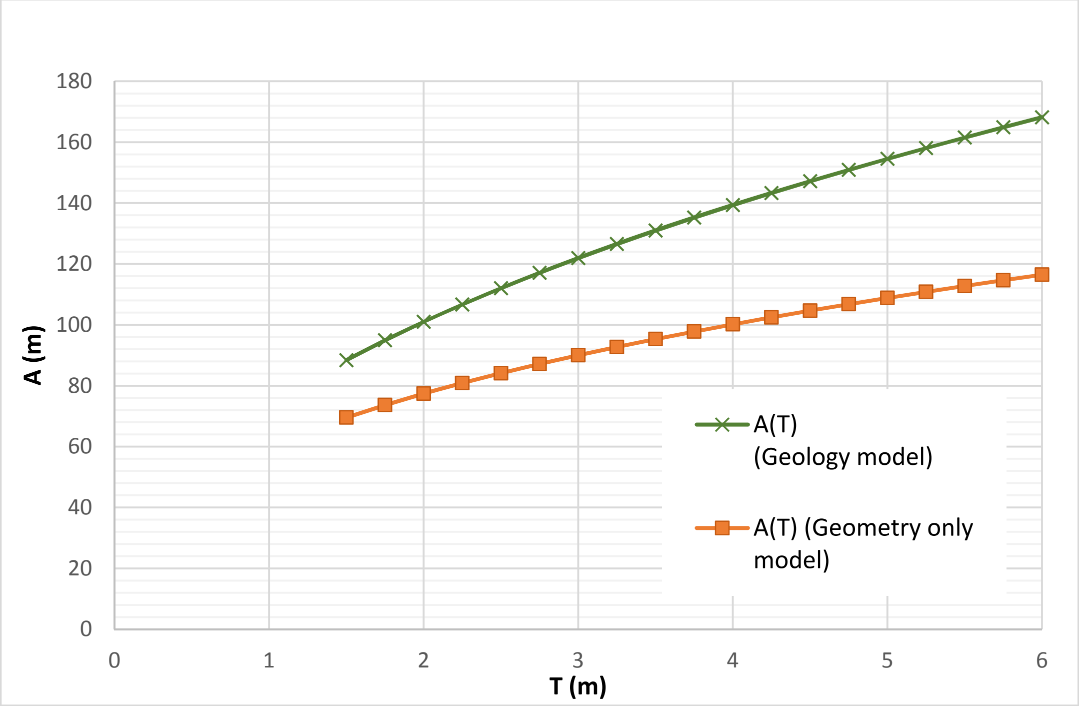


Figure 5. Variation of A-Zone Height for Varying Mining Height for the Ditton Models [W', H and t' held constant at database median values]

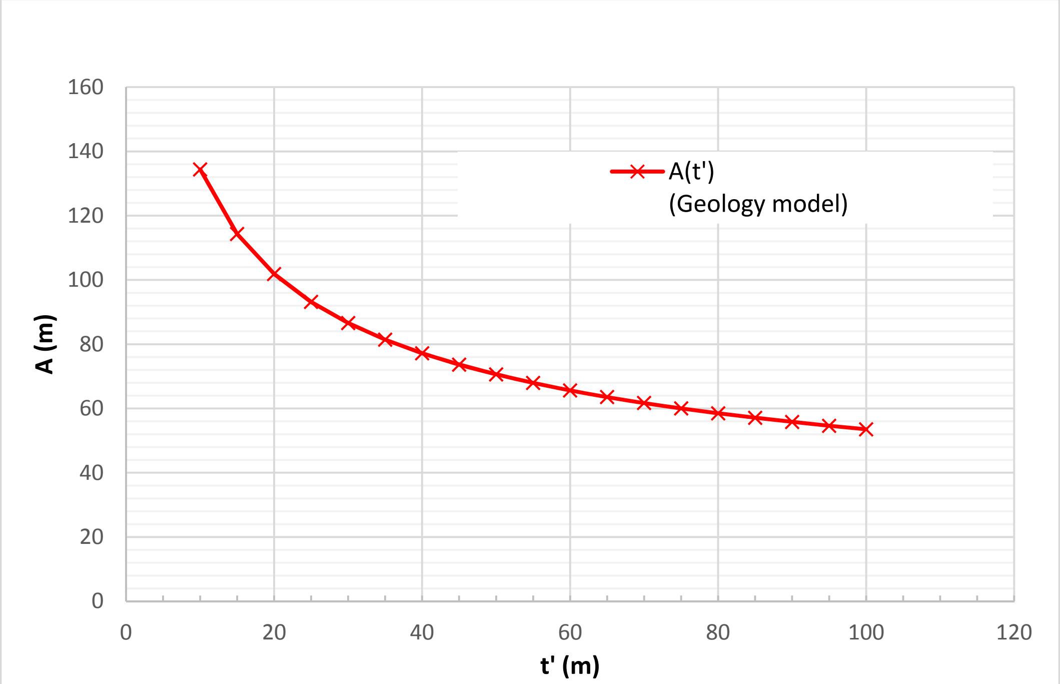
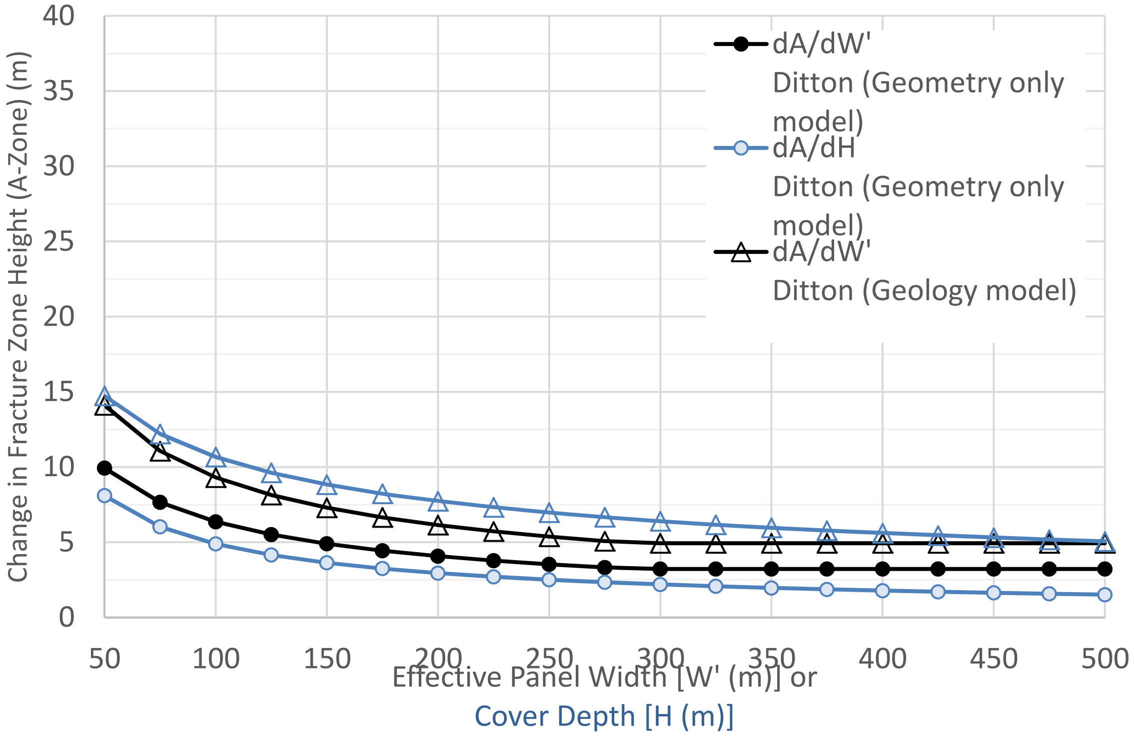


Figure 6. Variation of A-Zone Height for Varying Effective Stratum Thickness for the Ditton Model [W', H and T held constant at database median values]

[a]



[b]

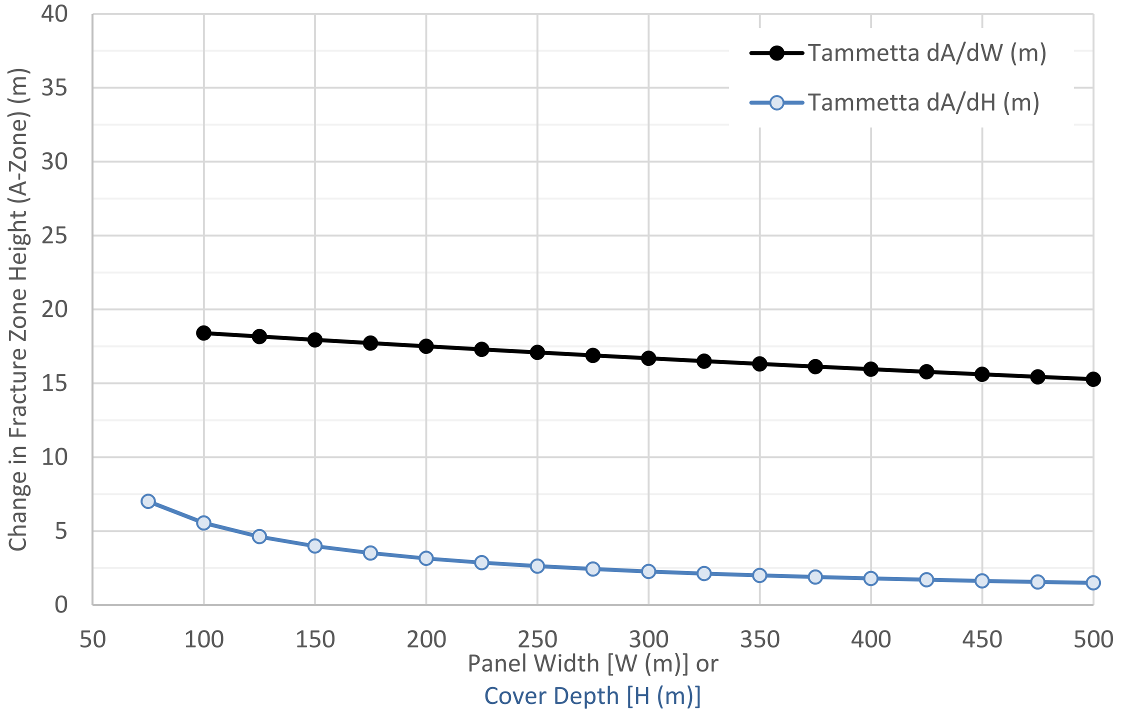
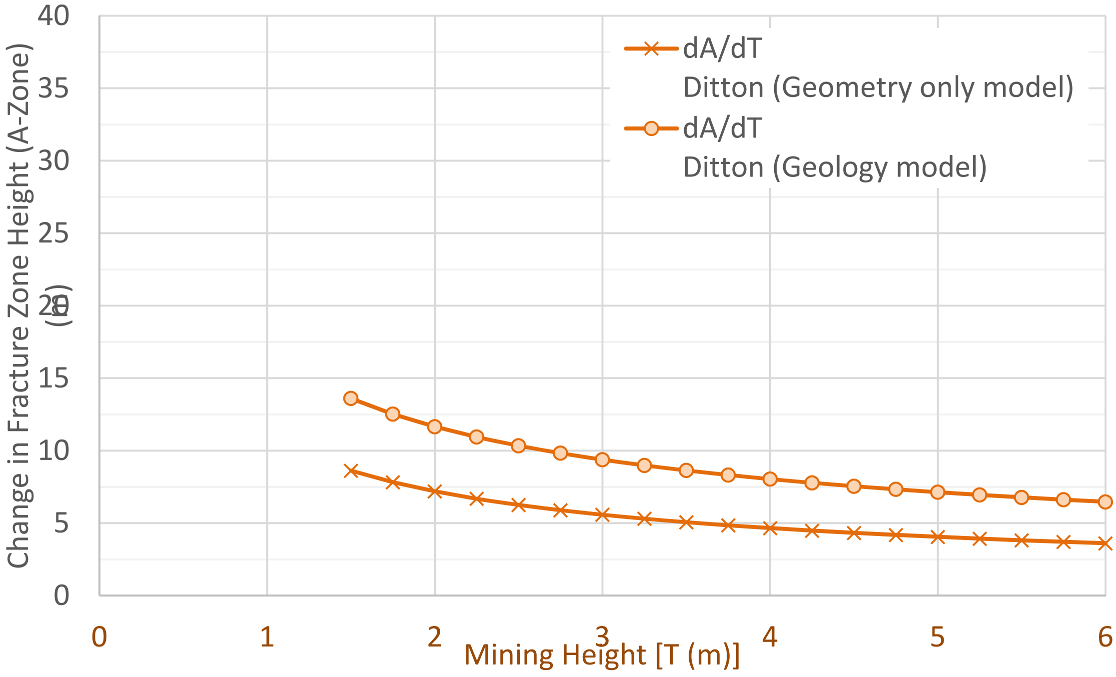


Figure 7. Sensitivity Analysis for the Change in A-Zone Height for 25 m Variation in Panel Width or Cover Depth: [a] Ditton Models; [b] Tammetta Model.

[a]



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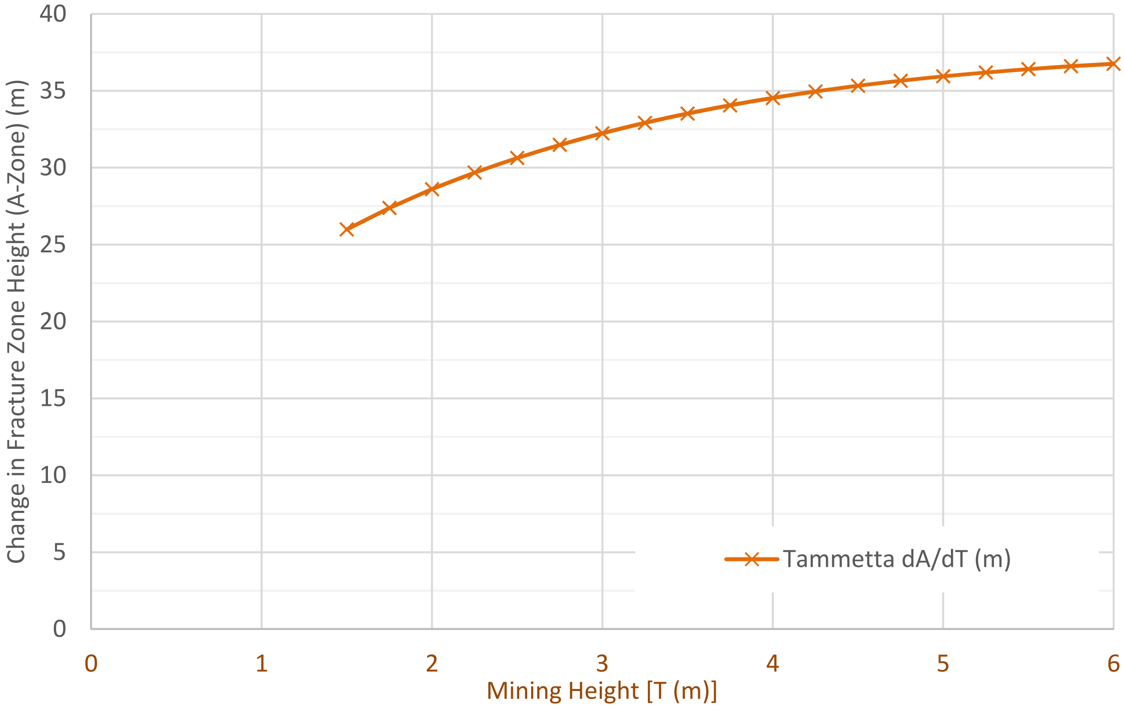


Figure 8. Sensitivity Analysis for the Change in A-Zone Height for 0.5 m Variation in Mining Height: [a] Ditton Models; [b] Tammetta Model.

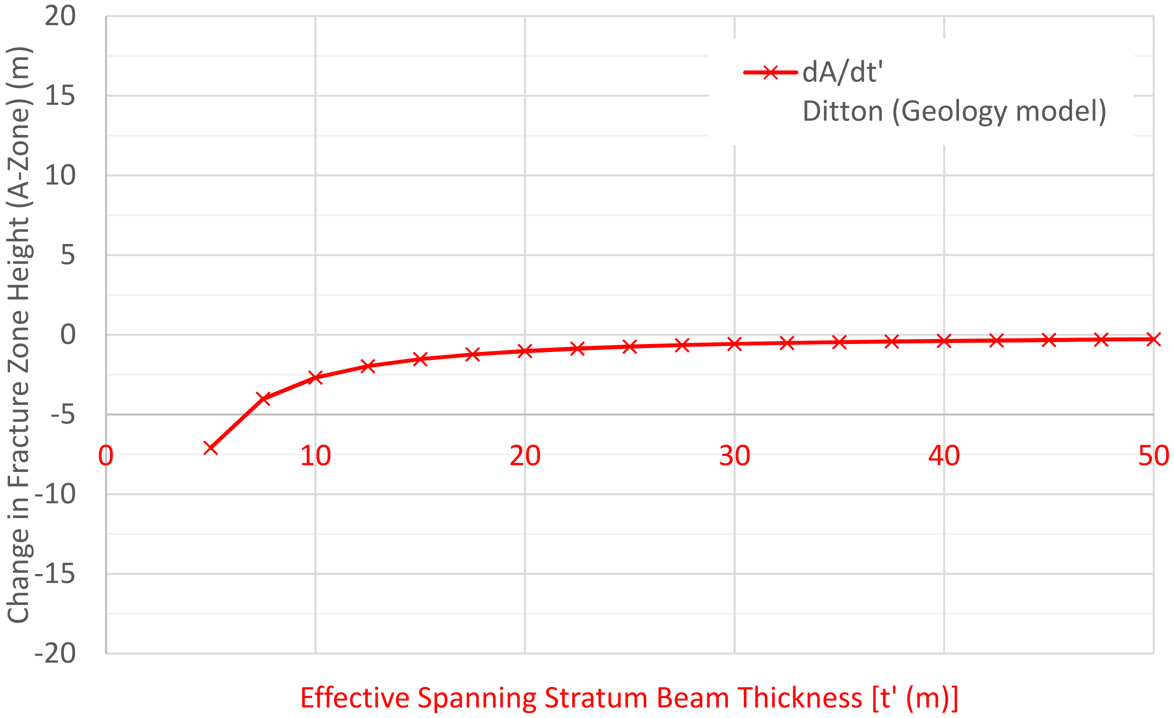
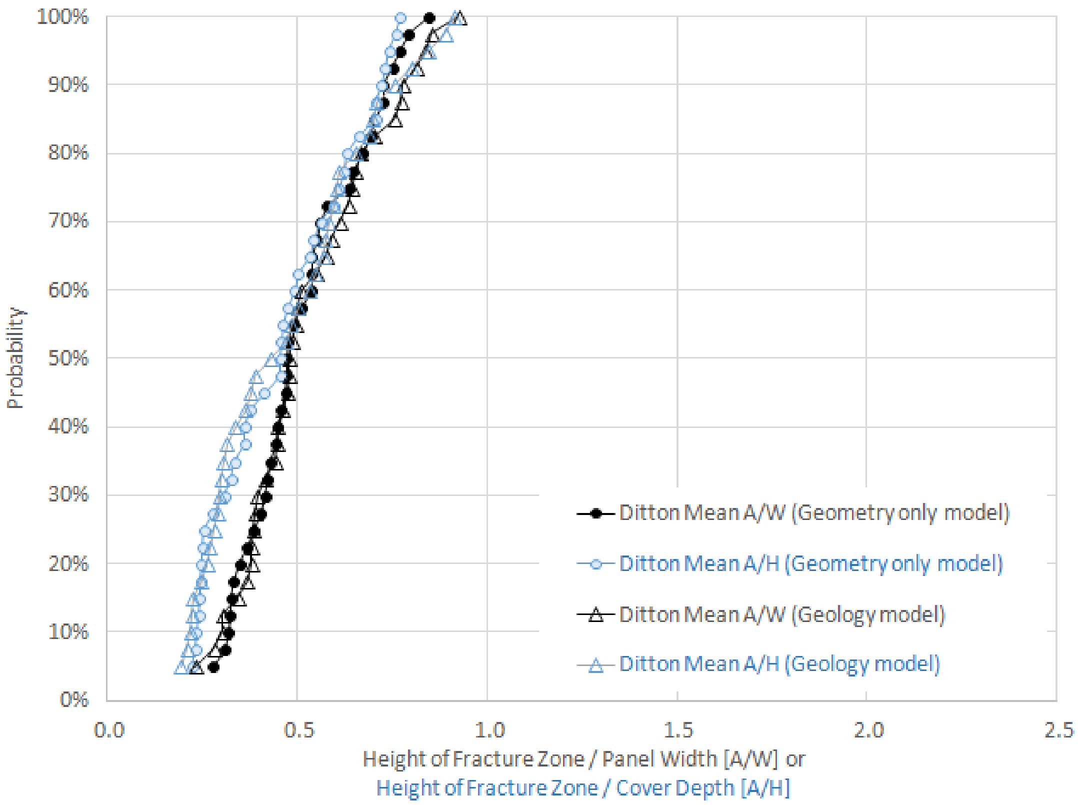


Figure 9. Sensitivity Analysis for the Change in A-Zone Height for 0.5 m Variation in Effective Stratum Thickness for the Ditton Geology Model.

[a]



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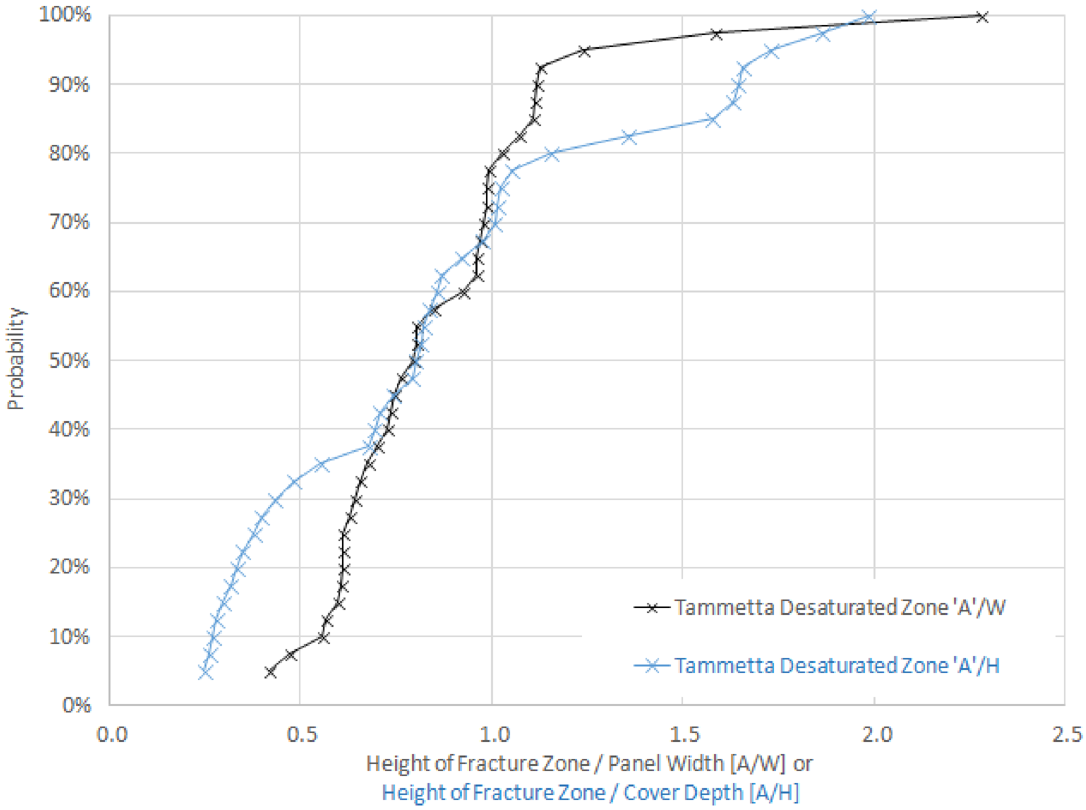
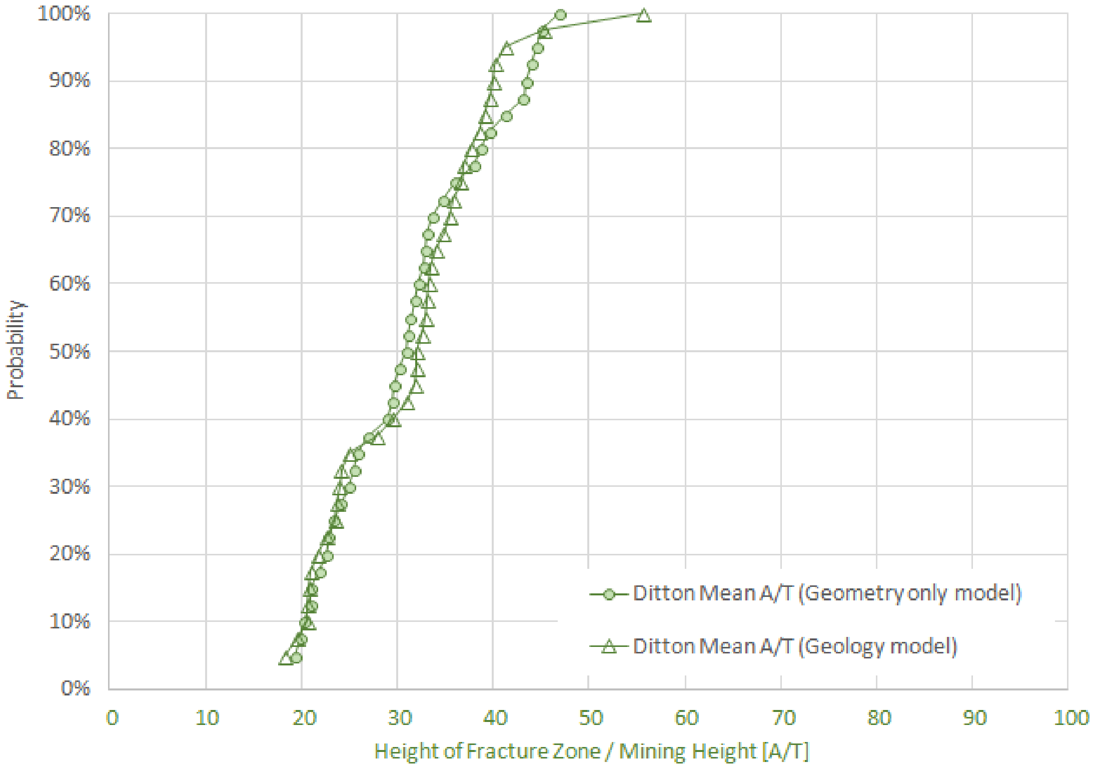


Figure 10. Probability Analysis for the Ratio of A-Zone Height to Panel Width or Cover Depth: [a] Ditton Models; [b] Tammetta Model.

[a]



[b]

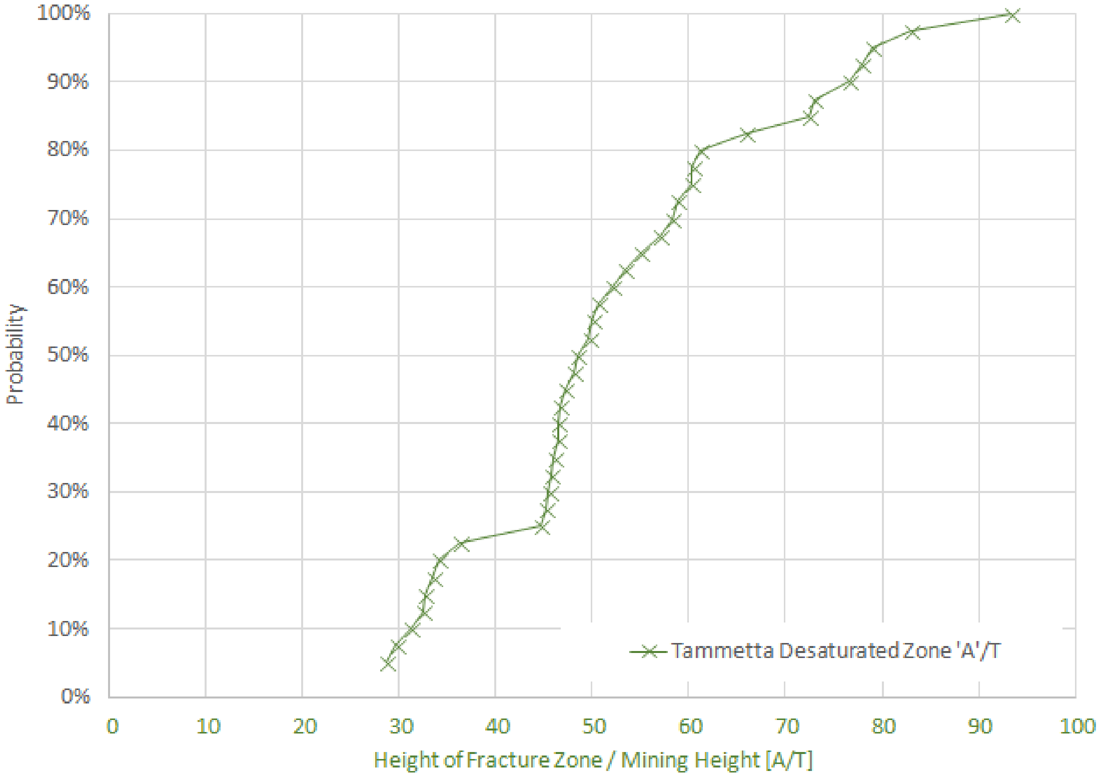


Figure 11. Probability Analysis for the Ratio of A-Zone Height to Mining Height: [a] Ditton Models; [b] Tammetta Model.

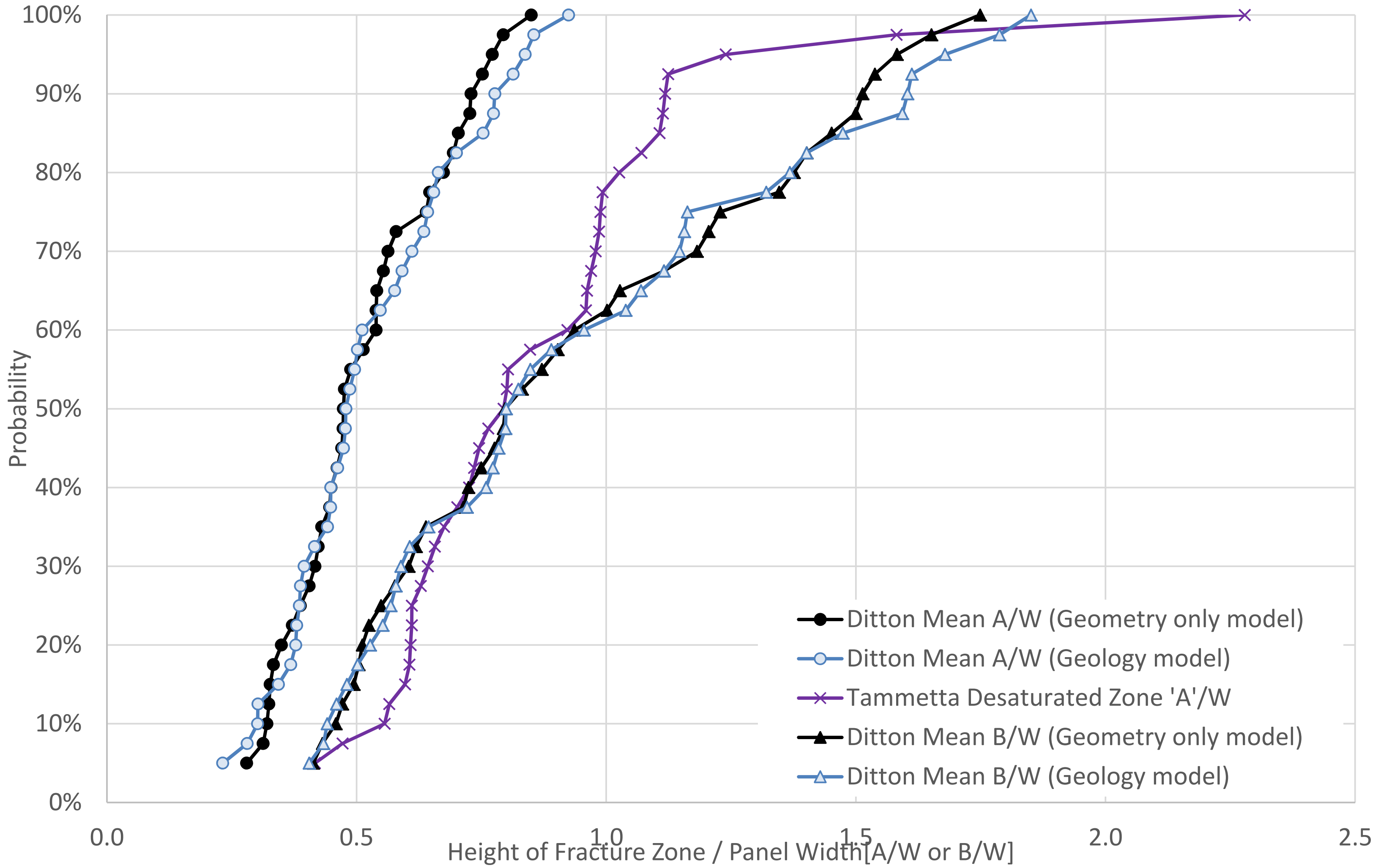


Figure 12. Probability Analysis for the Ratio of A-Zone and B-Zone Heights to Panel Width for Ditton and Tammetta Models.

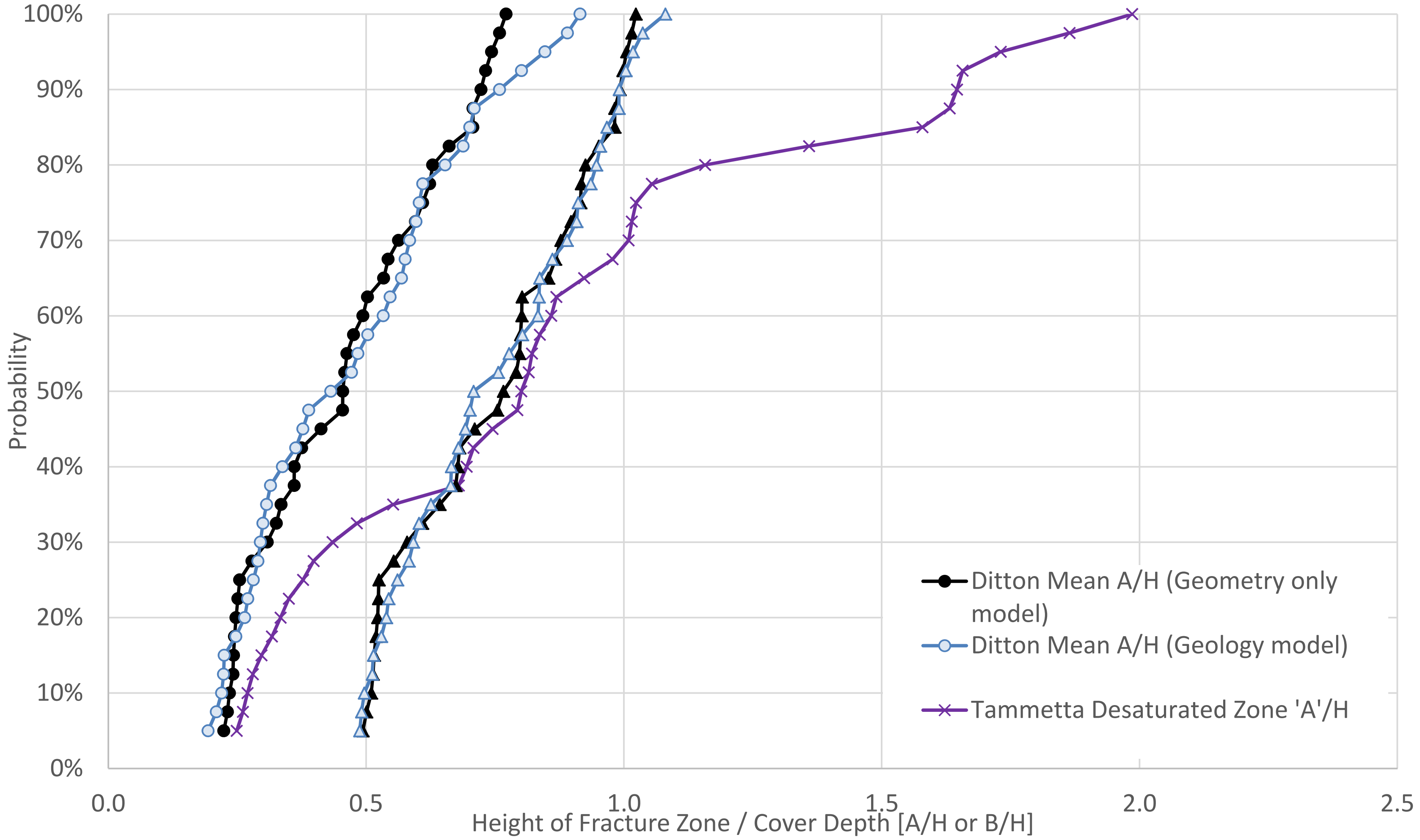


Figure 13. Probability Analysis for the Ratio of A-Zone and B-Zone Heights to Cover Depth for Ditton and Tammetta Models.

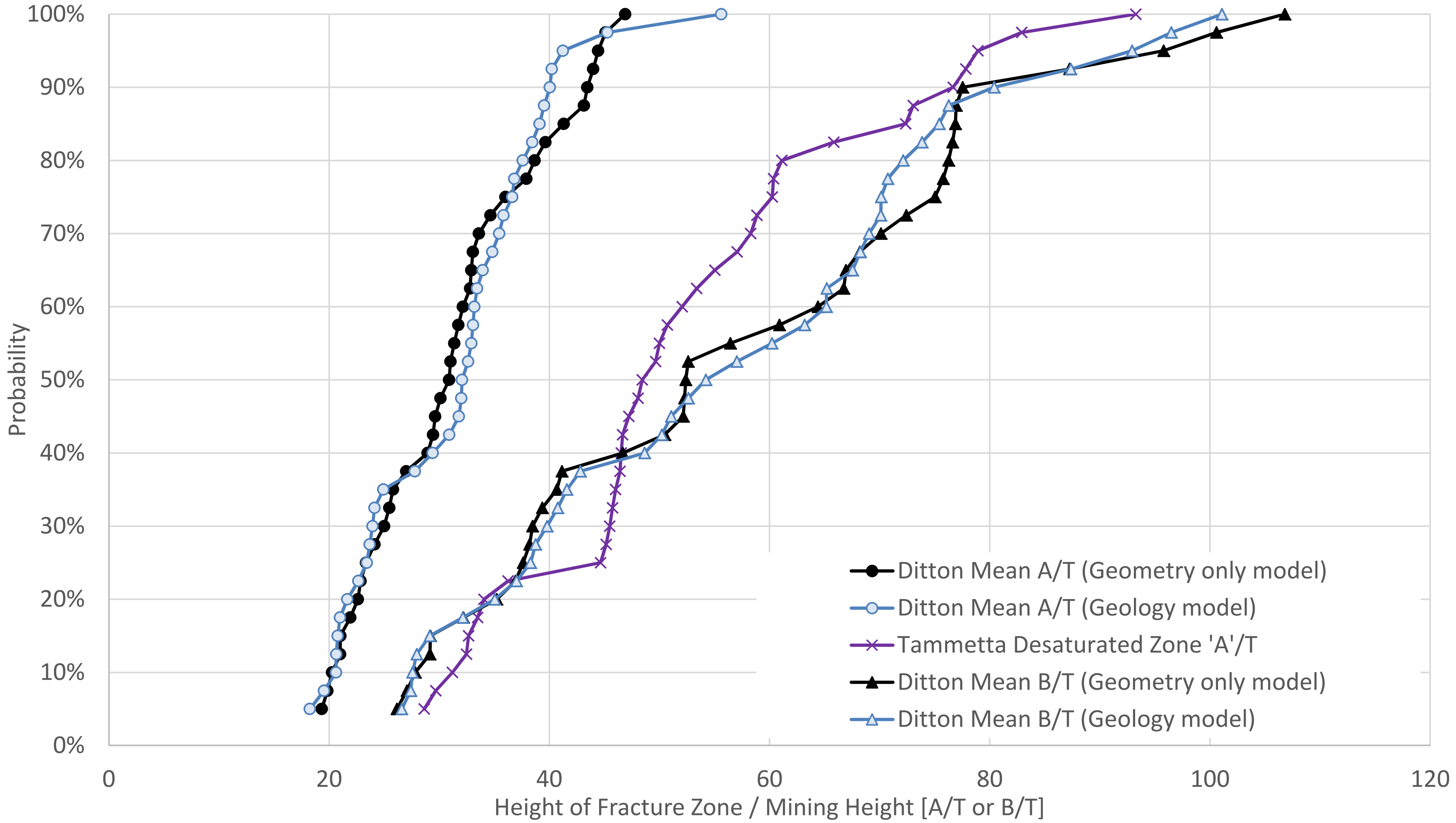


Figure 14. Probability Analysis for the Ratio of A-Zone and B-Zone Heights to Mining Height for Ditton and Tammetta Models.

# The Geology of the Shrub Swamps within Angus Place, Springvale and the Springvale Mine Extension Project Areas

## Elizabeth A. McHugh

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**Sept, 2014**

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# 1. Introduction

The current report discusses the influence of the upper geological strata in the Angus Place, Springvale and Springvale South mine extension project areas on the occurrence and morphology of the Newnes Plateau Shrub Swamps (NPSS).

The Newnes State Forest comprises the majority of the study area and the Angus Place/Springvale/Springvale South leases contain two NSW State listed Endangered Ecological Communities (EECs), namely the Newnes Plateau Shrub Swamps (NPSS) and the Newnes Plateau Rush Sedge Snow Gum Hollow Wooded Heath Grassy Woodland (NPRSSG). The Newnes Plateau Hanging Swamps (NPHS) are also present in the study area and, together with the former communities, form part of the Federally listed Temperate Highland Peat Swamp on Sandstone (THPSS). The present study focuses on the Newnes Plateau Shrub Swamps (NPSS) in the study area.

# 2. Regional Geology

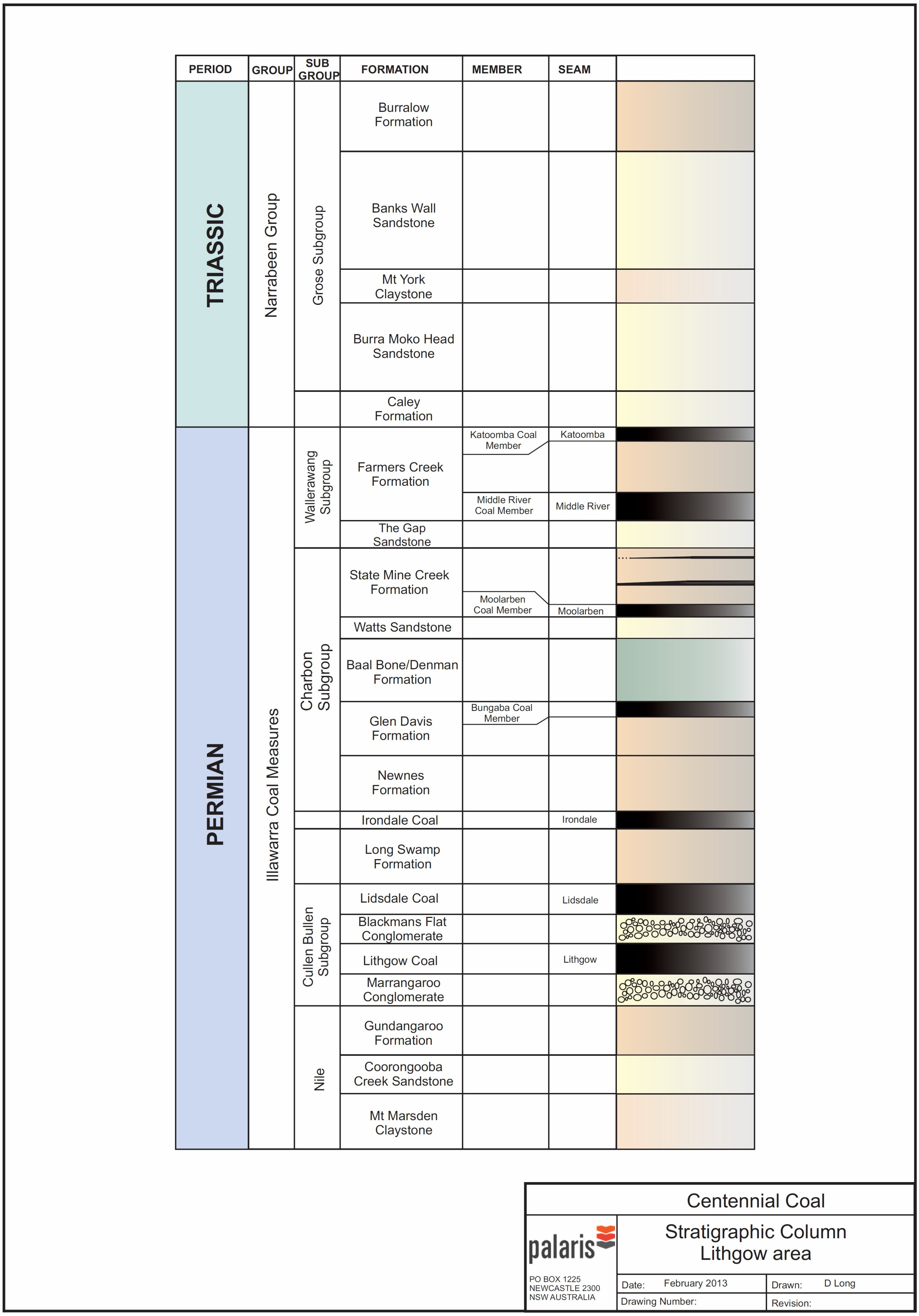
Angus Place and Springvale Collieries are located near the outermost portion of the Western Coalfield, being situated on the central western margin of the Sydney Basin. Strata of Permian and Triassic age overlie folded Silurian and Devonian rocks which sit on a Palaeozoic basement. Quaternary alluvium is present in river valleys.

During the Permian, two major periods of peat deposition occurred across the Sydney Basin, the second phase resulting in the formation of the Illawarra Coal Measures in the study area, of which the Lithgow Coal Formation is mined at Angus Place and Springvale collieries. As the Sydney Basin thins towards its western margin, both the Illawarra Coal Measures and the overlying Triassic Group are attenuated in thickness when compared to lateral equivalents in the Southern Coalfield.

The Western Coalfield contains minimal structural disturbance, with a regional dip in the Lithgow area of less than one degree with a dip direction of approximately 65 degrees. Monoclinal structures trend roughly north-south in the Western Coalfield accompanied by associated sub-parallel faulting. Basaltic flows and igneous intrusions occur in the general region but are absent from the study area.

# 3. Local Geology

The Angus Place/Springvale lease areas, located on the extreme western margin of the Sydney Basin, display a diminution of the full Permo-Triassic sequence present in other areas of the basin. Consequently, the Illawarra Coal Measures are comparatively thin in the study area and the overlying Triassic strata incorporate only the Narrabeen Group, with the Hawkesbury Sandstone and Wianamatta Group absent. Figure 1 shows the stratigraphic sequence present in the study area.



| PERIOD | GROUP | SUB GROUP | FORMATION | MEMBER | SEAM |
|---|---|---|---|---|---|
| TRIASSIC | Narrabeen Group | Grose Subgroup | Burralow Formation | | |
| | | | Banks Wall Sandstone | | |
| | | | Mt York Claystone | | |
| | | | Burra Moko Head Sandstone | | |
| | | | Caley Formation | | |
| PERMIAN | Illawarra Coal Measures | Wallerawang Subgroup | Farmers Creek Formation | Katoomba Coal Member | Katoomba |
| | | | | Middle River Coal Member | Middle River |
| | | | The Gap Sandstone | | |
| | | Charbon Subgroup | State Mine Creek Formation | Moolarben Coal Member | Moolarben |
| | | | Watts Sandstone | | |
| | | | Baal Bone/Denman Formation | | |
| | | | Glen Davis Formation | Bungaba Coal Member | |
| | | | Newnes Formation | | |
| | | | Irondale Coal | | Irondale |
| | | | Long Swamp Formation | | |
| | | Cullen Bullen Subgroup | Lidsdale Coal | | Lidsdale |
| | | | Blackmans Flat Conglomerate | | |
| | | | Lithgow Coal | | Lithgow |
| | | | Marrangaroo Conglomerate | | |
| | | Nile | Gundangaroo Formation | | |
| | | | Coorongooba Creek Sandstone | | |
| | | | Mt Marsden Claystone | | |

Centennial Coal

palaris

Stratigraphic Column
Lithgow area

PO BOX 1225
NEWCASTLE 2300
NSW AUSTRALIA

Date: February 2013

Drawn: D Long

Drawing Number:

Revision:

Figure 1 Stratigraphic Column for Angus Place/Springvale

The Permian strata in the Angus Place and Springvale lease areas include several coal-bearing units interspersed with sandstones, shales and minor tuffaceous claystones.

The Triassic sequence consists predominately of fine-to-coarse-grained sandstones, shales, siltstones and claystones of the Narrabeen Group. This fluvial sequence is punctuated by the Mt York Claystone Formation, a persistent and characteristic non-tuffaceous claystone unit described below.

## 4. Structure and Topographic Expression

The topography of the study area (Figure 2) is characterized by significant NNW- and NNE- trending lineaments in association with minor east-west features. It has been noted by previous workers, for example, SRK (2012), that surface lineaments, such as ridges, rivers and creeks, reflect underlying geological structures.

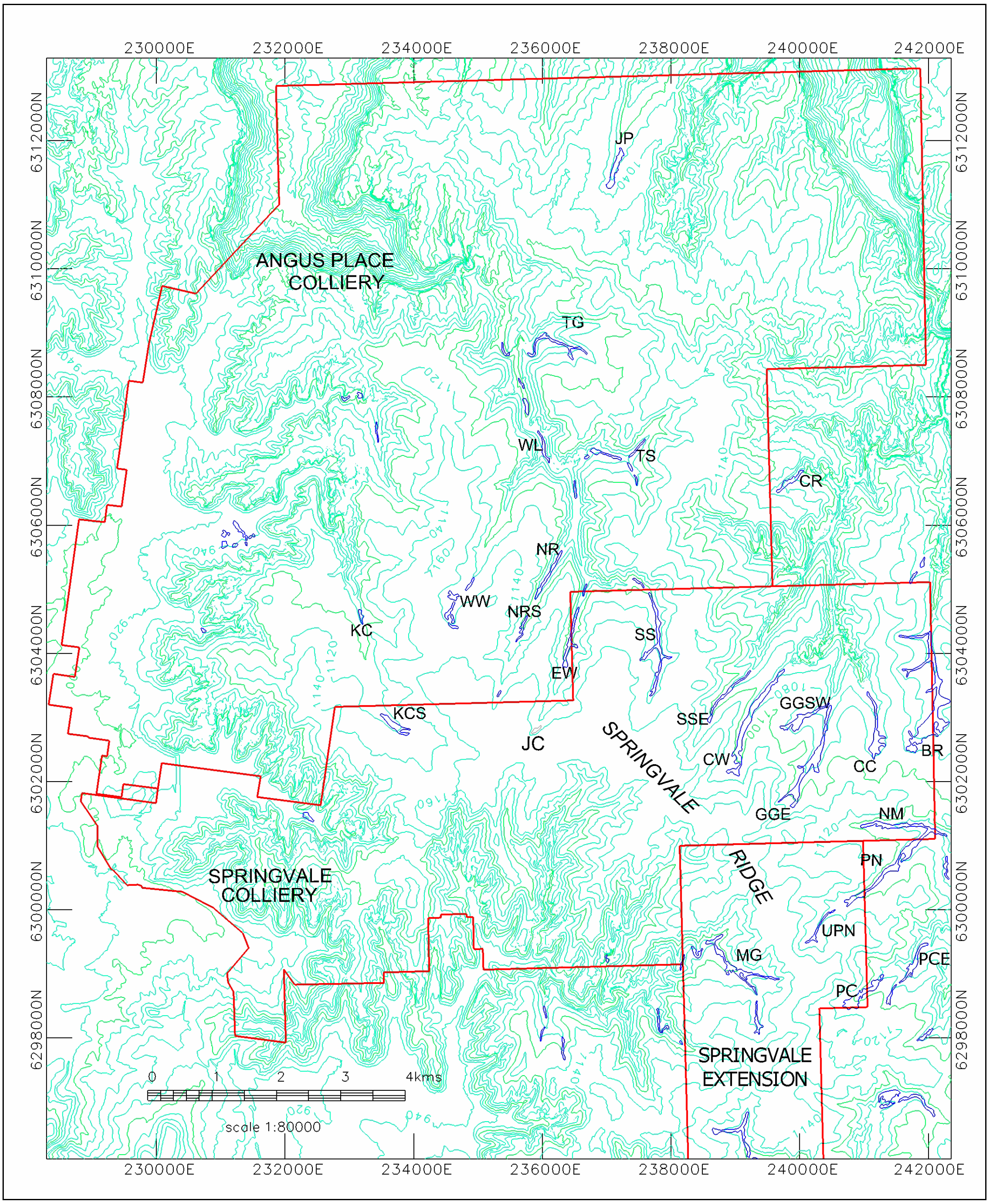


**Figure 2 Topography of Angus Place/Springvale/Springvale South Extension**
(Shrub swamps shown in blue)

In the Angus Place/Springvale area, basement geological structures are believed to impact strongly on the overlying Permo-Triassic sequence, particularly as the latter is comparatively thinner than in the southern and eastern regions of the Sydney Basin, where the stratigraphic sequence is more extensively developed.

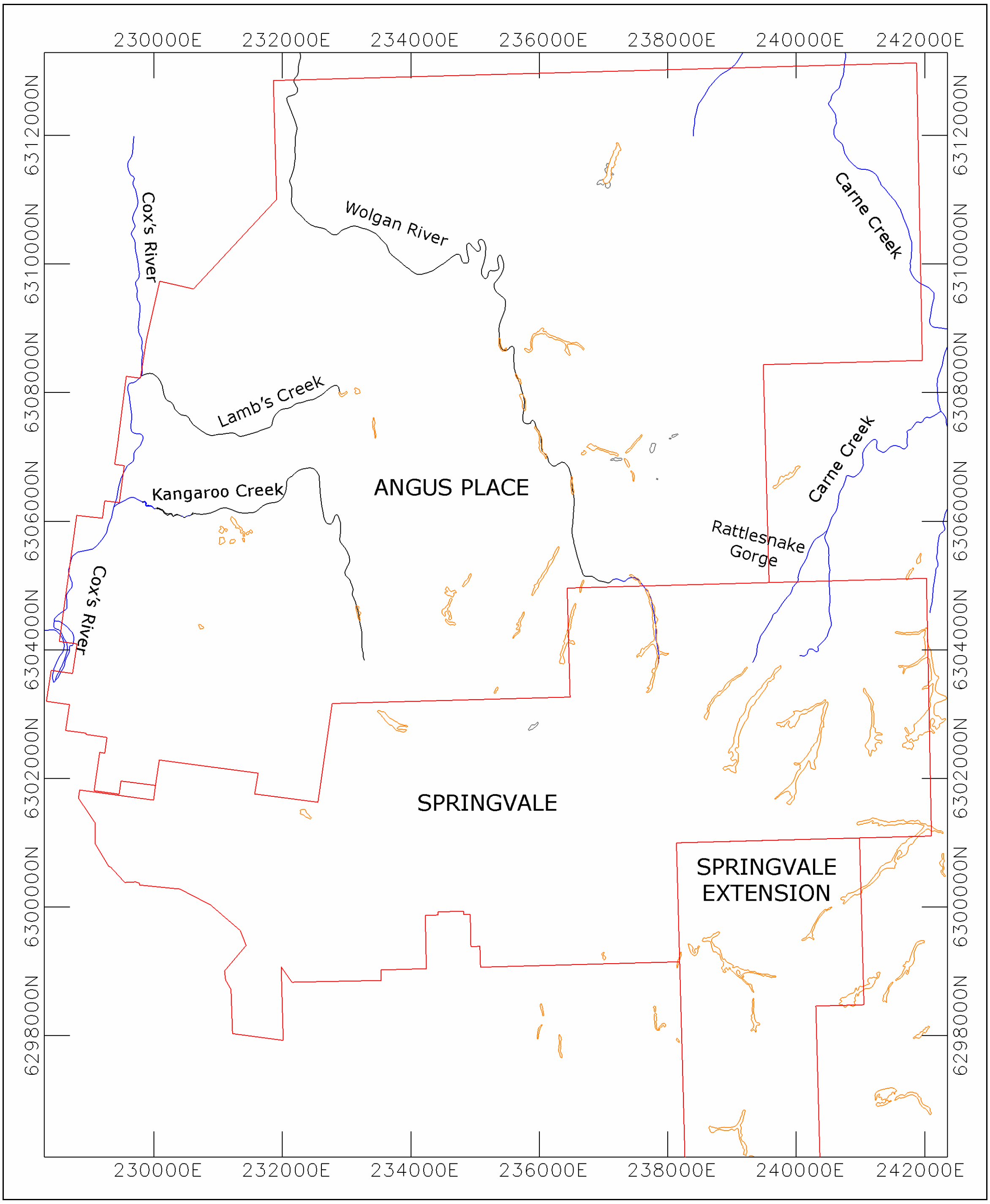


**Figure 3 Angus Place / Springvale Major Rivers and Creeks**

Cox's Creek to the immediate west of the study area reflects the predominantly north-south trending pattern of lineation that characterizes the study area (Figure 3). Within the Angus Place/Springvale lease areas, the Wolgan River assumes a NNW direction as it flows from its headwaters at the base of the elongated ridge system in Springvale (Figure 2) and continues downstream in the same northwesterly direction to the northern extent of the study area. The east-west topographic feature present in the area is denoted along the length of the Wolgan River by numerous short-term swings in this river from the east to the west. These diversions increase in size and frequency as the Wolgan travels north-west from its headwaters.

Similar occurrences are noted in Kangaroo Creek where the upper reaches reflect the NNW flow direction of the Wolgan River. Again, the east-west topographic feature is apparent in several minor swings from east to west before this creek assumes a final westerly swing before joining the north-south oriented Cox's River. Lamb's Creek, immediately north of Kangaroo Creek is influenced solely by this east-west topographic feature.

Carne Creek displays a NNW orientation in its lower reaches to the north-east of the study area, but adopts a NNE lineation in its upper reaches, such that the Sunnyside East, Carne West and Gang Gang tributaries also follow the same NNE trend. West Wolgan, East Wolgan, Narrow Swamp and West Wolgan watercourses to the west also adopt the NNE trend.

Rattlesnake Gorge (Figure 3), a western tributary of Carne Creek, displays a marked east-west lineation, similar to that of Lamb's Creek, while Twin Gully Swamp and Tri-Star Swamp in Angus Place also favour the east-west lineation present. The latter host watercourse is influenced by the NNE and NNW lineations, where the upper reaches follow both regional preferences.

Perhaps the best illustration of the interaction of the NNW-NNE and east-west structural/topographic systems occurs near the confluence of the upper tributaries of the Wolgan River, where the NNW trending Sunnyside Shrub Swamp host creek makes an abrupt westerly change in direction and then is met by the NNW-trending East Wolgan Creek. All structural elements are present at this site, before the Wolgan River resumes its predominant NNW-trending direction.

SRK (2012) noted three structural trends in the Angus Place/Springvale area. These included a north-south trend, (including NNE and NNW), a marked NW trend and a less dominant NE trend. These lineaments are considered to represent surface expressions of basement trends. Hence the east-west trending features which are present in the study area are likely to be less persistent, shallow level features, possibly en-echelon features linking the dominant NNE-NNW structural zones which occur throughout the study area and beyond.

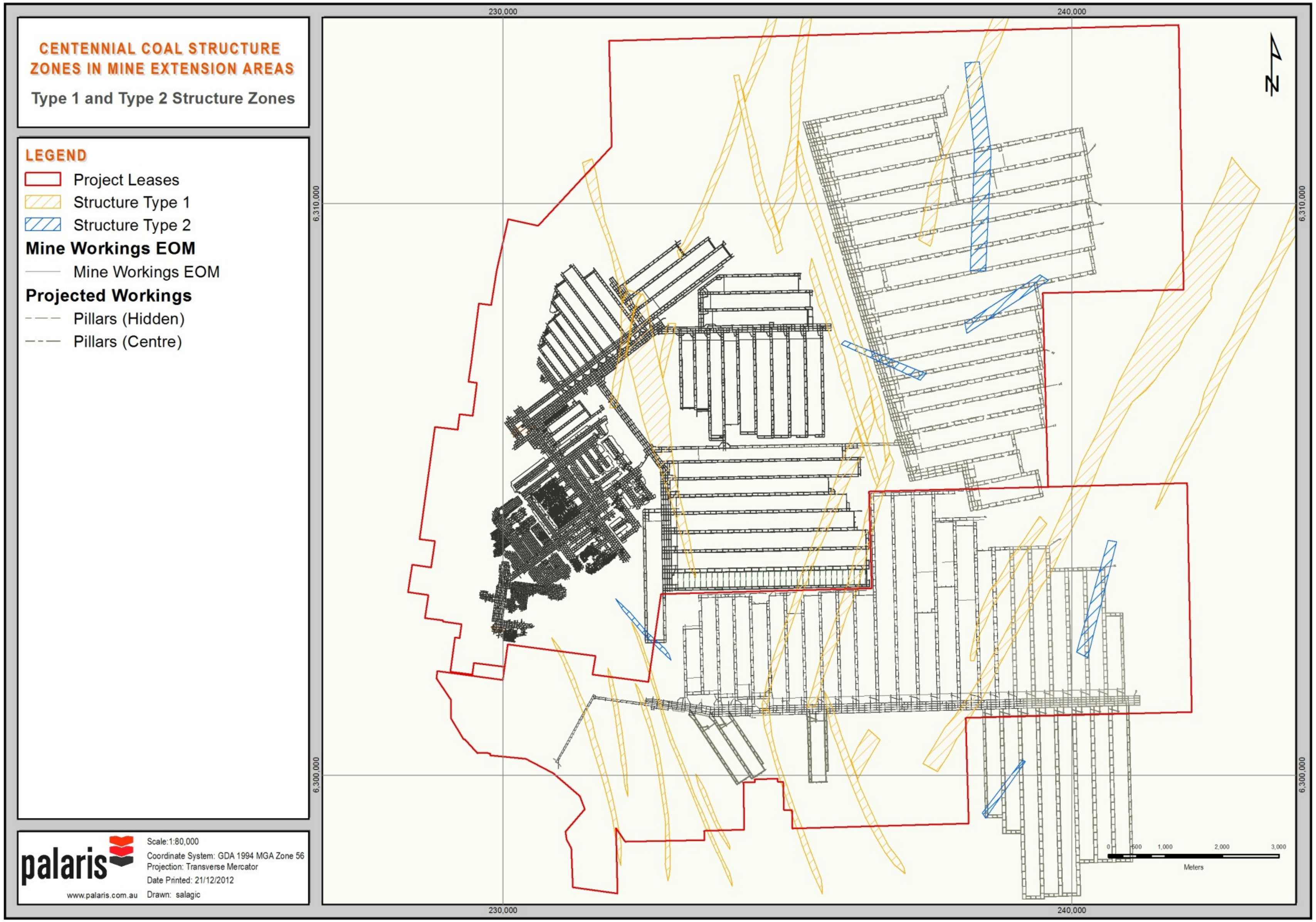


**Figure 4 Angus Place / Springvale – Structure Zones (Palaris 2012)**

The Type 1 features shown on Figure 4 are NNW- and NNE-trending basement-to-surface structural zones throughout the Angus Place and Springvale leases. Wolgan River and Carne Creek and their respective tributaries represent surface expressions of the two Type 1 lineament directions.

Hence there exists a dominant north-south structural trend across the study area, with a persistent but less significant east-west trend also present. The Springvale Ridge system (Figure 2), which will be discussed in subsequent sections, displays a predominant east-west orientation, continuing into Clarence Colliery to the east of the study area. However, this ridge system, at its southern extension, adopts a north-south lineation. In addition, the elevated ridge system which extends from Angus Place to Springvale via Sunnyside ridge trends in a NNE direction. The area south of the Springvale Ridge system displays more dominant north-south lineaments as reflected both in Figures 2 and 4, with minor east-west topographic expressions, such as the Marrangaroo Creek and Farmers Creek watercourses, together with the creek to the south-west of the Springvale lease which incorporates the shrub swamp near the downcast shaft.

It would appear that the geological structures in the basement rocks which form part of the Lachlan Fold Belt are reflected, at least in part, in the surface topography of the Triassic sequence above.

# 5. Stratigraphy

In the present report, only the Triassic strata of the Banks Wall Sandstone and the overlying Burralow Formation will be discussed in detail, since it is only within these two units in which the Newnes Plateau Shrub Swamps (NPSS) are situated. However, the Mt York Claystone Formation is also included due to the important role it plays in the hydrology of both the shrub and hanging swamp systems of the Newnes Plateau.

## *I. Burralow Formation*

This formation consists of medium- to coarse-grained sandstones interbedded with frequent sequences of fine-grained, clay-rich sandstones, siltstones, shales and claystones. These latter fine-grained units can be several metres in thickness and their presence differentiates the Burralow Formation from the underlying Banks Wall Sandstone. The base of the Burralow Formation is defined in this study as the base of the lowermost significant fine-grained, clay-rich unit above the more sandstone-rich lithology of the Banks Wall Sandstone.

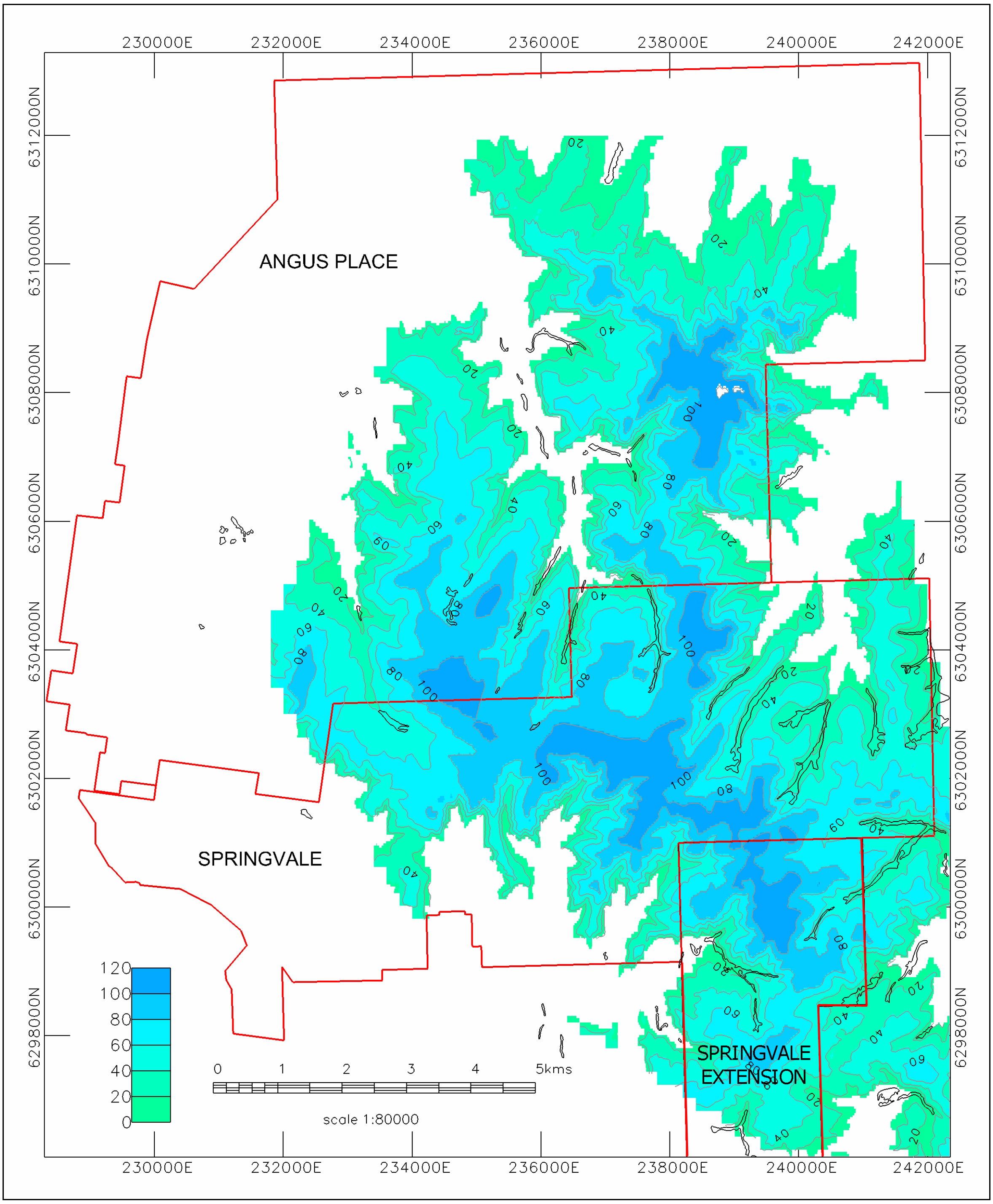


**Figure 5 Burralow Formation Isopach**
(Note: shrub swamps shown with black outline)

Figure 5, an isopach of the Burralow Formation, shows maximum thicknesses of approximately 110 metres, principally in the north-east of Angus Place East and the south-eastern extent of Springvale Colliery at the headwaters of East Wolgan, Sunnyside, Sunnyside East, Carne West, and Gang Gang Shrub Swamps. Hence the Burralow Formation, as defined in the study area, is thicker than previously proposed in the general Lithgow region in earlier works, for example, Goldbery (1972) and Herbert and Helby (1980).

McHugh (2011, 2013) studied the upper stratigraphy of the Angus Place/Springvale leases, in particular the Burralow Formation, and identified both a lithological and topographic link between the presence of the Burralow Formation and the occurrence of the Newnes Plateau Hanging Swamps (NPHS). Several of the claystone horizons, together with clay-rich, fine-to-medium grained sandstones and shales were found to be acting as aquitards, or semi-permeable layers within the stratigraphic sequence of the Burralow Formation. These aquitards decrease the hydraulic gradient of rainwater and groundwater movement percolating through the weathered and semi-weathered strata of the Burralow Formation and form a permanent water source for the formation and maintenance of the hanging swamps. In total, McHugh identified seven units, designated YS1 to YS6 (including the areally-limited YS5a), which were capable of sustaining the hanging swamps in the area, provided the topographic conditions were amenable to the formation of a hanging swamp.

Further, the presence of these aquitards in the Burralow Formation sequence also performs a vital function in the presence and persistence of the Newnes Plateau Shrub Swamps. The importance of the hydrological implications of these aquitards in the study area will be discussed in subsequent sections.

## *II. Banks Wall Sandstone*

The dominant lithology of the Banks Wall Sandstone is medium- to coarse-grained sandstone, with the formation having an average thickness of just under 100 metres. The steep-sided cliff faces comprising the banks of the Wolgan River and Carne Creek consist of the massive sandstones of the Banks Wall Sandstone.

A significant characteristic of this unit is its deep weathering pattern, with zones of iron-stained sandstone alternating with zones of relatively unweathered sandstone. This trend continues throughout the formation and also extends into the sandstone layers of the Mt York Claystone, the Burra-Moko Sandstone and the Caley Formation. Core photographs from Angus Place and Clarence Colliery to the south-west of the study area indicate that the depth of weathering extends to approximately 210 metres.

The minimal gamma response of the Banks Wall Formation, as shown in downhole geophysical logs, reflects the overall low clay content and relative absence of fine-grained units. This has resulted in the informal term “muted zone” used to describe this unit in terms of its geophysical response. The significance of this term will be discussed in subsequent sections.

The Banks Wall Sandstone is underlain by the first significant claystone band of the Mt York Claystone.

## *III. Mt York Claystone*

The top of the Mt York Claystone is partly gradational with the overlying Banks Wall Sandstone and is defined for the purposes of the present study as the uppermost fine-grained horizon that is thicker than 2 metres. Stratigraphically, it is situated approximately 100-110 metres above the Katoomba Seam. Typically the unit comprises up to three discrete claystone bands up to 4 metres thick, the principal horizon displaying the characteristic red-brown colour of the unit. These two- to three claystone horizons are interbedded with sandstone/siltstone bands up to 8 metres in thickness. The average thickness of the correlated Mt York Claystone in the study area is 22 metres and the unit has a gradational lower boundary with the Burra-Moko Sandstone below. That is, thick claystone bands also occur within the underlying formation and it is sometimes debatable where the boundary should be defined.

Petrographic analysis of selected horizons in the Burralow Formation, Banks Wall Sandstone and the Mt York Claystone and their significance in terms of weathering patterns, fabric and hydrological impact will be discussed in a subsequent report.

# 6. Newnes Plateau Shrub Swamp Morphology

Previous studies of the Angus Place/Springvale area do not typically include the presence of the Burralow Formation, and instead refer to the Banks Wall Sandstone as the uppermost outcropping unit. The Burralow Formation is crucial in the development and maintenance of both the Newnes Plateau Shrub Swamps (NPSS) and, in particular, the Newnes Plateau Hanging Swamps (NPHS). However, the present study focuses predominantly on the Newnes Plateau Shrub Swamps.

Figure 6 shows the distribution of Newnes Plateau Shrub Swamps throughout the study area in relation to Burralow Formation outcrop.

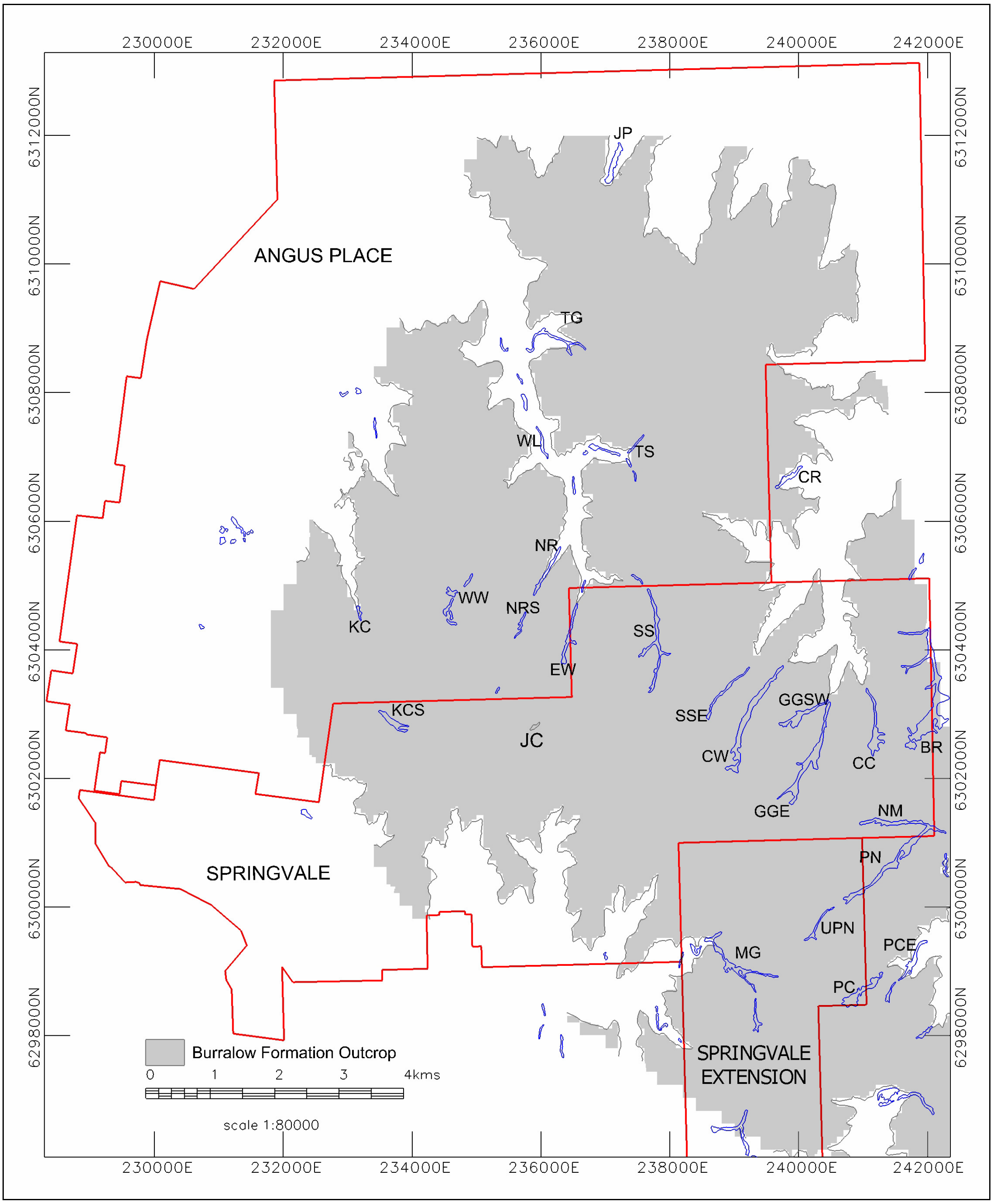


Figure 6  Shrub Swamp Locations and Burralow Fm Outcrop

**Key to swamp abbreviations:**
JP: Japan (Trail 6), TG: Twin Gully, WL: Wolgan, TS: Tri-star, CR: Crocodile, NR: Narrow, NRS: Narrow South, WW: West Wolgan, EW: East Wolgan, KC: Kangaroo Creek, KCS: Kangaroo Creek South, JC: Junction, SS: Sunnyside, SSE: Sunnyside East, CW: Carne West, GGSW: Gang Gang Southwest, GGE: Gang Gang East, CC: Carne Central, BR: Barrier, NM: Nine Mile, PN: Pine, UPN: Pine Upper, PC: Paddy's Creek, PCE: Paddy's Creek East, MG: Marrangaroo

The majority of the shrub swamps are located within the confines of the Burralow Formation, particularly in the Springvale lease and are defined in this report as "Burralow-type" shrub swamps. However, two shrub swamps are situated wholly within the Banks Wall Sandstone in the Angus Place lease, and are denoted as "Banks Wall-type" shrub swamps, while a third population comprises "mixed-type" swamps. These latter shrub swamps are situated stratigraphically such that their upper reaches are located within the Burralow Formation but terminate in the Banks Wall Sandstone, which occurs as the host creek erodes into the country rock distally from the watershed areas where these shrub swamps are predominantly located.

The underlying lithology of each shrub swamp controls its morphology and areal extent. Topography also plays a role in shrub swamp morphology; however the presence or absence of a Burralow Formation substrate largely dictates the shape and extent of a particular shrub swamp. Hence Banks Wall-type and "mixed-type" shrub swamps are generally smaller in area and occur in relatively steep-sided gullies.

In comparison, the Burralow-type shrub swamps characteristically occur in much broader and gently sloping depressions (Figure 6) and are commonly longer and permanently waterlogged in their lower reaches.

## 7. Burralow Formation Aquitards (YS6 to YS1)

As previously indicated, the aquitard units of the Burralow Formation play a critical role in the formation of the Newnes Plateau Hanging Swamps, and a similarly important role in the presence and maintenance of the Newnes Plateau Shrub Swamps.

Aquitards are semi-permeable lithological units which permit only relatively small amounts of water to percolate through them into the underlying strata. Aquitards retard water flow underground; that is, they act as a partial barrier to downward groundwater movement. Aquitards separate aquifers and partially disconnect the flow of water underground, directing water downdip to discharge points in nearby gullies.

Due to the number of suitably thick aquitards in the Burralow Formation, there is a significant decrease in the flow of water vertically through the strata due to gravity in this upper unit. This effectively retains increased volumes of water within the formation; water that would otherwise flow unimpeded down-gradient through to underlying formations.

While the dominant lithology of the Banks Wall Formation consists of medium- to coarse grained sandstones with only minor finer grained units, the Burralow Formation is relatively rich in interbedded fine-grained, clay-rich sandstones, shales, siltstones and claystones. Although the Burralow Formation consists of abundant fine-grained semi-permeable units, it was determined that only units of approximately one metre or above in thickness would be capable of acting as an aquitard that would alter the hydraulic gradient for a hanging swamp to form. The development of the latter feature would also depend on topographic constraints.

With seven such identified aquitards in total ( YS6, YS5, YS5a, YS4, YS3, YS2 and YS1), there is a significant retardation of water percolation through the Burralow

Formation from surface to base to permit the formation not only of the Newnes Plateau Hanging Swamps, but to significantly contribute moisture at outcrop points in gullies containing the Newnes Plateau Shrub Swamps.

Apart from the seven named aquitard plies, additional thinner clay-rich horizons also exist within the Burralow Formation. While these units may not be of the required thickness or lateral continuity to form a hanging swamp or contribute significantly to in-gully groundwater levels in shrub swamps, they nevertheless act as a group to further decrease the hydraulic gradient of downward-percolating water within the Burralow Formation as a whole. Groundwater sourced from the presence of these aquitard units thus supplements input from precipitation, which assists in maintaining the floristic community of the resultant shrub swamps.

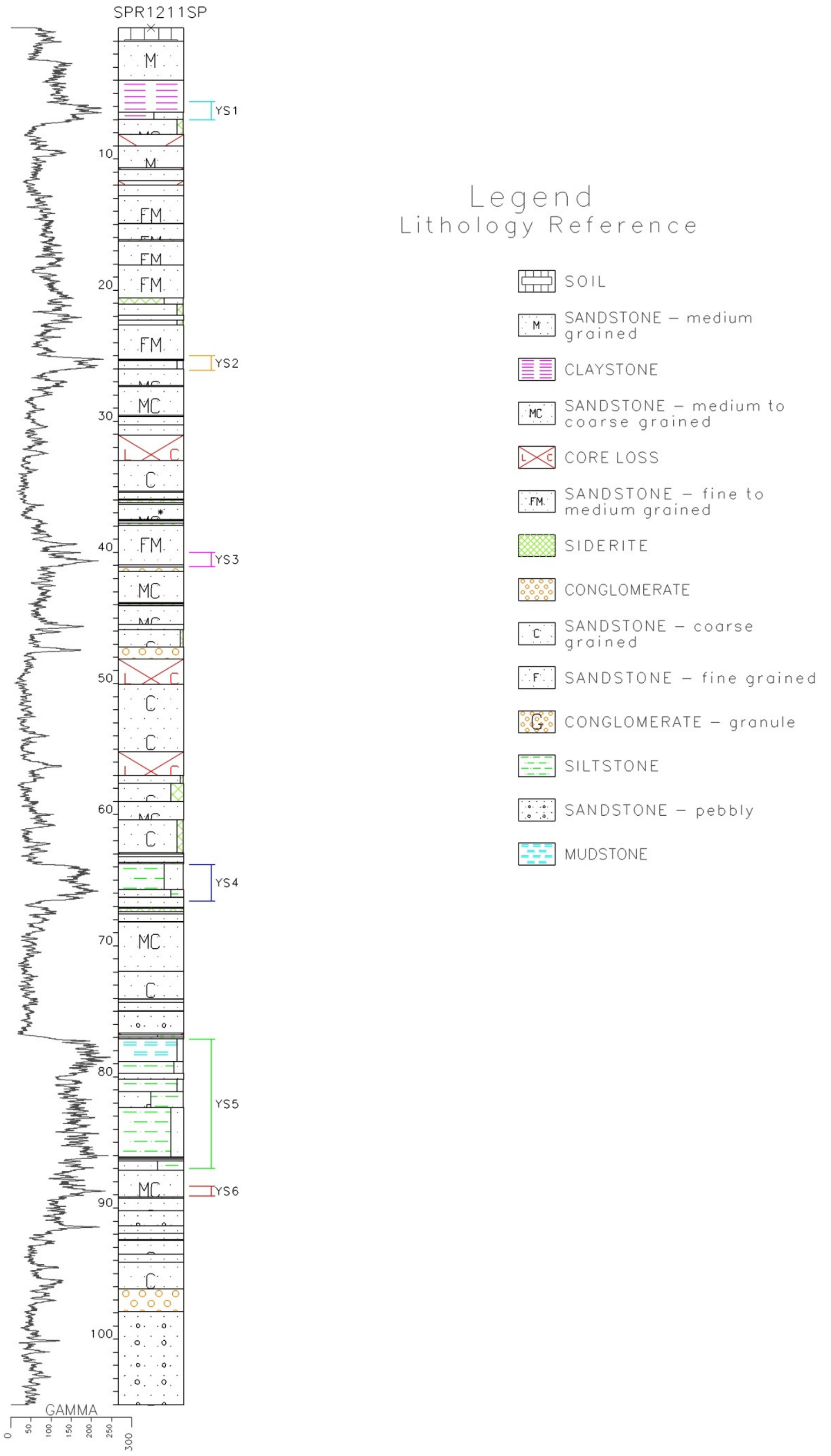


**Figure 7 SPR1211SP Graphic Lithological Log**

Figure 7 displays an example of the full suite of functioning aquitards from YS1 to YS6 (note YS5a is absent from this borehole). Appendix A shows core photographs covering the interval shown in Figure 7.

SPR1211SP is a fully-cored hole in the Springvale area and the resultant gamma response highlights the clay-rich shales, fine clayey sandstones and claystones that serve to act as a sequence of progressive semi-impermeable horizons within the Burralow Formation. These horizons essentially maintain the hydraulic head higher than would be expected and thus provide a permanent water source for both the associated hanging swamps and the shrub swamps that are located adjacent to down-dip discharge points.

The sole unconfined aquifer in the more elevated sites within the study area lie above the YS1, the remainder of the strata between aquitards in the Burralow Formation act as individual "aquifers" at surface points where the coarser sandstone units of the formation crop out on gully sides. The high degree of weathering of many of the sandstone units also assists in this process, and is also indicative of the degree of water movement through these units.

By contrast the Banks Wall Sandstone gamma response is considerably muted compared to that of the Burralow, containing relatively few semi-permeable units and hence is easily differentiated in downhole logging from the overlying Burralow Formation. In hydrogeological terms, the Banks Wall Sandstone is referred to as the "muted zone" for the purposes of this report, that is, it is not a major source of groundwater originating from the presence of aquitard horizons.

## 8. Hydrogeological Influence of the Mt York Claystone

The Mt York Claystone acts as a major hydrological confining unit and, as noted by McHugh (2011), effectively forms a more efficient hydrological barrier than the thinner aquitards of the upper sequences. This is due to its lithological composition, its greater thickness, which averages over 20 metres in the study area, and its lateral continuity within and beyond the Angus Place/Springvale leases.

The Mt York Claystone lies between the upper Narrabeen Group (Burralow Formation and Banks Wall Sandstone) and the underlying Burra-Moko Head Sandstone and Caley Formation as shown in Figure 8 below.

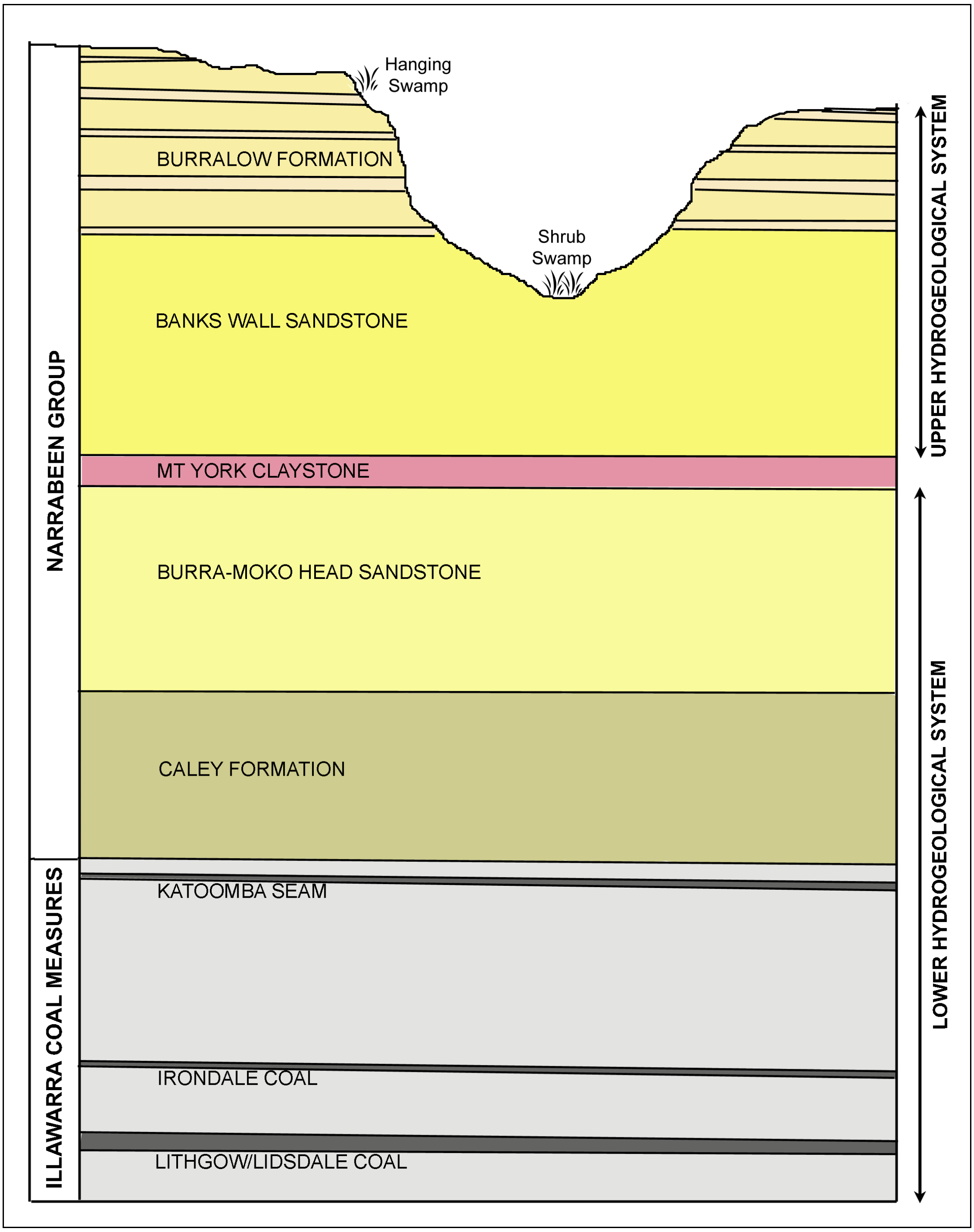


**Figure 8 Schematic Hydrogeological Section**

Figure 8 shows the presence of a dual hydrological system operating in the study area, with the upper hydrological system located above the Mt York Claystone and the lower hydrological system below the base of the Mt York Claystone. This diagram also illustrates schematically the manner in which Newnes Plateau Hanging Swamps are associated with outcropping aquitards of the Burralow Formation. The Newnes Plateau Shrub Swamps benefit from the presence of these aquitards by redirecting groundwater laterally to gully discharge points and valley wall seepage acts as a source of groundwater to shrub swamps in adjacent gullies. This diagram shows a Banks Wall-type shrub swamp. Burralow-type shrub swamps also receive direct in-gully groundwater input from single or repeated aquitard intersection due to erosion of the host gully. Both sub-types of shrub swamps are discussed below.

# 9. Burralow-type Shrub Swamps versus Banks Wall-type Shrub Swamps

The presence of the Burralow Formation is essential to the formation of both the Newnes Plateau Shrub Swamps (NPSS) and the Newnes Plateau Hanging Swamps (NPHS). The series of aquitards present in the Burralow Formation are intimately linked, together with topographic factors, with the formation of the hanging swamps, which occur at outcrop points of suitable aquitards.

Similarly, the Newnes Plateau Shrub Swamps would not exist without the presence of the Burralow Formation and its characteristic groundwater-retaining properties, since the aquitards provide an important supplementary and permanent supply of water to the shrub swamps located within the Burralow Formation

Shrub swamps located wholly or partly within the Banks Wall Sandstone also attain substantial seepage from the Burralow Formation but do not in general benefit from the degree of groundwater seepage that shrub swamps in the Burralow Formation experience. Hence, the morphology of the Banks Wall-type shrub swamps differs significantly from that of the Burralow-type. A third shrub swamp category, “mixed-type”, refers to shrub swamps which contain both Banks Wall Sandstone and Burralow Formation gully substrates.

| Swamp Name | Swamp Type | Associated Hanging Swamps | Colliery |
|---|---|---|---|
| Japan (Trail 6) | Banks Wall | Y | Angus Place |
| Twin Gully | Mixed | Y | Angus Place |
| Tri-Star (EW) | Banks Wall | Y | Angus Place |
| Tri-Star (NE) | Mixed | Y | Angus Place |
| Tri-Star (SE) | Mixed | Y | Angus Place |
| Crocodile | Mixed | Y | East of Angus Place |
| Narrow | Mixed | Y | Angus Place |
| Narrow South | Burralow | N | Angus Place |
| Kangaroo Creek | Mixed | N | Angus Place |
| West Wolgan | Burralow | Y | Angus Place |
| East Wolgan | Mixed | N | Angus Place/Springvale |
| Sunnyside | Burralow | Y | Angus Place/Springvale |
| Sunnyside East | Burralow | Y | Springvale |
| Carne West | Burralow | Y | Springvale |
| Gang Gang Southwest | Burralow | N | Springvale |
| Gang Gang East | Burralow | N | Springvale |
| Carne Central | Burralow | N | Springvale |
| Nine Mile | Burralow | N | Springvale/Clarence |
| Pine | Burralow | N | Springvale South/Clarence |
| Upper Pine | Burralow | Y | Springvale South |
| Paddy's Creek | Burralow | N | Springvale South/Clarence |
| Paddy's Creek East | Mixed | Y | Clarence |
| Marrangaroo | Mixed | Y | Springvale South |

**Table 1 Angus Place and Springvale Shrub Swamp Categorisation**

Table 1 shows swamp category type for each shrub swamp in Angus Place, Springvale, Springvale South extension and the western area of Clarence colliery. “Mixed-type” swamps are characterized by dual gully substrates, that is, both Banks Wall Sandstone and Burralow Formation lithologies form the valley floor.

In the “mixed-type” scenario the upper reaches of the shrub swamp are located stratigraphically within the Burralow Formation while the lower reaches are situated within the Banks Wall Sandstone due to erosion of the host gully. Such swamps, as with the Banks Wall-type shrub swamps, are typically shorter in length than their Burralow Formation equivalents.

**Carne West Swamp**

**Japan Swamp**

**Figure 9 Contrast in Swamp Morphology between Burralow-type and Banks Wall-type shrub swamps**

The above photo demonstrates the effect of a Burralow Formation substrate versus a Banks Wall substrate on gully morphology. Burralow-type swamps, that is, swamps which are stratigraphically situated wholly within the Burralow Formation and which transect several aquitards as a result, generally comprise open, spoon-shaped valley floors. They are comparatively more extensive in both length and width due to sequential in-gully groundwater input as compared to Banks Wall or “mixed-type” shrub swamps. Carne West Shrub Swamp (Figure 9) which is situated in the Springvale lease is an example of a Burralow-type shrub swamp.

By contrast, Japan Shrub Swamp (Figure 9) is stratigraphically situated wholly within the Banks Wall Formation. Japan Shrub Swamp (also known as Trail 6 Shrub Swamp) is located within the Angus Place lease (Figure 6). As Figure 9 demonstrates, swamp width in general is significantly narrower than Burralow-type equivalents. Gully morphology is also steeper in Banks Wall substrates due to the differing lithological composition of the Banks Wall Sandstone and the Burralow Formation. These concepts are discussed in detail in subsequent sections.

Figure 10 below shows a longitudinal section down the centre-line of Carne West Shrub Swamp which is a Burralow-type shrub swamp. Carne West Shrub Swamp is located within the Springvale lease (Figure 6).

This swamp has a fall of approximately 55 metres and, as shown, the gully floor passes stratigraphically from above the YS3 through to the YS5 at the lower extremity of the swamp. Hence groundwater can be sourced from strata above YS2 and YS3 from the upper reaches to the endpoint of the swamp, from above YS4 midway along the swamp course to its endpoint and from above YS5 near the lower reaches.

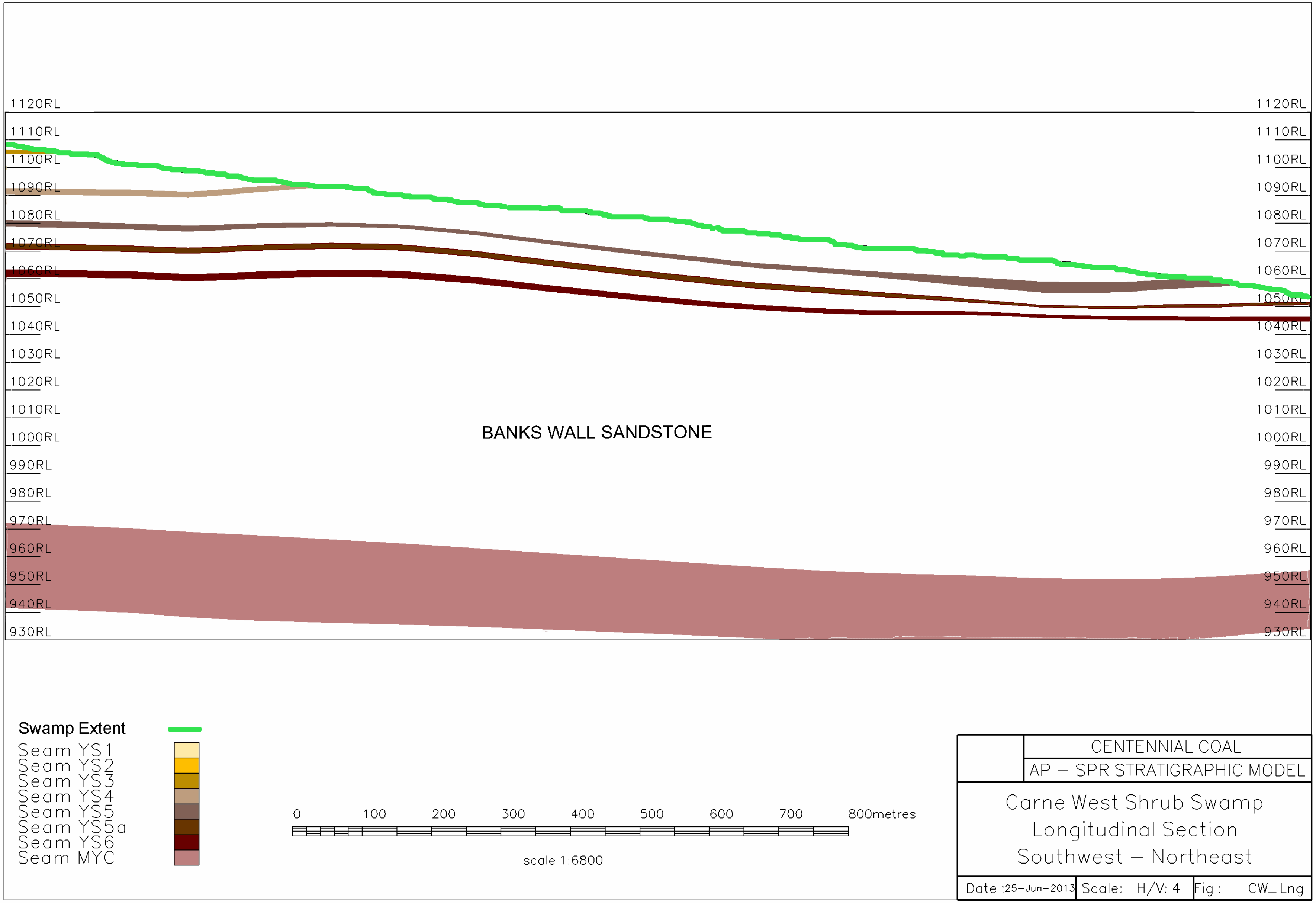


**Figure 10 Longitudinal Stratigraphic Section of Carne West Shrub Swamp**

Figure 11 shows Carne West Shrub Swamp (including Carne West Hanging Swamp) and the outcrop of the YS plies in plan form. The YS2 can be clearly seen to be a source of groundwater seepage in the far upper reaches of the swamp, augmented in the upper reaches by the YS3 and in the middle reaches by the YS4. Note that the YS1 ply would also retain groundwater in the upper sequences of the gully sides which would slowly percolate to assist in the maintenance of the Carne West Hanging Swamp as well as the extreme upper reaches of Carne West Shrub Swamp. Hence, the YS aquitards assist in providing supplementary groundwater to shrub swamps which are contained either wholly or partially within the Burralow Formation. Carne West Shrub Swamp acquires water via three sources; precipitation, valley wall seepage from several nearby aquitards and direct in-gully groundwater. In addition, Carne West Shrub Swamp has a relatively large recharge area as will be discussed in detail in subsequent sections.

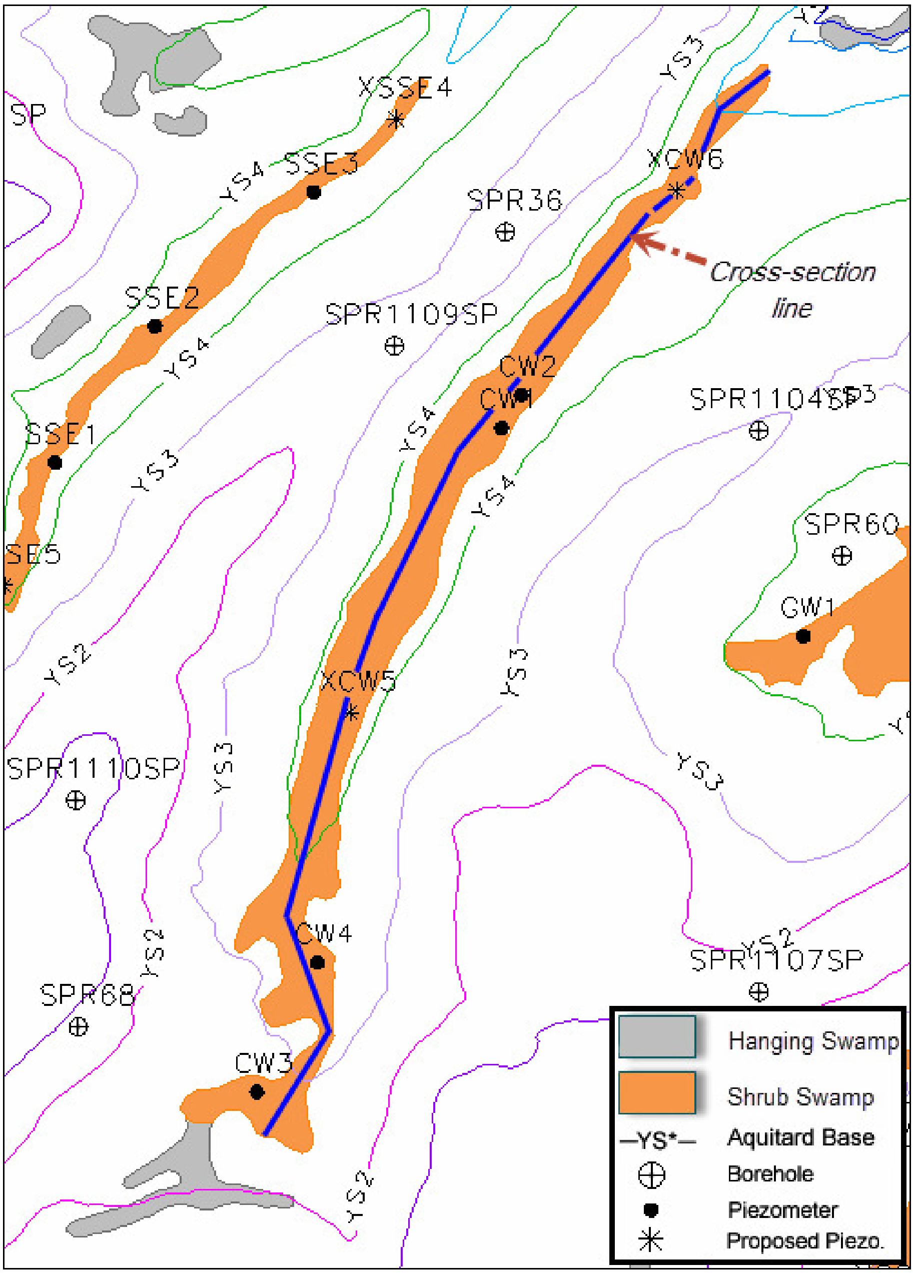


**Figure 11 Plan of Carne West Shrub Swamp**

Figure 12 shows a longitudinal section of this swamp. Occurring stratigraphically below the Burralow Formation, no significant aquitards are present to prevent unimpeded groundwater percolation or to direct groundwater laterally to discharge points along the length of the swamp. Groundwater input is reliant solely on precipitation and valley wall seepage, and Figure 12 demonstrates the lack of in-stream aquitards along the entire length of Japan Shrub Swamp.

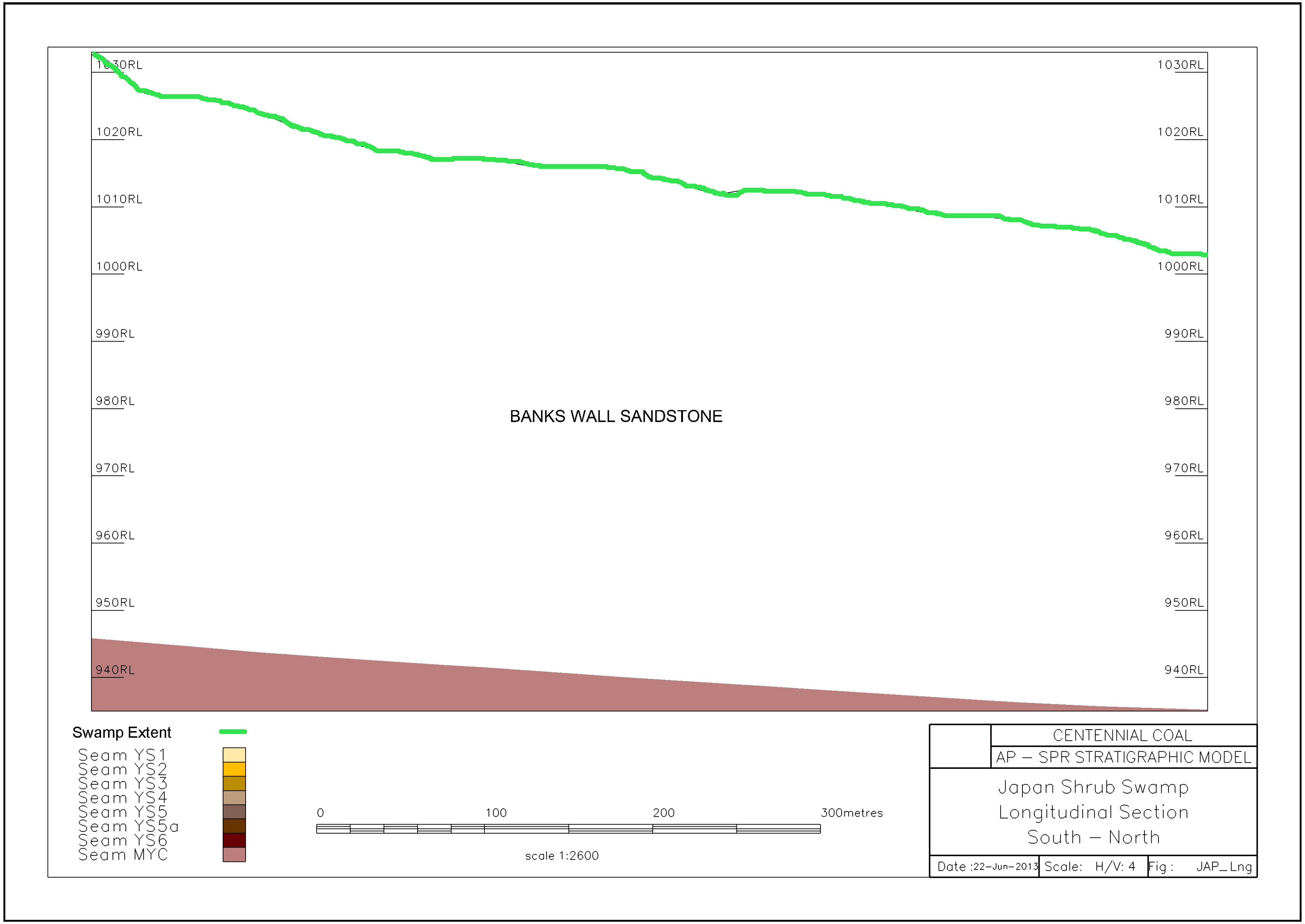


Figure 12 Longitudinal Stratigraphic Section of Japan Shrub Swamp

Figure 13 shows a plan of Japan Shrub Swamp and associated Japan Hanging Swamps. The latter are supported by groundwater seepage from above plies YS6 and YS5a, predominantly around the headwaters of the swamp.

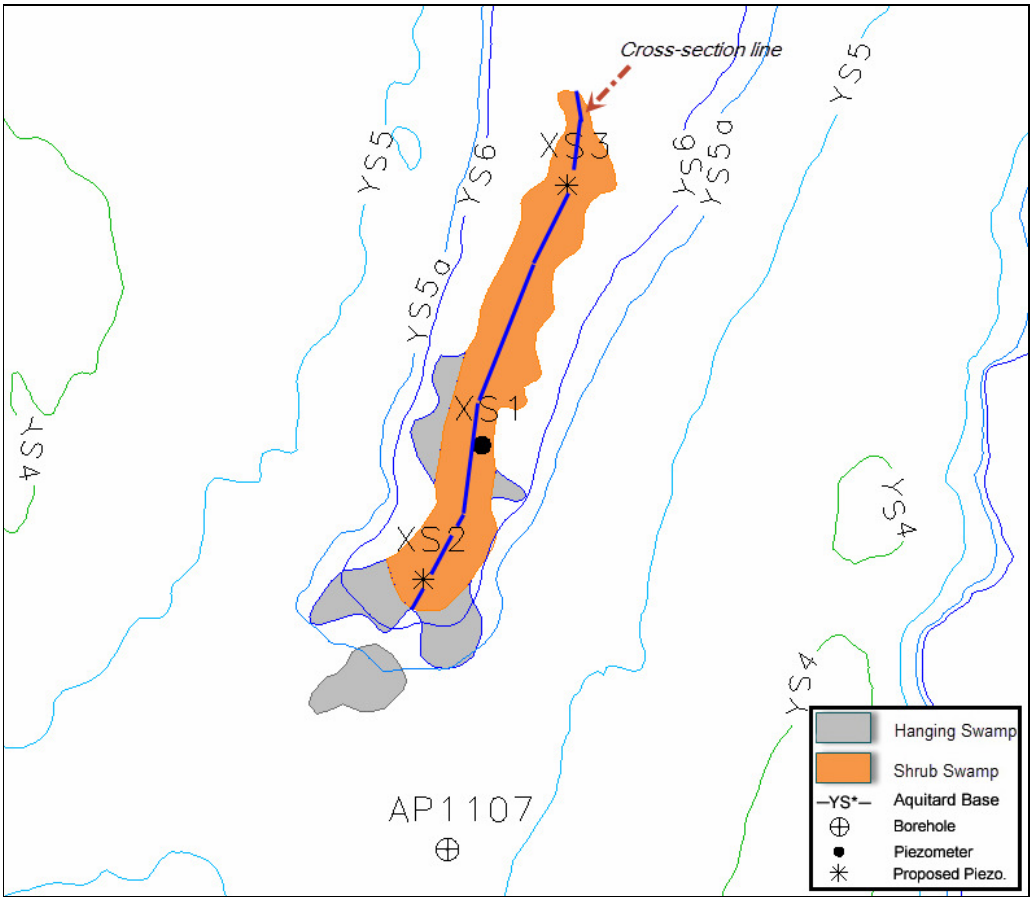


**Figure 13 Plan of Japan (Trail 6) Shrub Swamp**

Japan Shrub Swamp is located in a steep-sided gully in the Banks Wall Sandstone, and is 0.75km in length with a fall of 32 metres. Unlike Carne West Shrub Swamp discussed above, there are no aquitards outcropping along the length of the drainage line to assist with direct in-gully groundwater input. However, plies YS6, YS5a and to a lesser extent, YS5, would retain groundwater in the upper steep sides of this gully, which would eventually percolate down into the gully floor, thus providing a ready source of moisture in addition to annual precipitation. Ply YS4 to the west of the swamp is too distal to be a source of groundwater seepage. Japan Shrub Swamp is also adjacent to a relatively restricted recharge area. The importance of the latter phenomenon is discussed in a subsequent chapter.

Hence the Banks Wall Sandstone with its predominantly sandstone sequences results in areally smaller swamps. In addition, the lithological floor of the gullies of this swamp type allow for less erosion and thus form steeper-sided gullies as compared to the generally broader and shallower profiles of the Burralow-type shrub swamps. In comparison with swamps such as Carne West above, the morphology of Japan Shrub Swamp is also restricted as shown a subsequent section where Japan Shrub Swamp is discussed in further detail.

In a further comparison of differing swamp morphologies based on varying lithological substrates, Figure 14 shows a plan diagram illustrating the relative locations of Sunnyside Shrub Swamp, Sunnyside East and Carne West Shrub Swamps in the Springvale lease area. All three swamps are located wholly within the Burralow Formation and are thus Burralow-type shrub swamps.

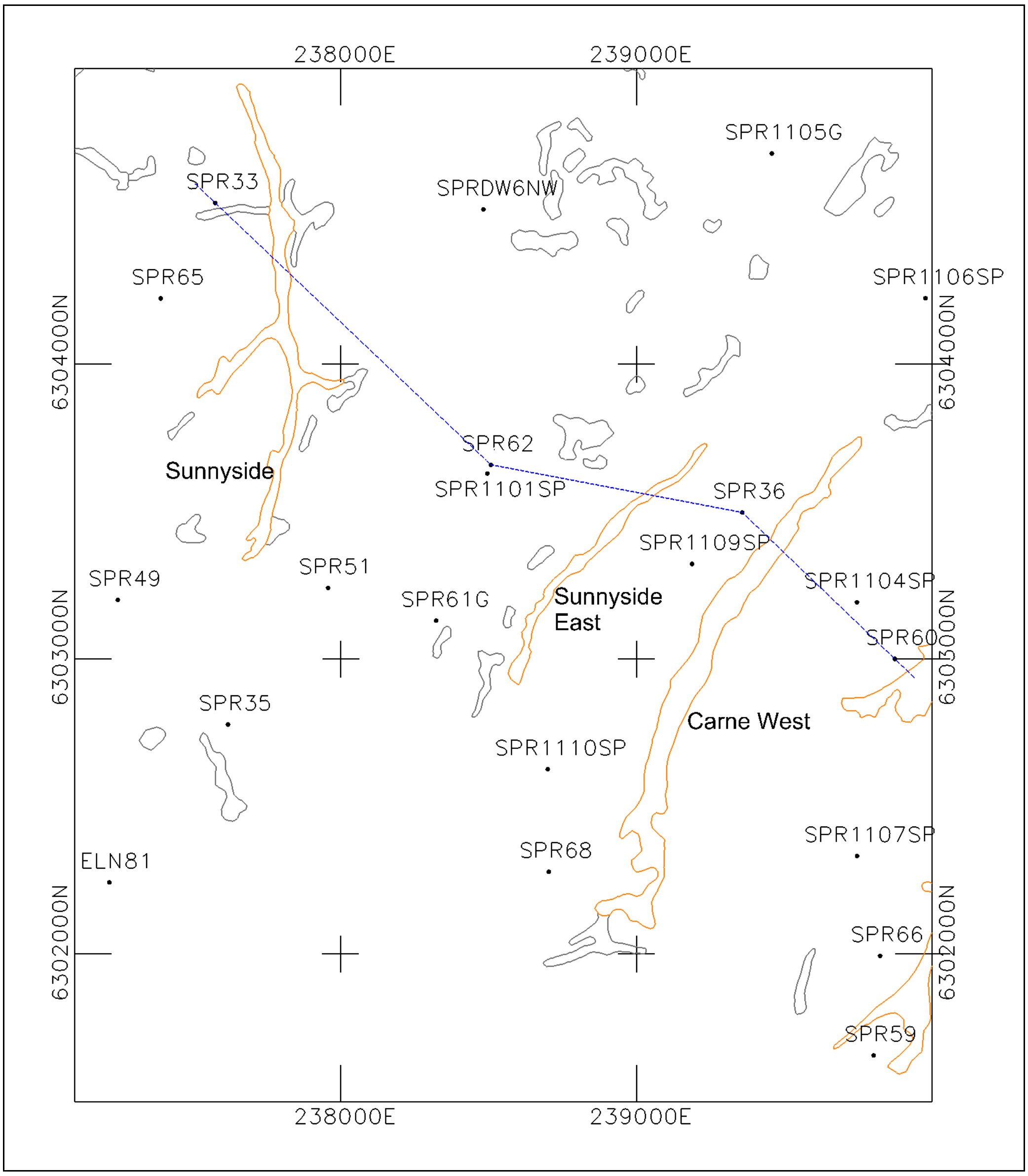


**Figure 14 Plan of Sunnyside, Sunnyside East and Carne West Shrub Swamps**

Figure 14 shows the location of Sunnyside, Sunnyside East and Carne West shrub swamps (in orange) in addition to the numerous hanging swamps in the vicinity (in grey). Relevant borehole locations are also shown. Figure 15 (below) is a cross-section of the above diagram.

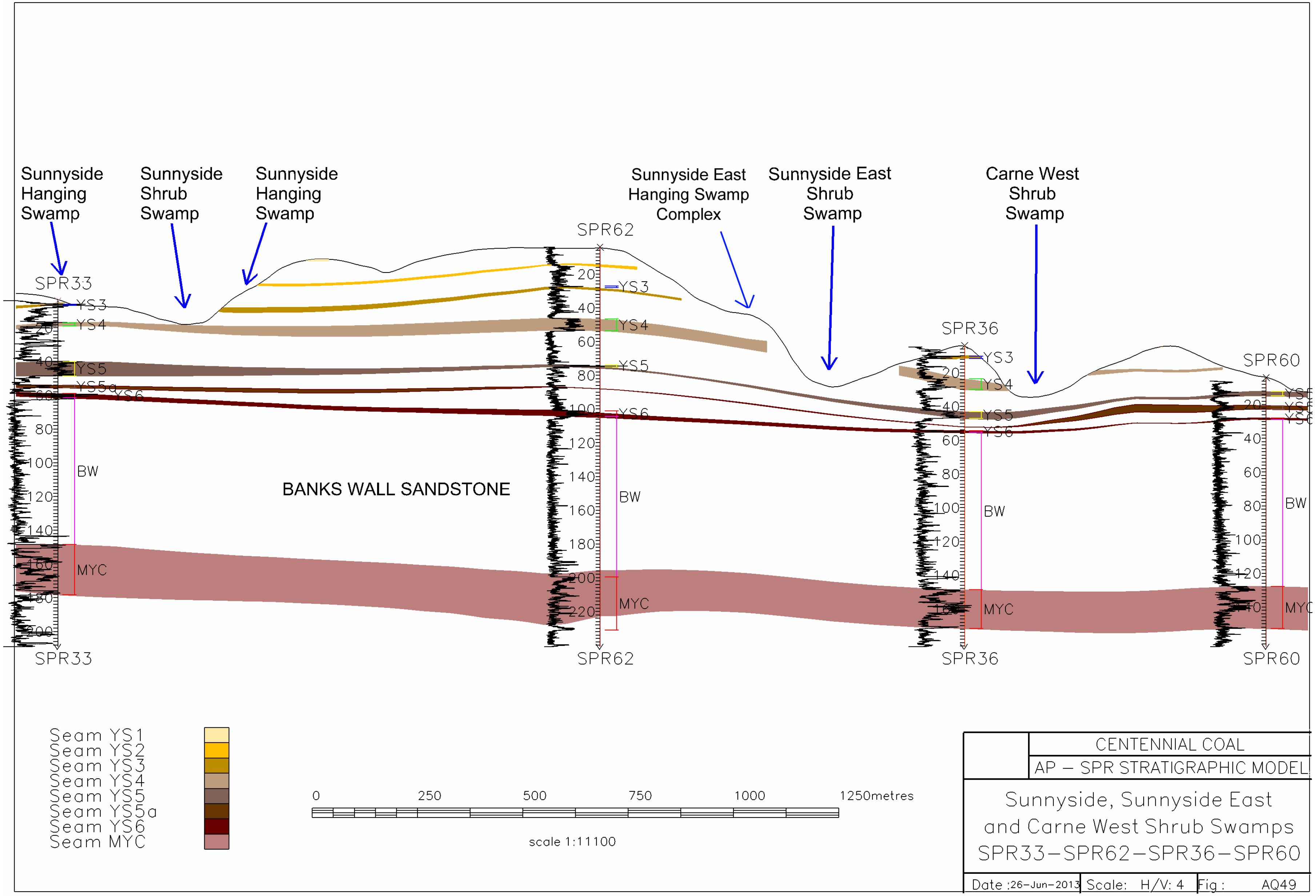


Figure 15 Sunnyside - Sunnyside East - Carne West Shrub Swamps Cross Section

As shown in Figure 15, swamp profiles in the eastern Burralow-type shrub swamps are generally asymmetrically concave with the lowest depression to the west of centre, often adjacent to the steeper side of the pertinent gully. This asymmetric profile can be seen in the above figure in the case of Sunnyside East and Carne West Shrub Swamps, as well as Sunnyside Shrub swamp which reflects an opposing concavity due to the general topography of this area. This shallow, spoon-shaped swamp morphology contrasts with that of the Banks Wall-type shrub swamps of which Japan Shrub Swamp (Figure 16 below) is a typical example. Banks Wall-type shrub swamps in general have much steeper-sided valley walls and a narrower width as compared to Burralow-type swamps, as previously illustrated in Figure 9.

Figure 15 (above) also illustrates the difference in geophysical response between the Banks Wall Sandstone and the overlying Burralow Formation. This west-east cross section, encompassing boreholes SPR 33, SPR 62, SPR 36 and SPR60, clearly shows the generally muted gamma response of the Banks Wall Sandstone compared to the Burralow Formation. The latter displays increased gamma response associated with clay-rich aquitard horizons. The gamma response of the Mt York Claystone which lies stratigraphically below the Banks Wall Sandstone also reflects the high clay content of this formation. Hence, in geophysical terms, the Banks Wall Sandstone is referred to in this study as the “muted zone”, as noted in Section 5 above.

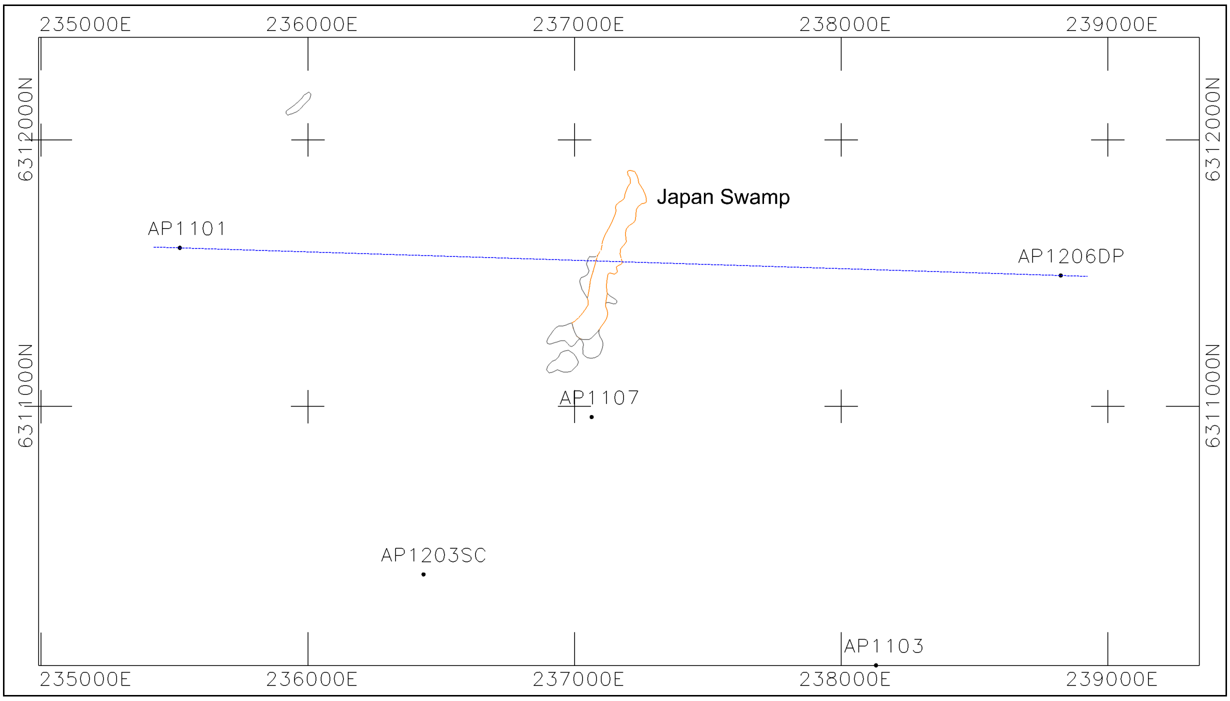


**Figure 16 Plan of Japan Shrub Swamp**

Figure 16 shows a plan diagram of the two boreholes used to create the cross section (Figure 17) below and includes the hanging swamp on the western flank of the host gully. Shrub swamps are in orange and hanging swamps are in grey.

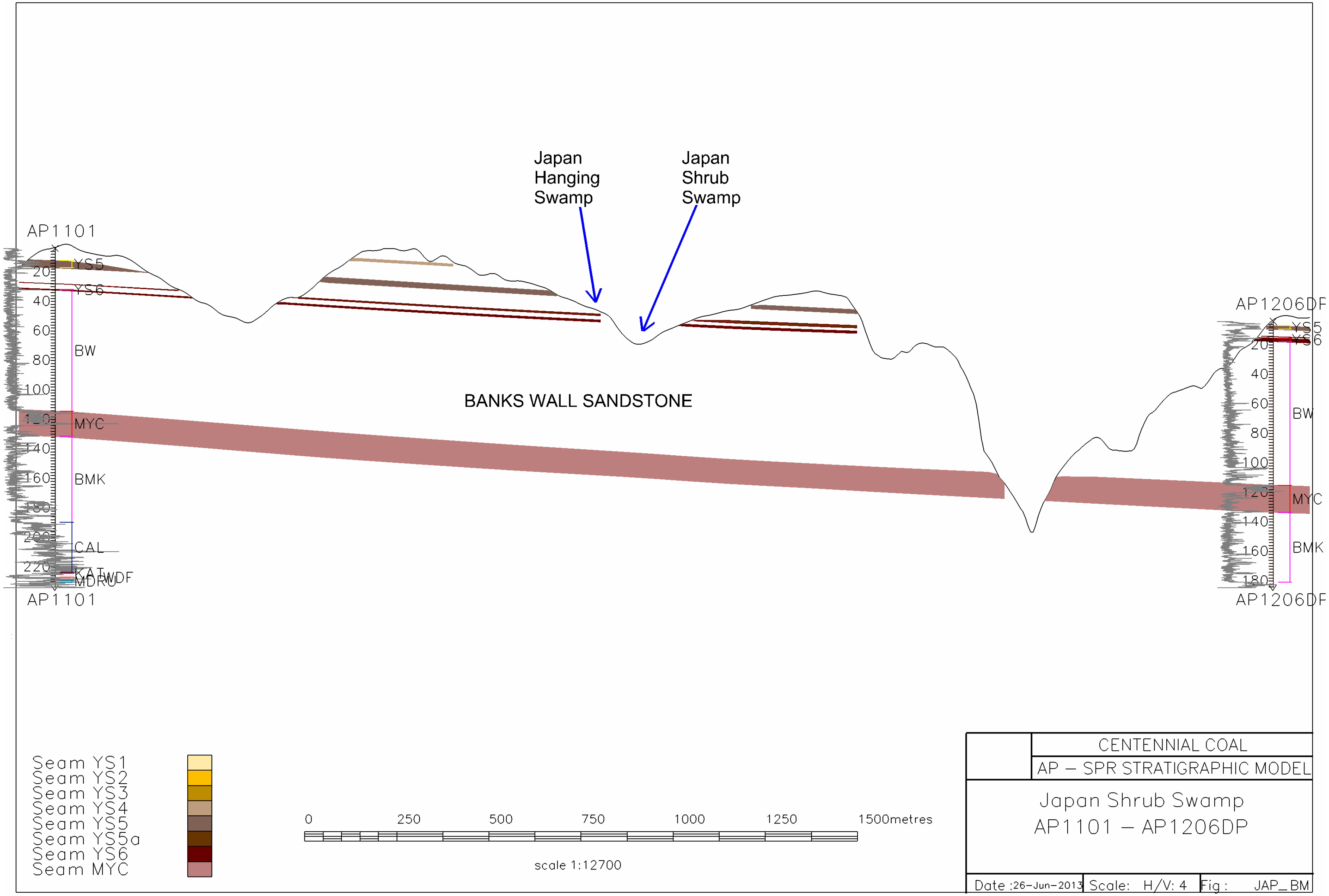


Figure 17 Japan Shrub Swamp Cross Section

Figure 17 shows a cross section of Japan Shrub Swamp and associated hanging swamps. With the same vertical exaggeration as the Burralow-type shrub swamp diagram (Figure 15), Japan Shrub Swamp appears as areally smaller with comparatively narrower gully sides. Additional gully profiles within this cross-section, particularly to the east of Japan Shrub Swamp also reflect this trend, displaying the steep-sided erosional gullies which are characteristic of watercourses located solely within the Banks Wall Sandstone.

Benson and Baird (2012) stated that monitoring of swamps in the western part of the Newnes Plateau revealed that these swamps are drier than those in the east. This finding further emphasizes the role of the Burralow Formation, and in particular, the important role of Burralow Formation thickness and therefore access to multiple aquitards to retain moisture content within this stratigraphic unit.

Benson and Baird also found that the eastern swamps were all associated with *Epodisma minus, Grevillea acanthifolia*, and *Epacris paludosa* which were virtually absent from the western swamps. This again reflects the influence of Burralow Formation thickness on both swamp morphology and swamp vegetation, due to its ability to retain water via the presence of numerous semi-permeable layers. Hence the Burralow Formation influences not only swamp morphology, including valley wall profiles and soil type, but ultimately swamp floristics.

# 10. Topography, Burralow Formation and Shrub Swamp Morphology

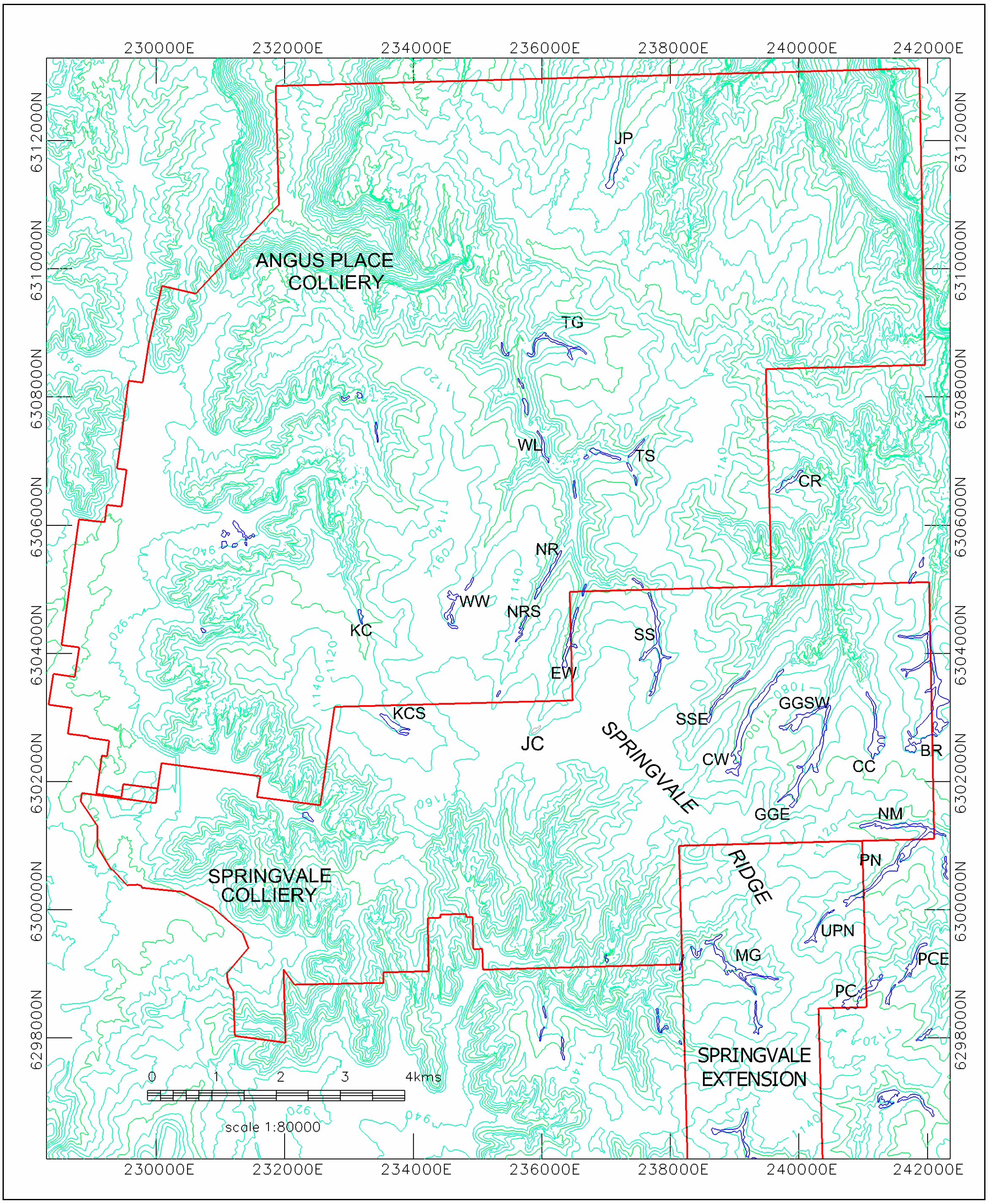


Figure 18 Topography and Shrub Swamp Locations in Angus Place/Springvale

**Key to swamp abbreviations:**
**JP: Japan (Trail 6), TG: Twin Gully, WL: Wolgan, TS: Tri-star, CR: Crocodile, NR: Narrow, NRS: Narrow South, WW: West Wolgan, EW: East Wolgan, KC: Kangaroo Creek, KCS: Kangaroo Creek South, JC: Junction, SS: Sunnyside, SSE: Sunnyside East, CW: Carne West, GGSW: Gang Gang Southwest, GGE: Gang Gang East, CC: Carne Central, BR: Barrier, NM: Nine Mile, PN: Pine, UPN: Pine Upper, PCE: Paddy's Creek East, PC: Paddy's Creek, MG: Marrangaroo**

Figure 18 shows topography and shrub swamp locations for the Angus Place and Springvale leases. As shown, the length, breadth and frequency of shrub swamps in the study area generally increases to the south-east, principally in the Springvale Colliery lease. This is due in part to the topography present but is also dependent upon the thickness of the Burralow Formation and the hydrological influence of its associated aquitards. Hence, there is a persistent pattern of increasing shrub width and length towards the south and east of the study area.

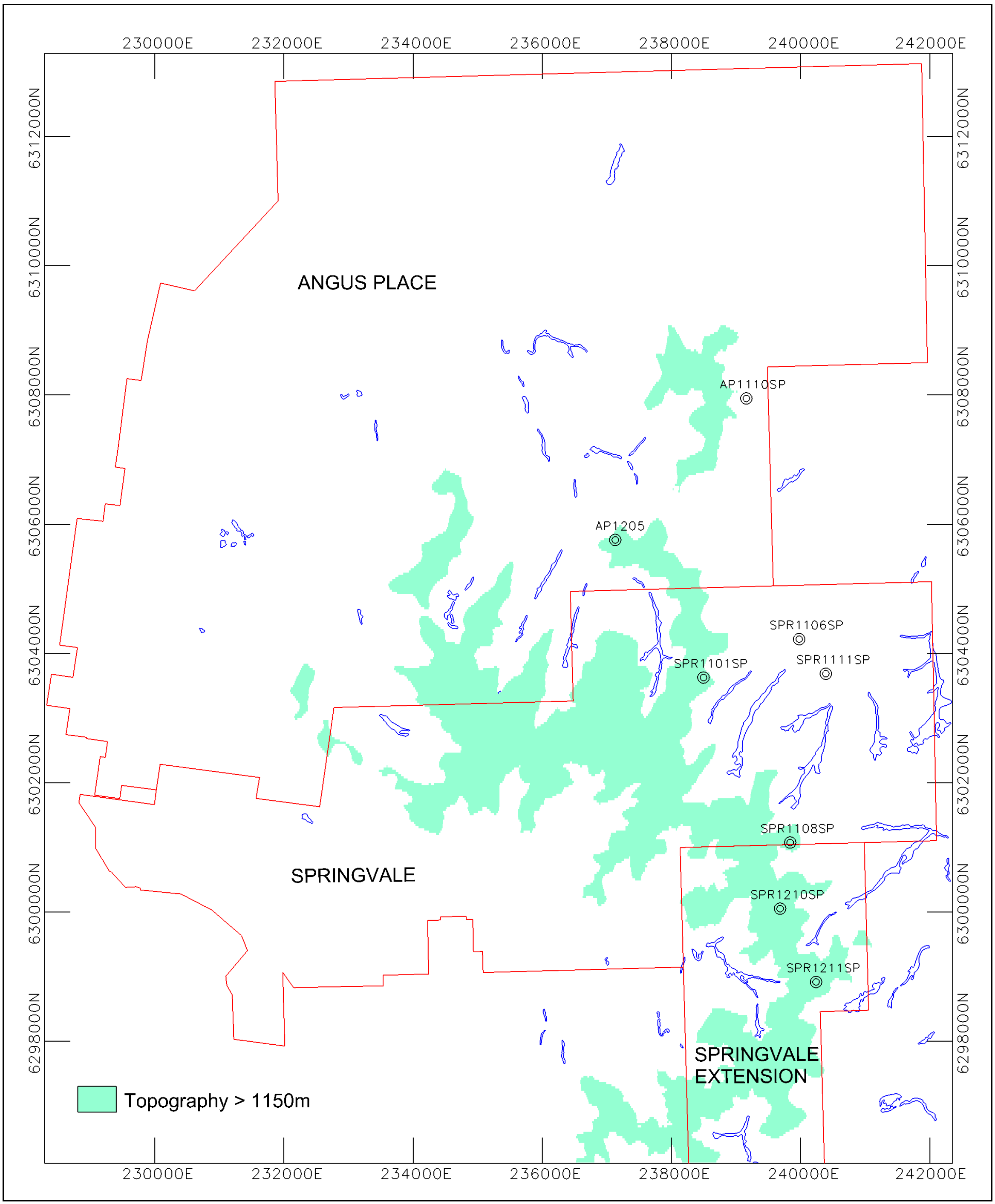


**Figure 19  Topography in Study Area above 1150 metres**

The highest point on the Newnes Plateau in the study area is 1180 metres but an arbitrary topographic height of 1150 metres has been selected to highlight the dominant ridge systems in the area (Figure 19).

As illustrated above, in Angus Place the highest elevation is 1150 to 1160 metres and is located west of AP1110SP. This short piezometer hole is located topographically lower than the arbitrary 1150-metre cut off, but still contains the full YS6 to YS1 sequence. Geophysically logged holes in the most elevated areas of Angus Place also indicate that the full aquitard sequence from YS6 to YS1 is present.

The maximum thickness of the Burralow Formation in Angus Place is 100 – 110 metres and coincides with the highest catchment area as described above. Hence, there is a positive correlation between Burralow Formation thickness and topographic elevation.

A second, more extensive ridge system (> 1150m -1180m) is present in the Springvale area and represents the most elevated region of the study area. This ridge system, Springvale Ridge (Figure 18), extends from south of the West Wolgan Shrub Swamp to south of the Narrow, East Wolgan, Sunnyside, Sunnyside East, Carne West, Gang Gang, Pine and Marrangaroo Creek Shrub Swamps, thus creating an extensive watershed for the formation of the creeks which support the above watercourses. Further, this topographic feature, like the elevated plateau in Angus Place described above, is underlain by the maximum thickness of the Burralow Formation and contains the full sequence of YS aquitards. Again there exists a positive correlation between topography and Burralow Formation thickness at this location.

An outlier of elevated topography occurs to the north-west of West Wolgan Shrub Swamp which serves to supplement groundwater seepage to this swamp complex via the series of aquitards present in the Burralow Formation at this location.

These elevated ridges, particularly the elongated twelve kilometre system in the Springvale area, are important recharge areas for both the hanging and shrub swamps. In Angus Place, the 1150+ metre zone is more areally restricted and few major waterways are associated with this feature. The nearest shrub swamps are Tri-Star and Twin Gully Shrub Swamps to the west at a distance of between one to two kilometres, and Crocodile Shrub Swamp, over one kilometre to the east (Figure 6).

The Springvale Ridge system provides not only an extensive recharge area for the associated creeks and shrub swamps, but the maximum thickness of the Burralow Formation is an important component in the hydrological cycle that drives the formation of both shrub and hanging swamps in the region.

The full YS aquitard sequence (YS6 to YS1) is present in all cored holes within the designated 1150+ metre shaded area, that is, AP1110SP, AP1205, SPR1108SP, SPR1210SP and SPR1211SP. Borehole SPR1101SP, located between Sunnyside and Sunnyside East Shrub Swamps, does not contain the YS6 ply as the borehole was terminated above this horizon.

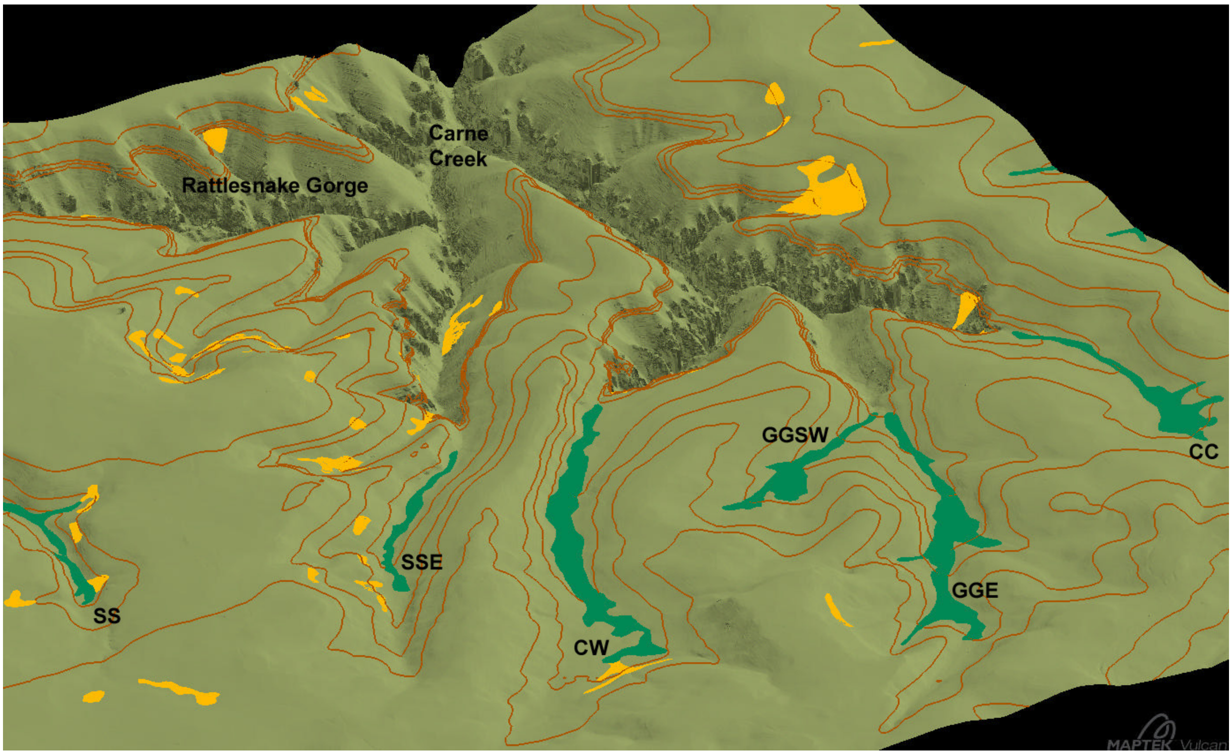


**Figure 20 Schematic View of Carne Creek Shrub Swamp Systems**

Figure 20 shows a view looking north-west from the direction of the Springvale Ridge system. Aquitard horizons which support the shrub and hanging swamps are shown in brown. Shrub swamps are marked in green and hanging swamps in yellow.

Carne West Shrub Swamp (CW) in teal green, with its associated Newnes Plateau Hanging Swamp (in yellow) can be seen in the middle foreground. To the east is the Gang Gang Shrub Swamp complex (GGSW and GGE), while Carne Central Shrub Swamp (CC) is to the extreme right of the figure.

To the west of Carne West swamp lies Sunnyside East Shrub Swamp (SSE) together with an array of hanging swamps (in yellow) associated with several aquitards cropping out west of this swamp. The lower tip of Sunnyside Shrub Swamp (SS) can be observed in the left foreground on the opposing side of Sunnyside Ridge which forms part of the extensive recharge areas discussed above. Several hanging swamps are also associated with this shrub swamp.

This figure illustrates the extensive subcrops of aquitards present in this area of the Angus Place/ Springvale lease. As the regional dip is less than one degree, the aquitard horizons generally follow topography. Hence there is a relative lack of aquitard outcrops in the flatter, elevated ridge areas, whereas the gully sides form frequent outcrop points. As was noted in Section 9, aquitard horizons crop out along the sides of valley walls, as well as within gully floors, thus supplying a constant source of groundwater moisture for both the shrub swamps in the gullies and the hanging swamps that occur along cliffs and the steeper upper sections of valley sides.

The presence of hanging swamps throughout the lease area is an important indictor of the amount of groundwater contained within the aquitard/aquifer system operating throughout the vertical extent of the Burralow Formation. As noted above and shown in Figure 20, there exists an extensive suite of hanging swamps to the immediate west of Sunnyside East Shrub Swamp. Sunnyside Shrub Swamp also has associated hanging swamps, the southern examples of which can be seen in the above figure. Other hanging swamps are present in Figure 18, including those in Rattlesnake Gorge, the western tributary of Carne Creek in the upper left of this figure. The latter demonstrate the typical outcrop pattern for hanging swamps.

Hanging swamps occur in both high and low relief areas, while shrub swamps are restricted to areas of low relief. The formation of a hanging swamp is dependent on the presence of a suitably thick aquitard (generally > 1 metre) and an appropriate topographic setting. The hanging swamps of the Newnes Plateau are discussed in a separate report, however their presence and morphology are indicative of considerable reserves of water held within aquifer units of the Burralow Formation, which is also of crucial importance to the development of shrub swamps.

As can be observed in Figure 20, by virtue of the regional dip, the aquitard horizons are often present along the sides of ridges and thus follow the gully sides of the host creek below. The presence of aquitards at these locations leads to the occurrence of valley wall seepage which is an important source of moisture for the shrub swamps in the upper reaches of both Carne Creek and the Wolgan River.

Apart from the seven major aquitards discussed earlier (that is, YS6, YS5a, YS5, YS4, YS3, YS2 and YS1), thinner aquitard units also are present within the Burralow Formation which, while they may not be capable of forming a hanging swamp, nevertheless supply a constant source of seepage at outcrop localities.

The presence of swamps in catchment headwaters cannot be fully explained by rainfall alone and require an additional continuous source of hydration though periods of restricted rainfall. As noted in Section 9, the presence of the Burralow Formation is essential to the formation of both hanging and shrub swamps. Piezometer readings, both in-stream and on ridge locations, record only part of the full hydrological picture for any given swamp system. Valley wall seepage, which occurs however minutely at some locations along aquitards outcrops, still permits continuity of hydration during periods of drought. More importantly, in regard to Burralow-type swamps, direct in-gully groundwater input forms a crucial contributor to swamp hydration and morphology.

Figure 20 illustrates the relative abundance of aquitards in the Burralow Formation providing continual groundwater supplies to both shrub and hanging swamps along valley sides. Aquitards also crop out within the host gully of a shrub swamp, for example, in Carne West and Gang Gang Shrub Swamps, and hence provide additional input of groundwater to the valley wall seepage. The latter phenomenon accounts for the relatively extensive morphologies of these two shrub swamps. This concept will be further discussed in a subsequent report.

# 11. Major recharge areas within the Angus Place/Springvale Leases

The Springvale Ridge system as noted previously provides a major recharge zone for the shrub swamps to the north and south of this feature. The western half of the ridge system contains numerous boreholes which were geophysically logged (eg. SPR24, SPR 31, SPR 25R, SPR 44, SPR52, SPR35 and SPR 51) in which the full YS1 to YS6 sequence is present. Several short piezometer holes were also cored in the eastern extent of this elevated zone, with results as follows:

- In AP1110SP, the closest cored borehole to the Angus Place 1150+ m zone, the strata from approximately 6m to 36m consists largely of slightly weathered to unweathered fine- to medium-grained sandstone interspersed with thin zones of more highly weathered material. It is this resistant sandstone cap which likely forms the Angus Place elevated zone to the immediate west.

- AP1205 is similar to AP1110SP, with the resistant/competent sandstone extending to approximately 30m.

- SPR1108SP consists of slightly weathered fine-to-medium sandstone from 6m to 13m. From 13m to 42m, the strata consist of slightly weathered to unweathered fine- to medium-grained sandstone interspersed with zones of more highly weathered material. Figure 21 shows core photographs from 6 to 13.5 metres within this hole and illustrates the competent nature of this near-surface material.

- SPR1210SP contains a slightly weathered sandstone/siltstone cap from 6 to 8 metres, but this is underlain by more highly weathered material than shown in the previously discussed boreholes.

- SPR1211SP contains slightly weathered fine siltstone from 6 to 8 metres, but below this depth, there is a higher proportion of moderately to highly weathered material than slightly weathered, competent material.

The common feature from each of these bores is the presence of relatively unweathered, competent strata at very shallow depth.

By comparison, boreholes SPR1106SP and SPR1111SP which are located near the confluence of the Sunnyside East, Carne West and Gang Gang Creeks show quite different lithological patterns. Although both located in the Burralow Formation, these bores contain non-competent, heavily weathered and iron-stained material near the surface and hence, at this RL, no ridge system exists. Figure 22 shows the material present in the upper 12.3 metres of SPR1111SP which clearly demonstrates the extreme weathering at this site.

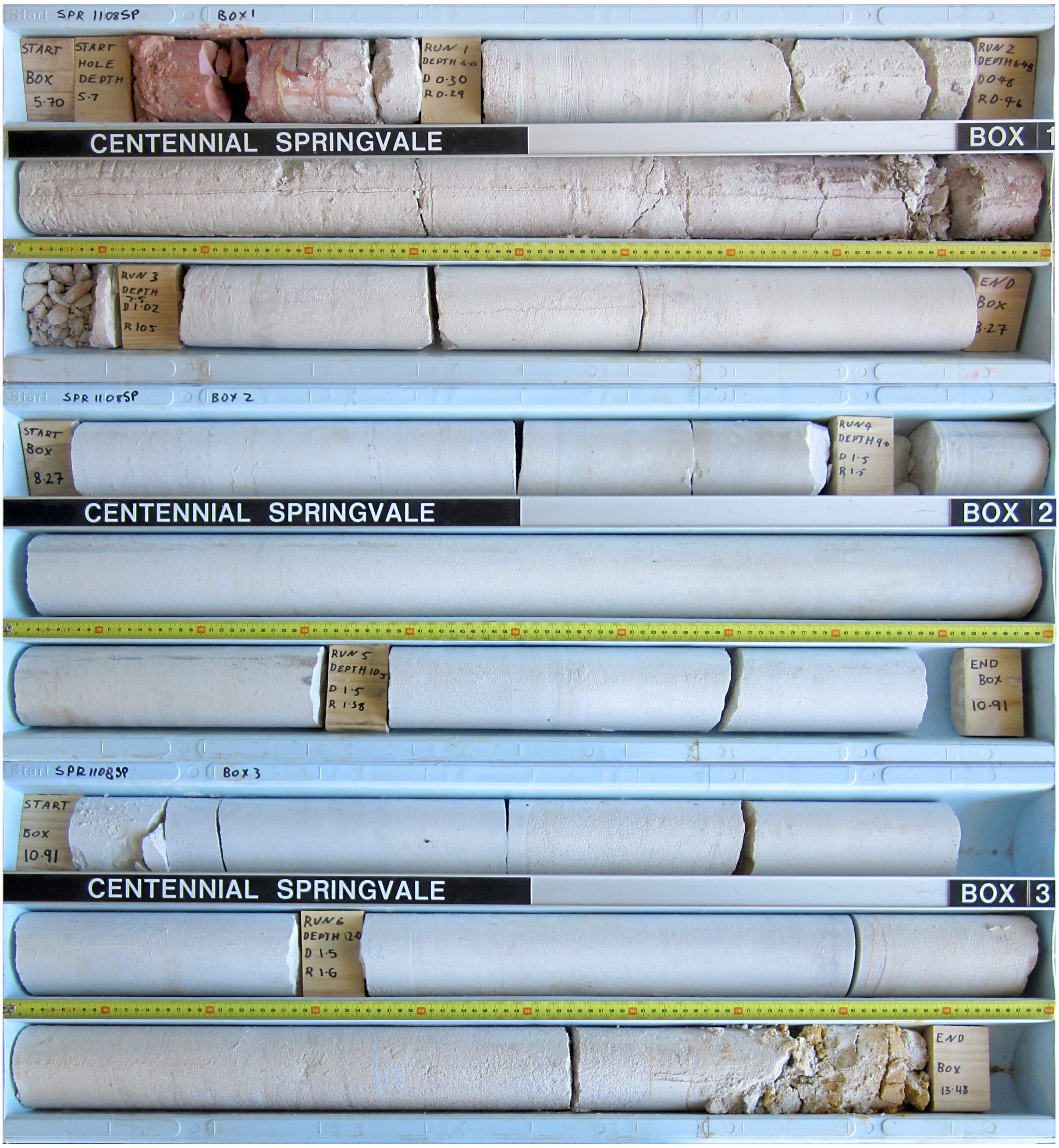


**Figure 21 Core Photos of SPR 1108SP (6-13.5 m)**

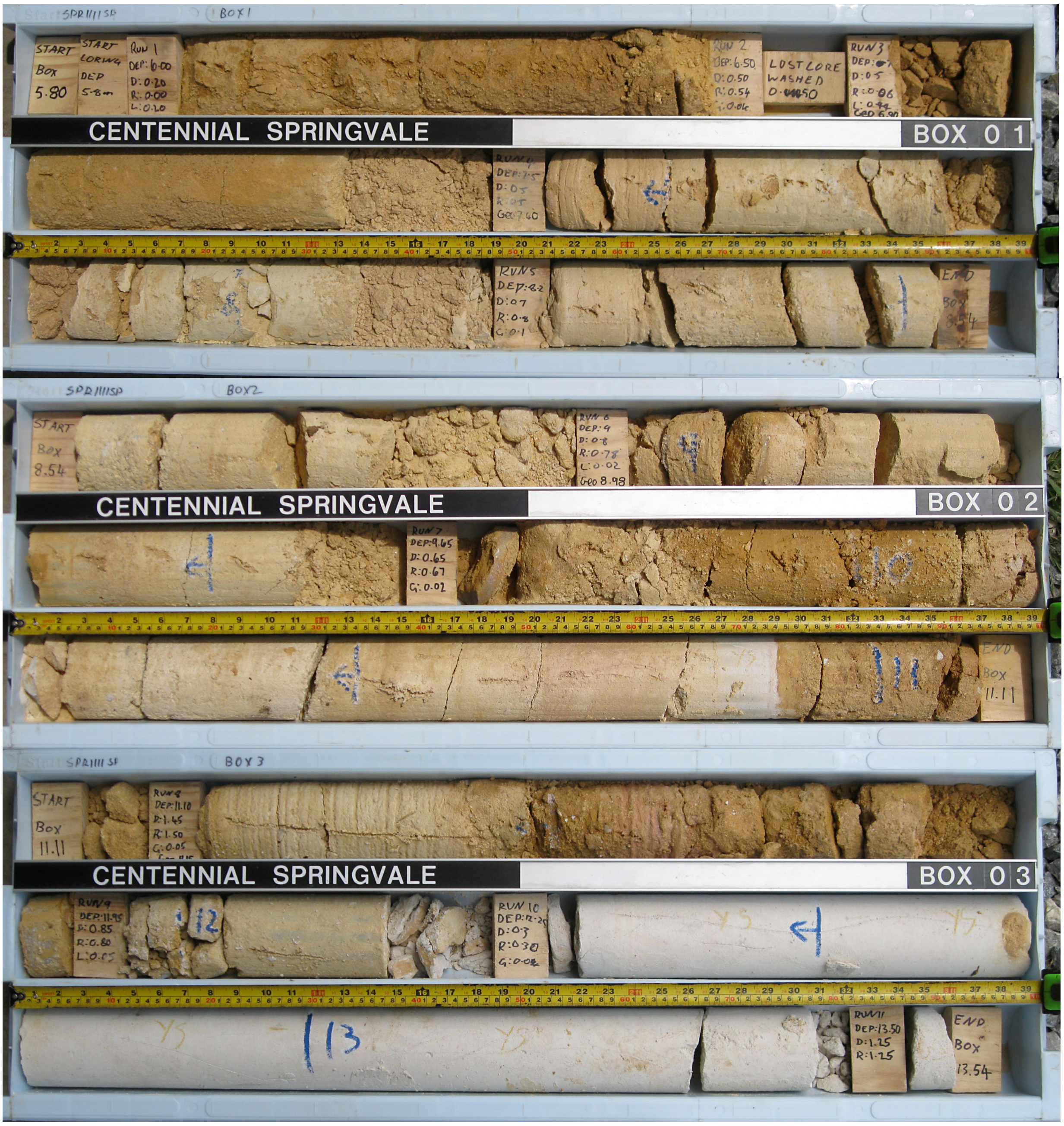


Figure 22 Core Photos of SPR1111SP (6-12.3m)

# 12. Selected Newnes Plateau Shrub Swamp Descriptions within Angus Place East

A selection of shrub swamps in both the Angus Place and Springvale South area are described in Sections 12 and 13 below in order to present an overall understanding of the varying morphologies between differing lithologically controlled shrub swamp types. As described in Section 10, the underlying lithology plays an important part in the morphology of the resultant shrub swamp.

Angus Place East consists of proposed longwall panels 1001 to 1017 east of the Wolgan River (Figure 23) and is overlain by three shrub swamps: Japan, Twin Gully and Tri-Star. An additional shrub swamp, Crocodile, is situated within the Angus Place lease area approximately 100m to the east of LW1003. All four swamps are discussed in this report and are shown in Figure 24 below. In addition, the Rattlesnake Gorge Hanging Swamp Complex and the Smithston Hanging Swamp Complex are briefly discussed due to their proximity to the proposed mining area. These swamps will be considered in detail in a subsequent report *The Hanging Swamps of the Newnes Plateau.*

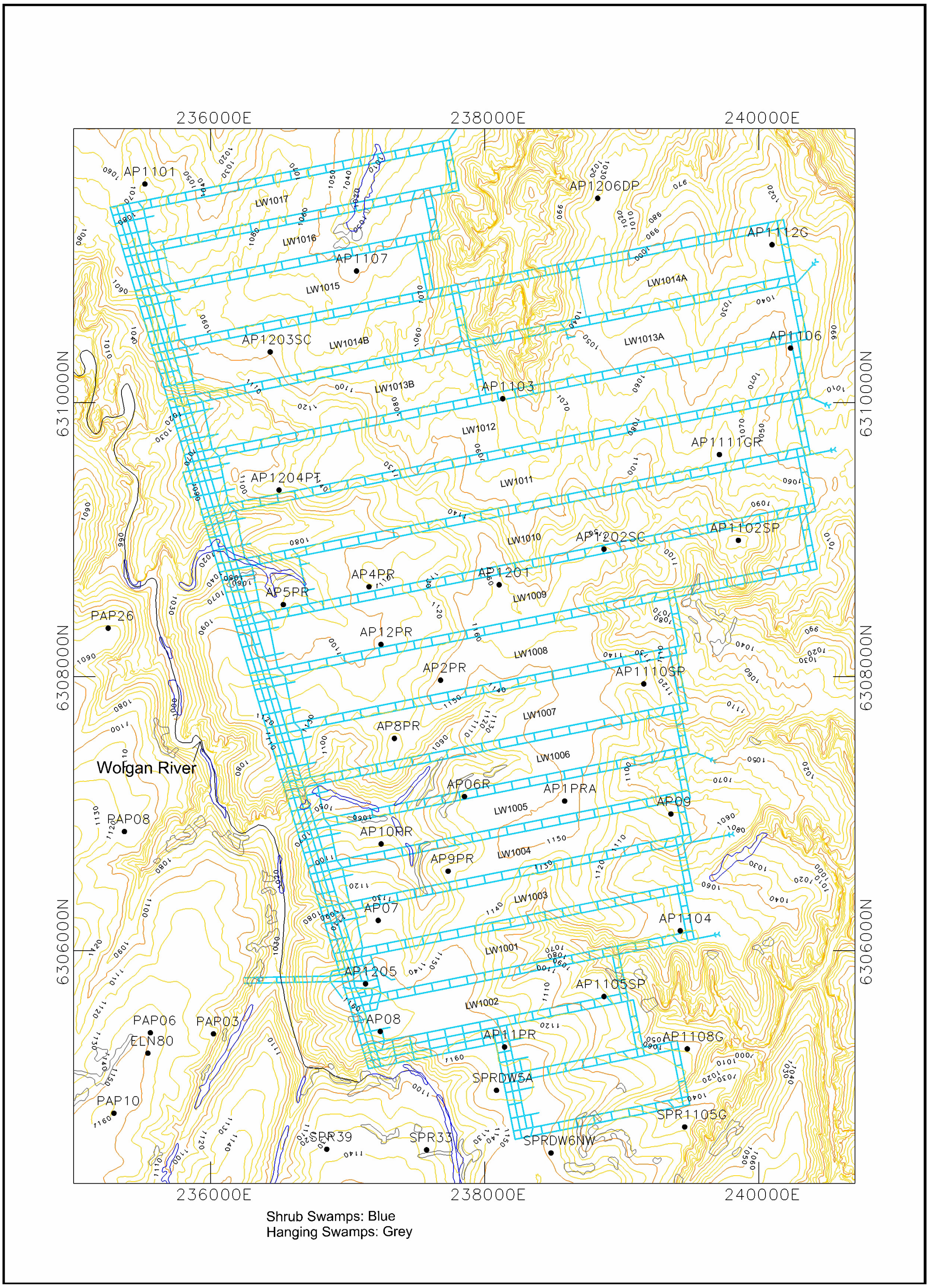


**Figure 23 Angus Place East showing shrub swamp locations, mine layout and topography**

Similar to shrub swamps located in the Springvale and Springvale South areas, Japan, Twin Gully, Tri-Star and Crocodile shrub swamps are located such that their headwaters are proximal to the more elevated regions of the Angus Place East lease.

However, unlike the Burralow-type swamps in the south-eastern parts of the Springvale lease, stratigraphic conditions differ to the north such that none of the Angus Place shrub swamps are “Burralow-type” swamps (Section 9).

All shrub swamps in the Angus Place East area comprise either “mixed-type” swamps or are contained wholly within the Banks Wall Sandstone. The result of this change in geological regime is that the size and morphology of the Angus Place East shrub swamps differ significantly from many of their shrub swamp equivalents in the Springvale area. The “Banks Wall” and “mixed-type” swamps of Angus Place are generally smaller and narrower than the “Burralow-type” swamps which dominate the Springvale lease. This is illustrated when comparing a shrub swamp such as Crocodile with the Pine and Upper Pine complex in the south-east of Springvale, for example.

Shrub swamps which are either wholly or partially situated stratigraphically within the Banks Wall Sandstone are also present in the Clarence Colliery lease area and are similarly restricted in morphology compared with Burralow-type swamps in the same vicinity. This phenomenon will be discussed in subsequent sections.

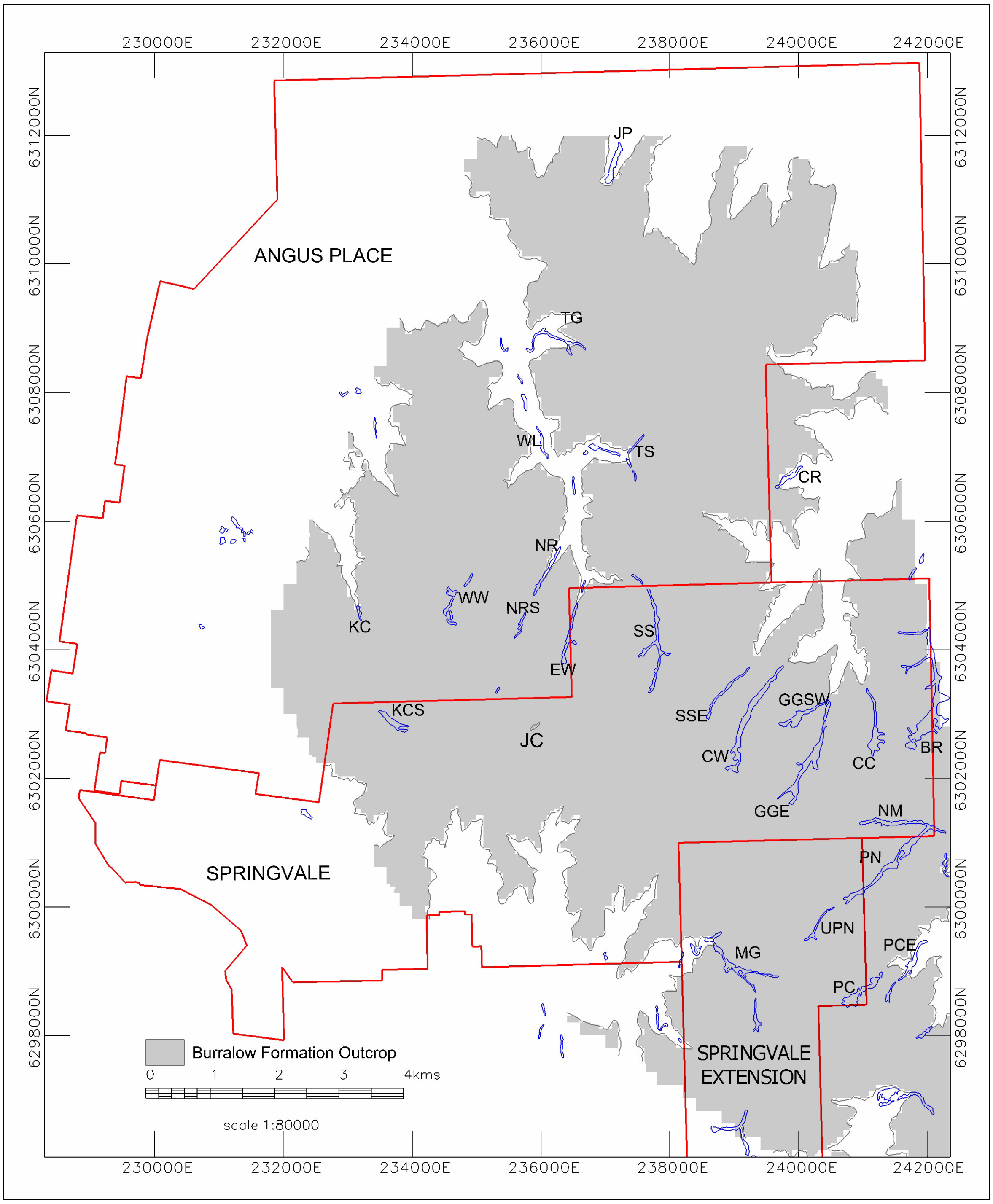


**Figure 24 Shrub Swamp Localities in Angus Place, Angus Place East, Springvale and Springvale South Extension and Burralow Formation Outcrop**

**Key to swamp abbreviations:**
JP: Japan (Trail 6), TG: Twin Gully, WL: Wolgan, TS: Tri-Star, CR: Crocodile, NR: Narrow, NRS: Narrow South, WW: West Wolgan, EW: East Wolgan, KC: Kangaroo Creek, KCS: Kangaroo Creek South, JC: Junction, SS: Sunnyside, SSE: Sunnyside East, CW: Carne West, GGSW: Gang Gang Southwest, GGE: Gang Gang East, CC: Carne Central, BR: Barrier, NM: Nine Mile, PN: Pine, UPN: Pine Upper, PCE: Paddy’s Creek East, PC: Paddy’s Creek, MG: Marrangaroo

As shown in Figure 24, Japan shrub swamp lies to the north of the Angus Place lease and is situated stratigraphically within the Banks Wall Sandstone. Almost due south is Twin Gully shrub swamp, which is a “mixed-type” swamp, with its upper reaches located stratigraphically within the Burralow Formation while the majority of the swamp is situated within the Banks Wall Sandstone. Similarly, Tri-Star shrub swamp also displays mixed-type characteristics, as the host gully moves stratigraphically from the Burralow Formation in the upper reaches down into the Banks Wall Sandstone in the main section of the swamp.

Approximately due east of Tri-Star (Figure 24), Crocodile Shrub Swamp is also a “mixed-type” swamp with its extreme upper reaches located within the Burralow Formation and the majority of the swamp situated stratigraphically within the Banks Wall Sandstone.

“Burralow-type” shrub swamps are absent from the Angus Place East lease, with all swamps displaying “mixed-type” or “Banks Wall-type” shrub swamp characteristics. This is due to topographic influences whereby the Wolgan River and Carne Creek watercourses have progressively eroded the plateau in this area to expose the Banks Wall Sandstone as the principal outcropping lithology within the four host gullies of the shrub swamps discussed above. This phenomenon demonstrates the effects of the partial or complete absence of the Burralow Formation on the relative morphologies of all four of the Angus Place East shrub swamps.

Figure 24 clearly demonstrates differences in shrub swamp characteristics between the northerly Angus Place lease and the general Springvale area, the latter consisting of thicker Burralow sequences, a consequent increase of aquitard horizons and decreased exposure of the Banks Wall Sandstone, all of which leads to an increase in length and width of the shrub swamps of the general Springvale area. Hence differences in gully substrates, in conjunction with topography, result in differences in shrub swamp morphology.

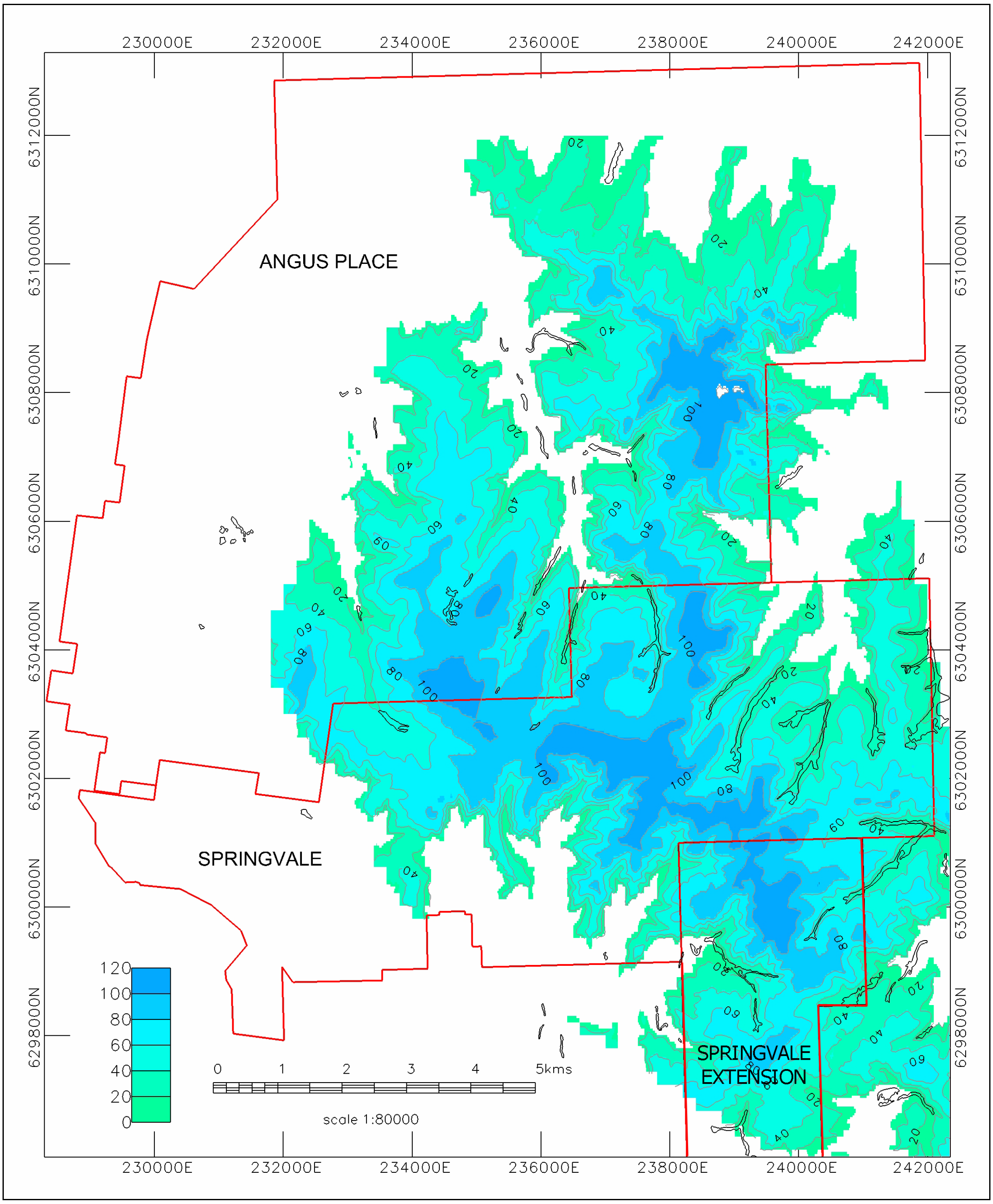


**Figure 25 Burralow Formation Isopach for Angus Place and Springvale leases (Note: shrub swamps shown in black outline)**

The importance of gully substrate lithology is shown in Figure 25 which illustrates the relative thickness and extent of the Burralow Formation in the Angus Place East and Springvale areas. There exists no equivalent of the extensive Springvale Ridge in the Angus Place East area and discussed in Section 10, hence the recharge area is comparatively smaller. This, in conjunction with the more heavily incised plateau which exposes larger sections of the Banks Wall Sandstone, means that the swamps in the Angus Place area are relatively shorter and narrower compared with those in Springvale and Springvale South due to the differing geological regimes present.

## *I. Japan Shrub Swamp*

Japan Shrub Swamp (also known as Trail 6 Swamp) trends approximately north-south, with a length of 750 metres and a maximum width of 75 metres (Figure 26). It has a fall of 32 metres, is wholly contained within the Banks Wall Sandstone and is distal from any known structure zones (Figure 4). The gully in which Japan shrub swamp lies forms part of the extreme upper reaches of a tributary of the Wolgan River and overlies longwalls LW1016 and LW1017.

Originally identified by DEC (2005) as a Newnes Plateau Hanging Swamp (NPHS) on the basis of aerial photograph interpretation, it was evident from geological and topographic data that this interpretation was incorrect and that the majority of the gully appeared to express characteristics of a Newnes Plateau Shrub Swamp (NPSS).

This swamp was subsequently ground truthed by R. Lembit (2010) and vegetation patterns were found to concur with geological findings, with Lembit reporting the presence of hanging swamps in the upper reaches of the host gully, and along side valleys as indicated in Figure 26.

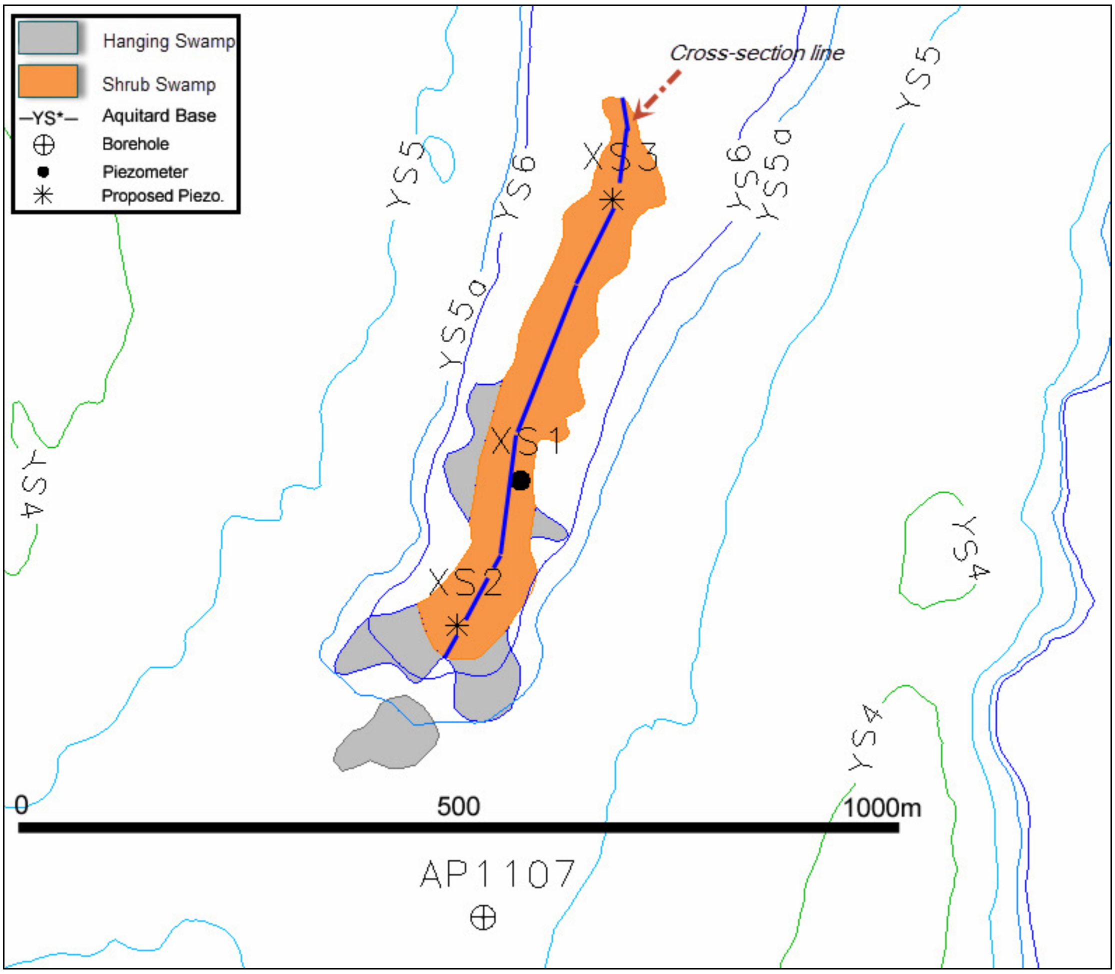


**Figure 26 Plan of Japan (Trail 6) Shrub Swamp**

Japan Shrub swamp is the largest shrub swamp in the Angus Place lease and its relatively expansive width as compared to Twin Gully, Tri-Star and Crocodile is due to its topographic positioning and presence of three aquitards along the length of the host valley. This swamp lies in a narrow, steep gully due to the characteristics of the Banks Wall Sandstone substrate which displays a different erosional pattern to gullies with Burralow substrates. Hence the narrow nature of the Japan gully results in the close proximity of aquitards YS6, YS5a and YS5 which supply valley wall seepage along the length of the gully such that a shrub swamp can be formed and sustained within the aquitard-poor Banks Wall Sandstone.

Aquitards YS6 and YS5a are sufficiently developed in thickness to permit a change in hydrological gradient to form the hanging swamps at the headwaters of Japan Shrub Swamp as well as along the down-dip western side of the gully (Figure 26).

**Figure 27 View of Japan Swamp (Trail 6)**

Figure 27 was taken in the middle of the drainage line of the swamp, oriented in a northerly (downstream) aspect approximately one-third of the way from the upper reaches of the host gully. This photo gives an indication of the relative narrowness of this swamp compared to Burralow-type shrub swamps described previously. This swamp is wholly underlain by the Banks Wall Sandstone and thus the morphology differs significantly from shrub swamps with Burralow Formation substrates.

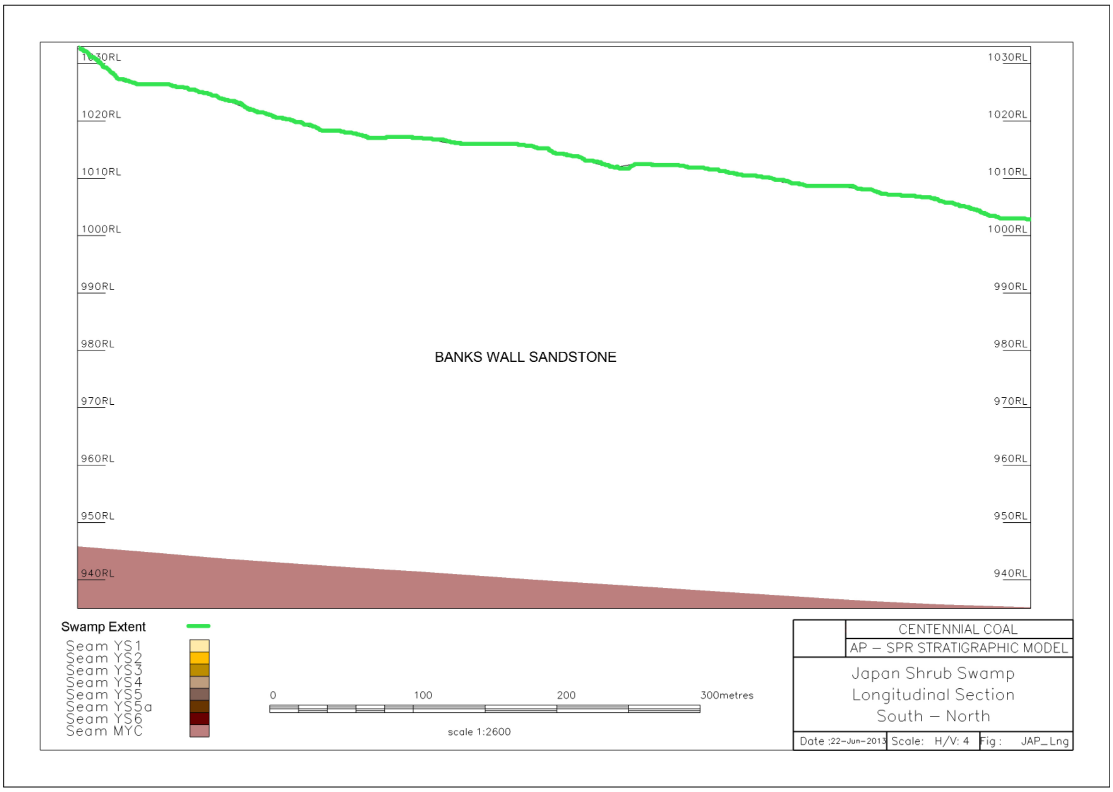


**Figure 28 Longitudinal Stratigraphic Section of Japan Shrub Swamp**

Figure 28 shows a south-to-north longitudinal stratigraphic cross section of Japan Shrub Swamp. Note the absence of Burralow Formation lithologies and the consequent continuous Banks Wall Sandstone substrate. The latter contributes to the relatively attenuated length of this swamp compared to Burralow-type swamps due to the absence of direct in-gully aquitards.

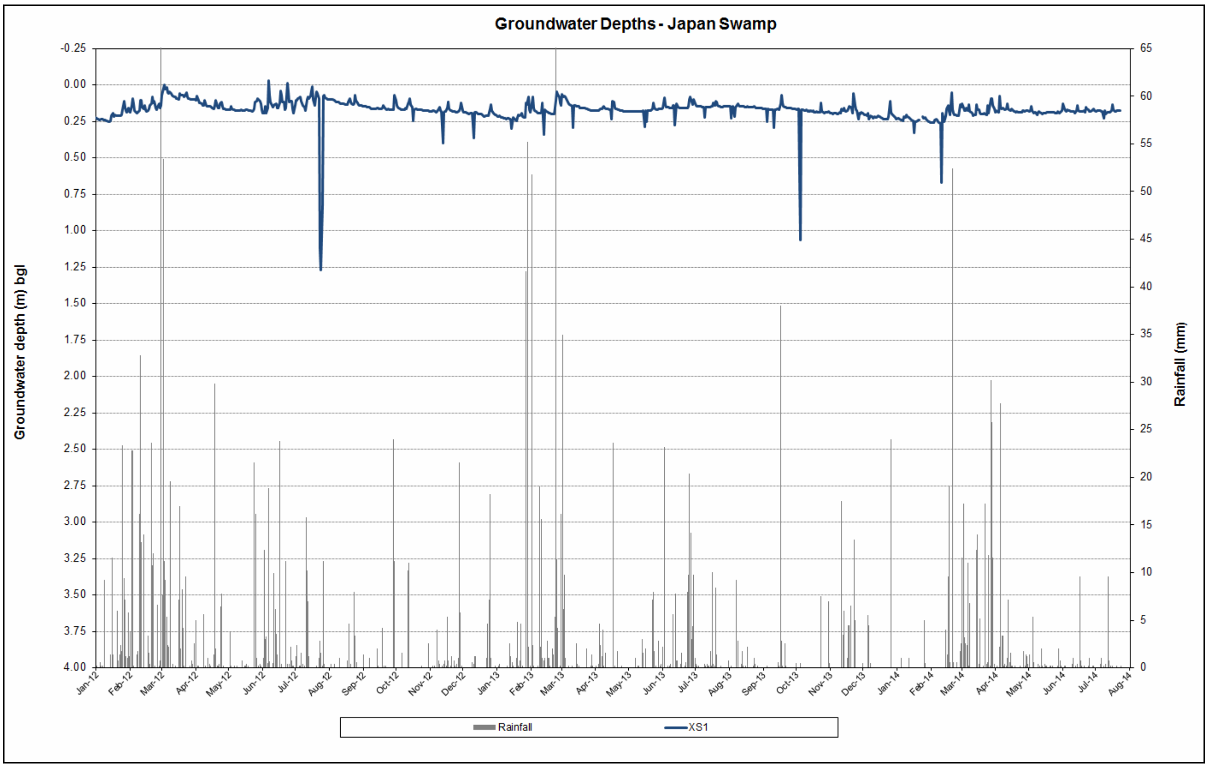


**Figure 29 Hydrograph of Japan Shrub Swamp**

Figure 29 shows piezometric data from January 2012 to late July 2014. Piezometer XS1 is situated roughly in the middle reaches of this swamp and overlies the pillar between longwalls LW1016 and 1017. Piezometer readings display consistently high groundwater levels over above period. The negative spikes represent regular groundwater sampling. The pronounced dips in August 2012 and November 2013 are due to data sampling problems (D. Hilyard pers.com). The negative spike on February 10, 2014 is due to purging and sampling of hole (J.Carr pers.com.). Overall, Japan Shrub Swamp at this locality displays typical groundwater-dependent shrub swamp characteristics. In order to capture the overall hydrological characteristics of the upper and lower reaches of this swamp, additional piezometers are suggested at XS2 and XS3 as shown in Figure 26.

## *II. Twin Gully Shrub Swamp*

This swamp trends roughly west-east, with the lower reaches of the host gully emptying into the Wolgan River to the west, and is distal from any known structure zones (Section 4, Figure 4). Twin Gully Shrub Swamp forks in its upper reaches (Figure 30) and has a maximum length in its longer tributary of just under 1200 metres. The average maximum width is 40 metres with a fall of 65 metres. The upper half of this shrub swamp lies above proposed longwall LW1010.

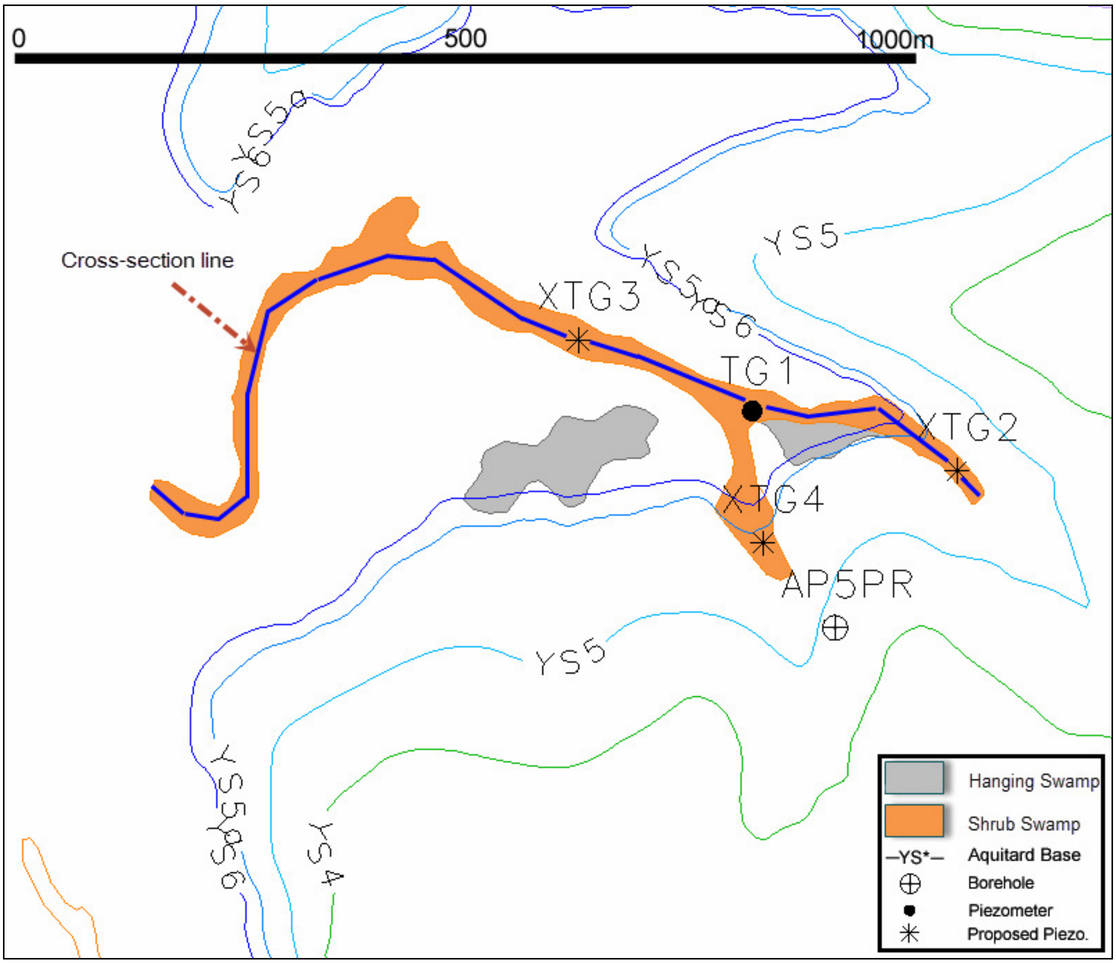


**Figure 30 Plan of Twin Gully Shrub Swamp**

As with the majority of the shrub swamps in the Angus Place area, Twin Gully is a "mixed-type" swamp, with its extreme upper reaches located stratigraphically within the Burralow Formation, topographically above the point where the host gully bifurcates. At this location, the swamp is supported by groundwater from the YS6 and YS5a aquitards. These plies provide direct in-gully seepage at this location thus widening the shrub swamp where the aquitard transects the gully floor (Figure 30).

Relatively high groundwater availability in the general vicinity is indicated by the presence of two hanging swamps (Figure 30) which are both hydrologically supported by the YS6 and YS5a aquitards. The importance of hanging swamps in the regional hydrological regime will be discussed in *The Hanging Swamps of the Newnes Plateau.*

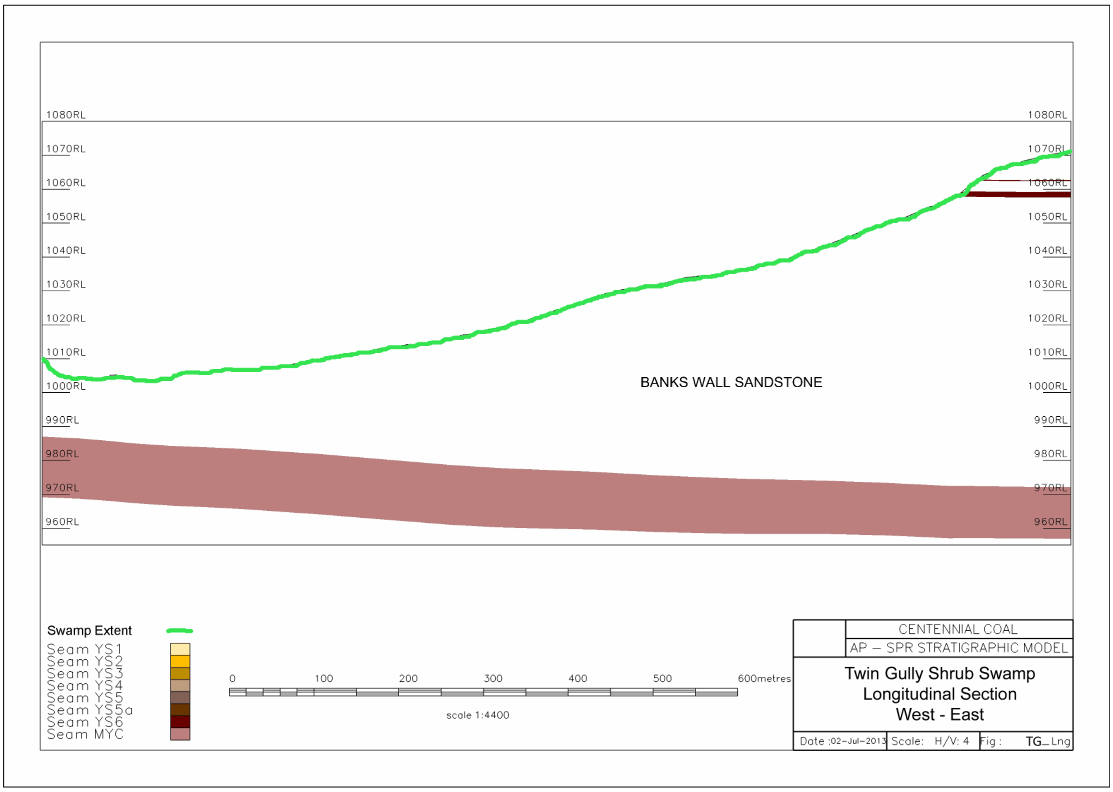


**Figure 31 Longitudinal Stratigraphic Section of Twin Gully Shrub Swamp**

The above longitudinal section of Twin Gully Swamp shows the eastern extremity as being underpinned by the Burralow Formation, with the majority of the swamp underlain by the Banks Wall Sandstone. The lithological characteristics of the Banks Wall Sandstone ensure that the morphology of the swamp is both relatively short and narrow as compared to Burralow-type shrub swamps within the Springvale lease.

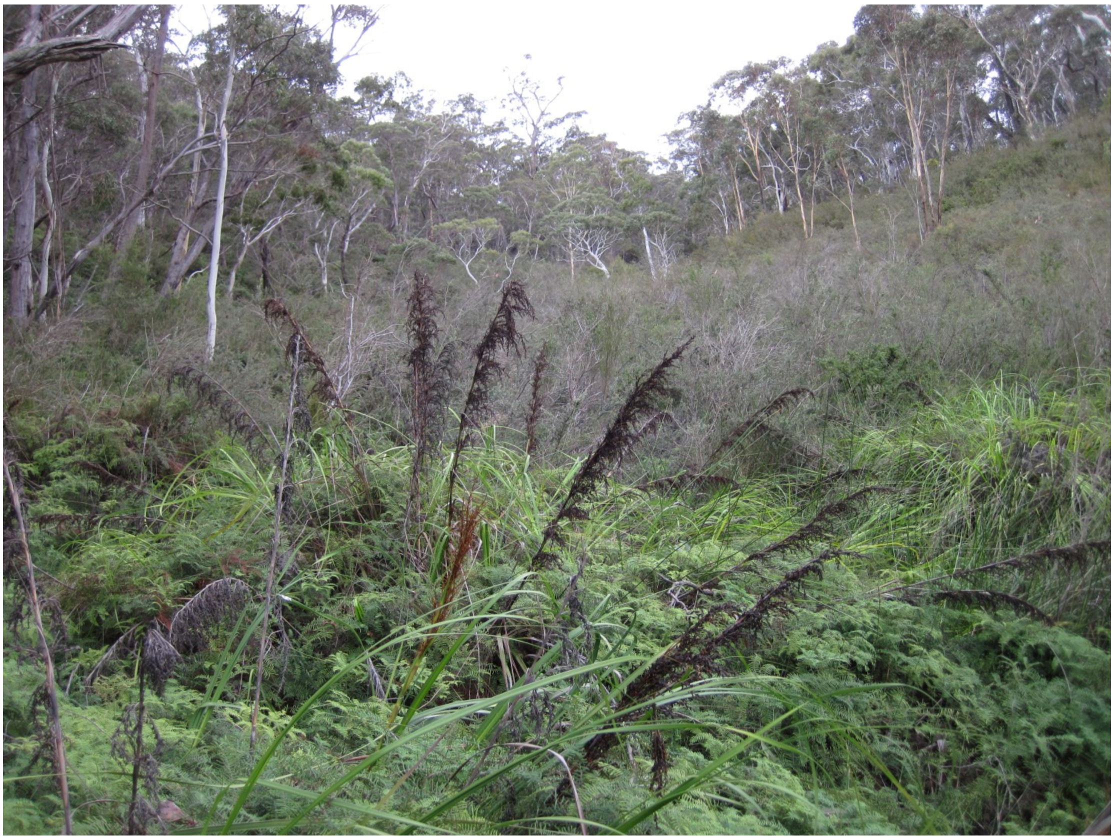


**Figure 32  View along eastern extent of Twin Gully Shrub Swamp**

Figure 32 was taken from 236 523E/ 6 308 783N GDA which is located almost half way along the eastern fork of Twin Gully swamp and close to the modelled boundary between the Banks Wall Sandstone and the Burralow Formation (Figure 30). This photo illustrates the relatively narrow morphology of the main drainage line of Twin Gully as compared to the more open expanses of the Burralow-type swamps in the Springvale area. While vegetation types are similar in both swamp types (Lembit, 2013), the Banks Wall Sandstone substrate at this location results in a more confined swamp width.

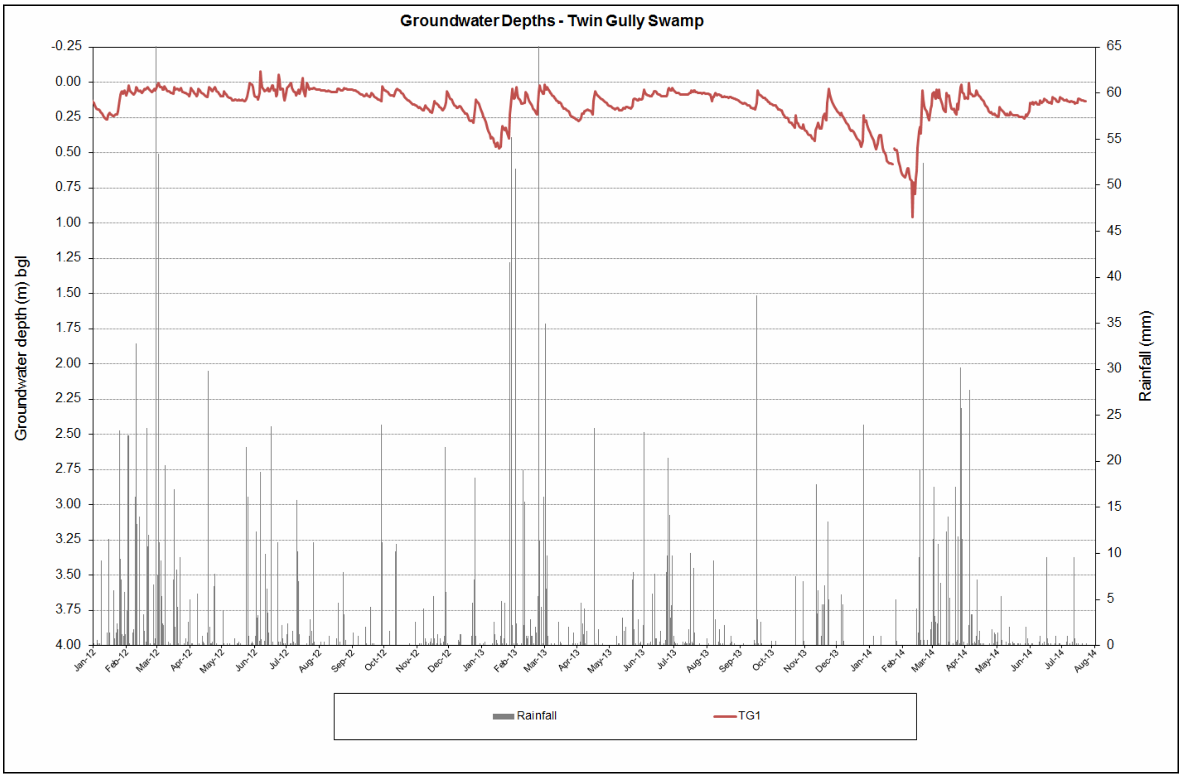


**Figure 33 Hydrograph of Twin Gully Shrub Swamp**

Twin Gully Swamp presently contains one piezometer monitoring station (TG1) which is located at the junction of the two upper tributaries (Figure 30). TG1 overlies proposed longwall LW1010 in a section that currently is not earmarked for extraction. Figure 33 shows that at location TG1 the groundwater level is generally high with minor fluctuations due to input from rainfall. Aurecon (2013) have identified this swamp as a permanently saturated groundwater-dependent entity with near-surface groundwater levels and minimal groundwater fluctuation.

However, it is suggested that three additional swamp piezometers be installed at locations XTG2, XTG3 and XTG4 (Figure 30). Proposed swamp piezometers XTG4 and XTG2 are located above proposed longwall LW1010 and will provide excellent indicators of groundwater levels within the upper reaches of Twin Gully both prior to and after longwall mining of LW1009. Combined data from the above three localities will assist in providing valuable data that may be used to determine feasibility of mining beneath Twin Gully Shrub Swamp.

Additional proposed swamp piezometer XTG3 has been chosen to provide accurate groundwater monitoring in the potentially drier Banks Wall Sandstone zone of this swamp, at a distance from the influence of the Burralow Formation and its associated aquitards, valley wall seepage and hanging swamps. Regular photo monitoring of the upper reaches of both upper tributaries of Twin Gully is also suggested as no pre-mining data of this nature currently exists.

It is also suggested that ground-truthing of the northern arm of the host gully of Twin Gully swamp be undertaken. DEC (2005) aerial photographic mapping does not delineate this area as a shrub swamp but regular ground photo monitoring of this area suggests that this northern arm includes vegetation that may be comparable with an MU52 classification. This tributary of Twin Gully trends ENE, overlies proposed longwall LW1101 and enters the southern main gully at the point where the known shrub swamp temporarily widens before taking a southerly course and ultimately emptying into the Wolgan River (Figure 30).

Ground-truthing is required to determine the extent of shrub swamp vegetation along this northern arm. Figure 30 indicates that the majority of this unmapped potential shrub swamp would be underpinned by the Banks Wall Sandstone, with the possibility of upper reaches being hydrologically assisted by the Burralow Formation. If vegetation mapping provides evidence for the presence of a shrub swamp at this location, additional swamp monitoring is advised. The location of any additional piezometers would be determined after vegetation mapping has been undertaken.

## *III. Tri-Star Shrub Swamp Complex*

Figure 34 shows the original DEC (2005) aerial mapping of the shrub and hanging swamps which comprise the Tri-Star complex.

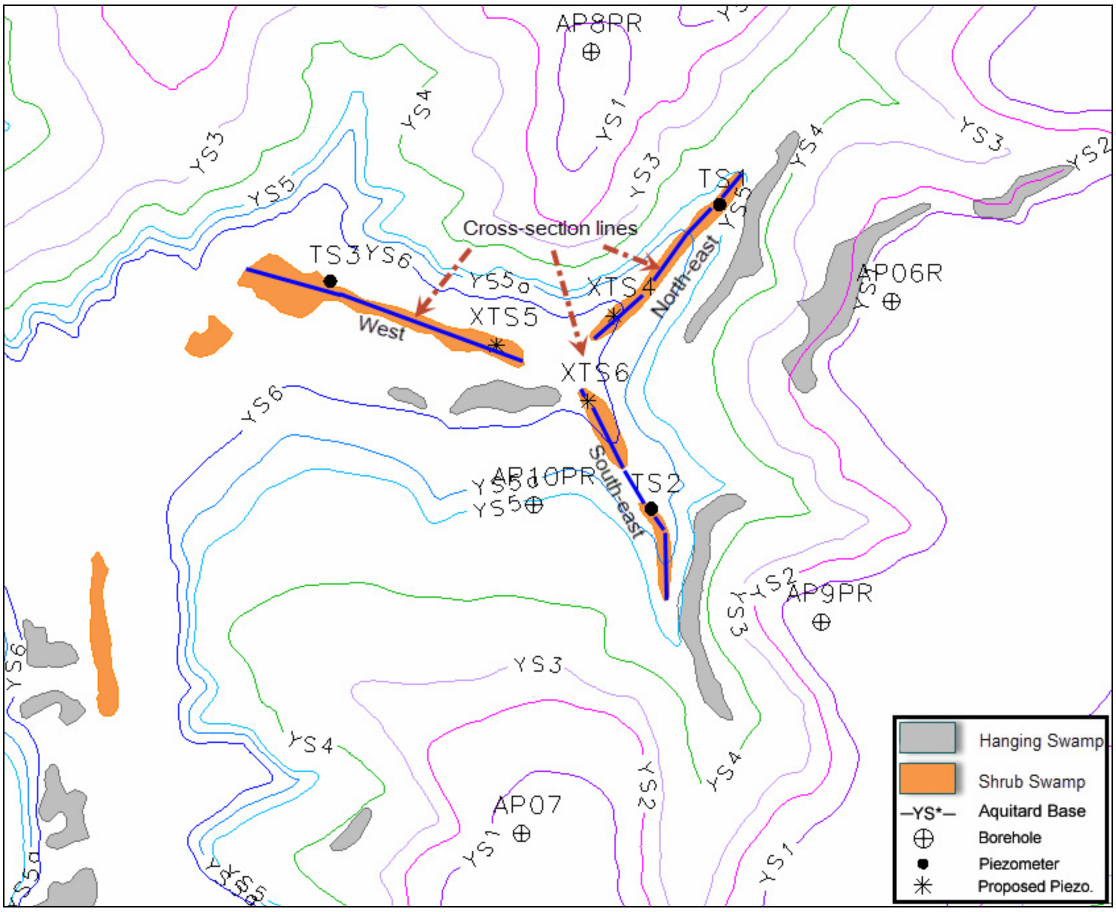


**Figure 34 Original DEC (2005) plan of Tri-Star Swamp Complex**

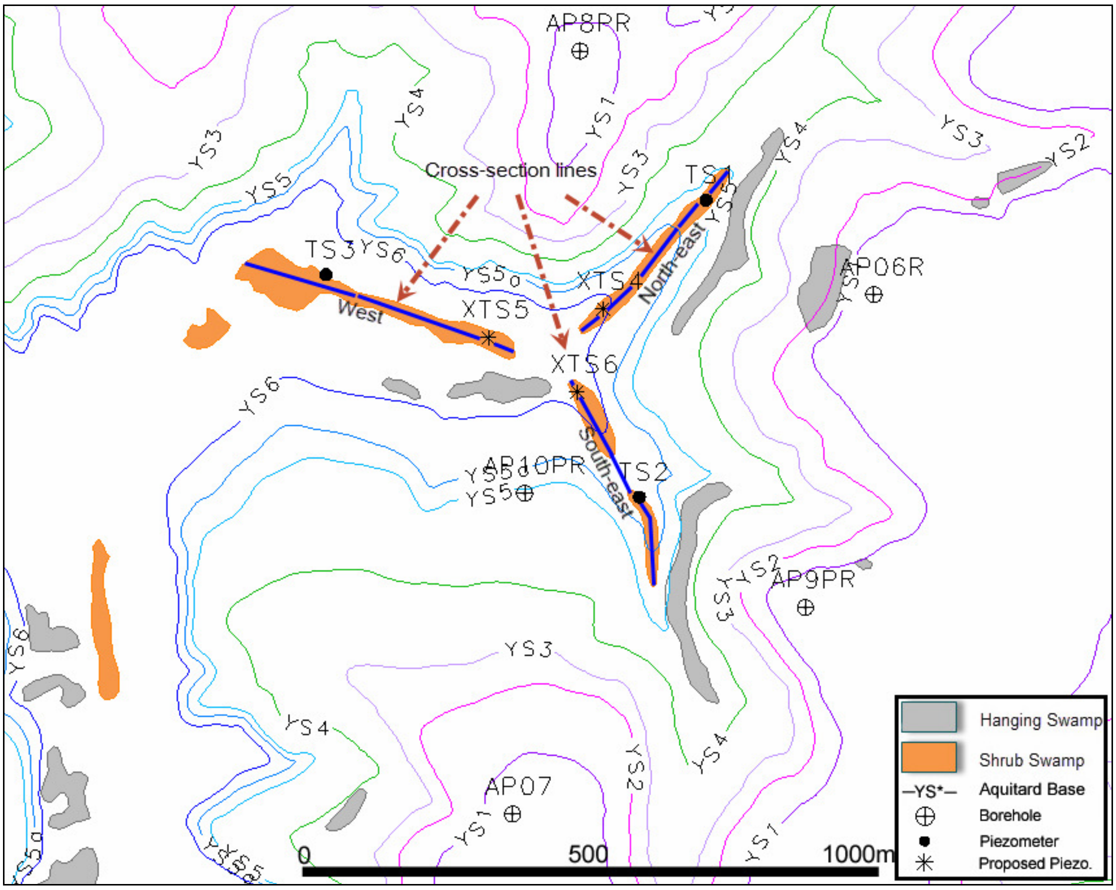


**Figure 35  Amended Plan of Tri-Star Shrub and Hanging Swamp Complex**

Tri-Star Shrub Swamp comprises a complex of three individual swamps which lie in a bifurcated host gully draining westward into the Wolgan River (Figure 35).

The three shrub swamps overlie longwalls LW1004, LW1005 and LW1006. Associated with these shrub swamps are numerous hanging swamps to the east and south-east. This swamp is not associated with any known structure zones (Section 4, Figure 4).

The principal western gully trends roughly east-west and is approximately 500 metres in length. It averages 35 metres in width with the exception of the extreme lower reaches where topographic influences result in a maximum width of 80 metres. It has a drop of approximately 20 metres. Stratigraphically, this section of the Tri-Star complex lies wholly within the Banks Wall Sandstone but receives drainage flow from the two upper tributaries.

The north-eastern tributary is 375 metres in length with a width of 30 metres. It has a drop of approximately 18 metres. This arm of the Tri-Star swamp complex is a "mixed-type" swamp, with its upper reaches located stratigraphically in the Burralow Formation and its lower reaches in the Banks Wall Sandstone.

The south-eastern tributary is divided into an upper and lower section (Figure 35). The lower section is 150 metres in length with a maximum width of 40 metres. The upper section is 185 metres in length with a maximum width of 30 metres. Like the north-eastern tributary, this arm of Tri-Star is a “mixed-type” with its upper reaches located stratigraphically in the Burralow Formation and the lower reaches in the Banks Wall Sandstone. The total drop of both segments of the south-east tributary of Tri-Star is 22 metres. In all, the Tri-Star shrub swamp complex has a total drop of approximately 50 metres from the upper reaches of the south-eastern arm to the lower reaches of the western shrub swamp in the principal drainage line.

Lembit (2014) mapped both the shrub and hanging swamps in the Tri-Star area. All three shrub swamps were found by Lembit to coincide with previous DEC (2005) aerial mapping (Figures 34 and 35). However, the hanging swamps associated with the Tri-Star shrub swamp group were found to differ from the original DEC mapping, including the addition of a new, small hanging swamp to the north-east of AP9PR (Figure 35). The latter is hydrologically supported by the YS1 aquitard.

The hanging swamp due west of AP06R is significantly smaller than originally mapped and the easternmost hanging swamp has been redefined by Lembit as being comprised of two, smaller hanging swamps. In addition, the hanging swamp to the north of AP10PR has been slightly modified.

The hanging swamps in this vicinity are hydrologically supported by the YS6 (with additional input from YS5a and YS5), YS4, YS2 and YS1. Hanging swamps dependent upon plies YS2 and YS1 (Figure 35) are susceptible to dry-out due to a relatively restricted catchment and the absence of the full sequence of aquitards to assist in maintaining elevated groundwater levels. Regular vegetation mapping is suggested for the Tri-Star area in general.

**Figure 36  View across north-eastern arm of Tri-Star Shrub Swamp**

Figure 36 shows a view looking north-west across the north-eastern tributary of Tri-Star swamp taken from 237 284E / 6 307 061N GDA. As with Twin Gully described above, swamp width is restricted due to the dominant Banks Wall Sandstone substrate as compared to Burralow-type shrub swamps. The steep north-western flank of the gully can be clearly seen. This photo location is adjacent to the modelled boundary between the Banks Wall Sandstone and the Burralow Formation.

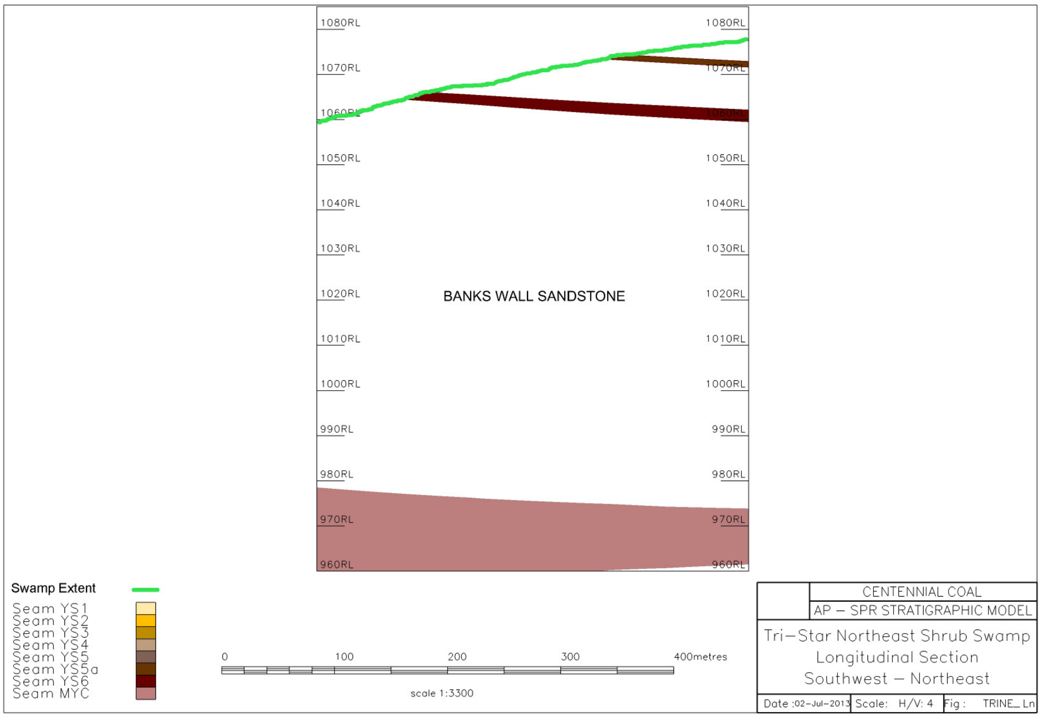


**Figure 37 Longitudinal Stratigraphic Section of Tri-Star Shrub Swamp (North-East segment)**

Figure 37 shows a south-west to north-east longitudinal cross-section of the north-east tributary of Tri-Star swamp. The upper two-thirds are located within the Burralow Formation and are located stratigraphically between plies YS6 and YS5. The lower reaches are located within the Banks Wall Sandstone, where the gradient steepens due to the change in geological regime. The majority of the swamp relies on valley wall seepage from the YS6 and YS5a aquitard together with direct in-gully input from these latter plies.

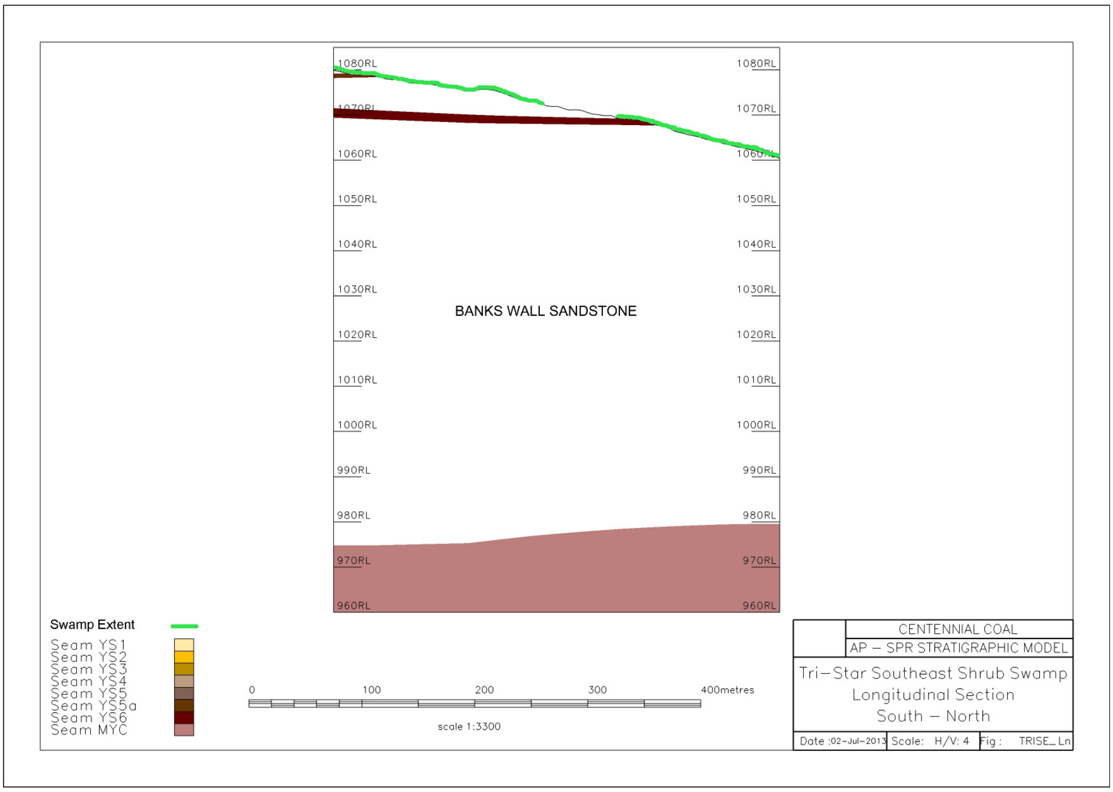


**Figure 38 Longitudinal Stratigraphic Section of Tri-Star Shrub Swamp (South-East segment)**

Figure 38 shows a south-east to north-west longitudinal cross-section of the south-east tributary of Tri-Star swamp. The upper two-thirds are located within the Burralow Formation and are located stratigraphically between plies YS6 and YS5a. The extreme upper reaches are situated between plies YS5a and YS5. The lower reaches are located within the Banks Wall Sandstone where, as with the northern tributary discussed above, the gradient steepens due to the change in geological regime. The majority of the swamp relies hydrologically on valley wall seepage from the YS6, YS5a and YS5 aquitards together with direct in-gully input from the lower two plies.

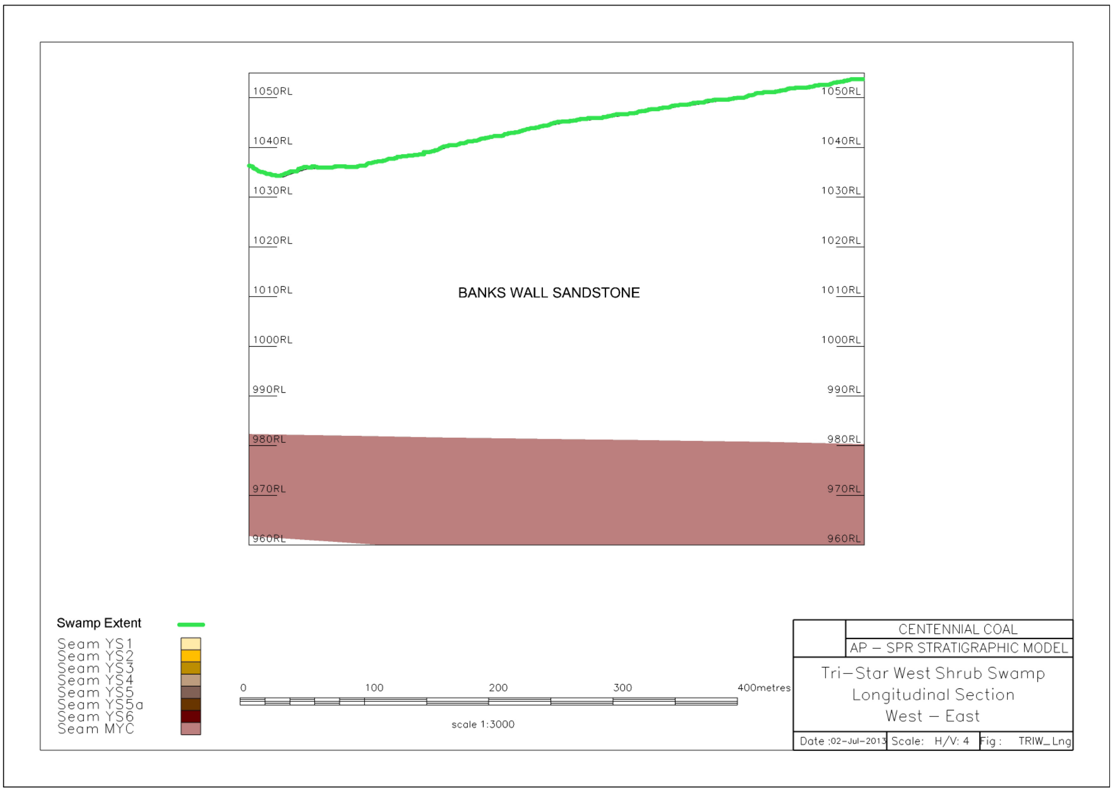


**Figure 39 Longitudinal Stratigraphic Section of Tri-Star Shrub Swamp (West-East segment)**

The main drainage line of Tri-Star shrub swamp (Figure 39) is stratigraphically located within the Banks Wall Formation. Shrub swamp formation relies on suitable topographic conditions, downstream flow from the upper tributaries and valley wall seepage from the YS6/YS5a/YS5 sequence of aquitards, particularly from the steeper northern flank of the gully at this location.

**Figure 40  Pre-mining slumping at Tri-Star Shrub Swamp in the lower reaches of the south-eastern tributary**

Pre-mining slumping has been observed in the area by Lembit (pers. com.). The above photo was taken at 237347E / 6306973N GDA, which is situated at the extreme lower reaches of the south-eastern tributary of Tri-Star Shrub Swamp. Lembit (2010) also noted the presence of “dieback and death of swamp plants” and that this location was “close to a drop point along the drainage line”. Slumping and die-back, as shown in Figure 40 above, can be natural phenomena which occur as a result of rainfall variation and associated erosional factors.

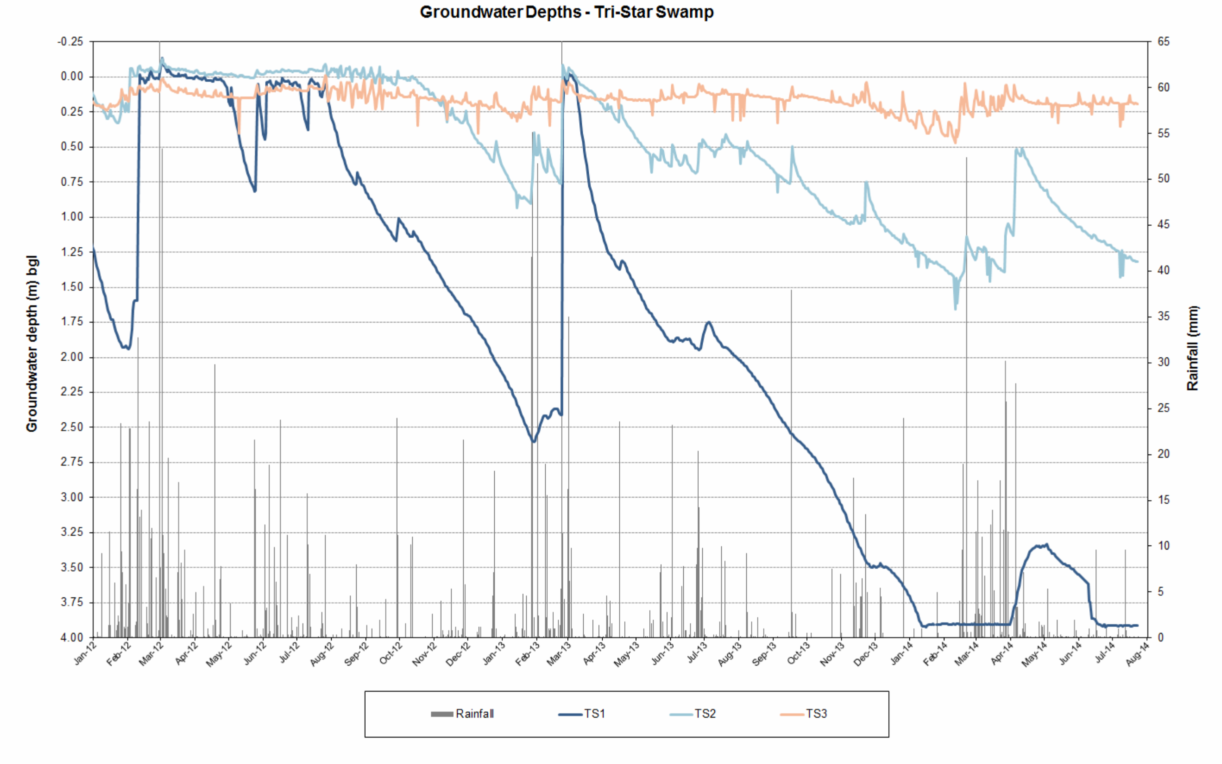


**Figure 41 Hydrograph of Tri-Star Shrub Swamp**

Figure 41 shows piezometric data from January 2012 to early August 2014 for all three swamps which form part of the Tri-Star complex. Piezometer TS3 (pink), which is located in the lower western reaches of the swamp and is situated within the Banks Wall Sandstone, displays a permanently waterlogged profile with minimal rainfall influence. Negative spikes in the profile represent regular groundwater sampling times.

Piezometer TS2 (light blue) is located in the south-eastern tributary of Tri-Star gully at the northern (lower) end of the upper extension of this swamp (Figure 35). Stratigraphically, it is situated within the Burralow Formation between plies YS5a and YS6. The hydrological pattern displayed at TS2 is essentially groundwater dependent, where groundwater stands at an average of 0.5 metres below ground surface, with a minimum reading of 1.5 metres below ground surface during February 2014. However, there exists slight to moderate increases in groundwater levels in response to rainfall.

Piezometer TS1 (dark blue) is located in the upper reaches of the north-eastern tributary of Tri-Star gully and is stratigraphically located within the Burralow Formation between plies YS5a and YS5 (Figure 35). This piezometer suggests a typical "periodically waterlogged" profile at this location with low rainfall periods corresponding to lower groundwater levels, particularly in the period April 2013 to early August 2014. Moderate rainfall in late February to late April 2014 resulted in slight increases in recorded levels which have subsequently levelled off to the lowest recording of groundwater levels from this site.

The differences in groundwater levels at TS1, TS2 and TS3 are lithologically and topographically controlled. As noted, TS3 in the lower reaches receives groundwater input from two upstream tributaries as well as valley wall seepage from proximal Burralow Formation aquitards. This monitoring station is also located approximately 25 metres above the standing watertable as determined by the proximity of the Wolgan River 400 metres to the west and as such would be expected to experience relatively high standing water levels.

Both TS1 and TS2 register lower groundwater levels than TS3 even though they are situated within the Burralow Formation. This is due to their higher elevation and the effect of the Banks Wall Sandstone substrate which comprises the lower reaches of both tributaries. Like similar "mixed-type" shrub swamps discussed in the Springvale area, these two tributaries consequently have restricted morphologies and varying degrees of groundwater influence.

The positioning of TS1 at the extreme upper reaches of the north-eastern swamp ensures that the groundwater levels are relatively low, hence conditions necessary for peat growth and thus swamp formation cease at this point. By contrast, TS2 is located relatively further downstream of the hydrologically-similar south-eastern arm and thus records higher groundwater levels as shown in Figure 41.

The Tri-Star shrub and hanging swamp complex as a whole is one of the most hydrologically interesting areas within the Angus Place/Springvale leases. This is particularly the case for the hanging swamps in this vicinity which are topographically exposed to high levels of evaporation and have a relatively restricted recharge area. These hanging swamps also have minimal groundwater support, with the higher elevation hanging swamps only supported hydrologically by the YS1 and YS2 aquitards.

Despite these factors, the presence of several hanging swamps in this locale is suggestive of relatively high groundwater levels within the strata. However, due to susceptibility to dry-out, it is recommended that additional piezometers be located within Tri-Star shrub swamp at locations XTS4, XTS5 and XTS6. These proposed piezometers would monitor groundwater levels prior and subsequent to mining and supply useful data to verify any changes which may occur in the associated hanging swamps as detailed above. The locations of these proposed monitoring locations are shown in Figure 35.

## *IV. Crocodile Shrub Swamp*

Crocodile Shrub Swamp trends southwest – northeast and the host gully is an upper tributary of Carne Creek (Figure 42). It is approximately 500 metres long and 50 metres wide (not including the fringing hanging swamps on the north-western flank of the gully). The fall is approximately 44 metres. The upper reaches of the swamp are situated marginal to the angle of draw for proposed longwall LW1003 but is distal from any known structure zones (Section 4, Figure 4).

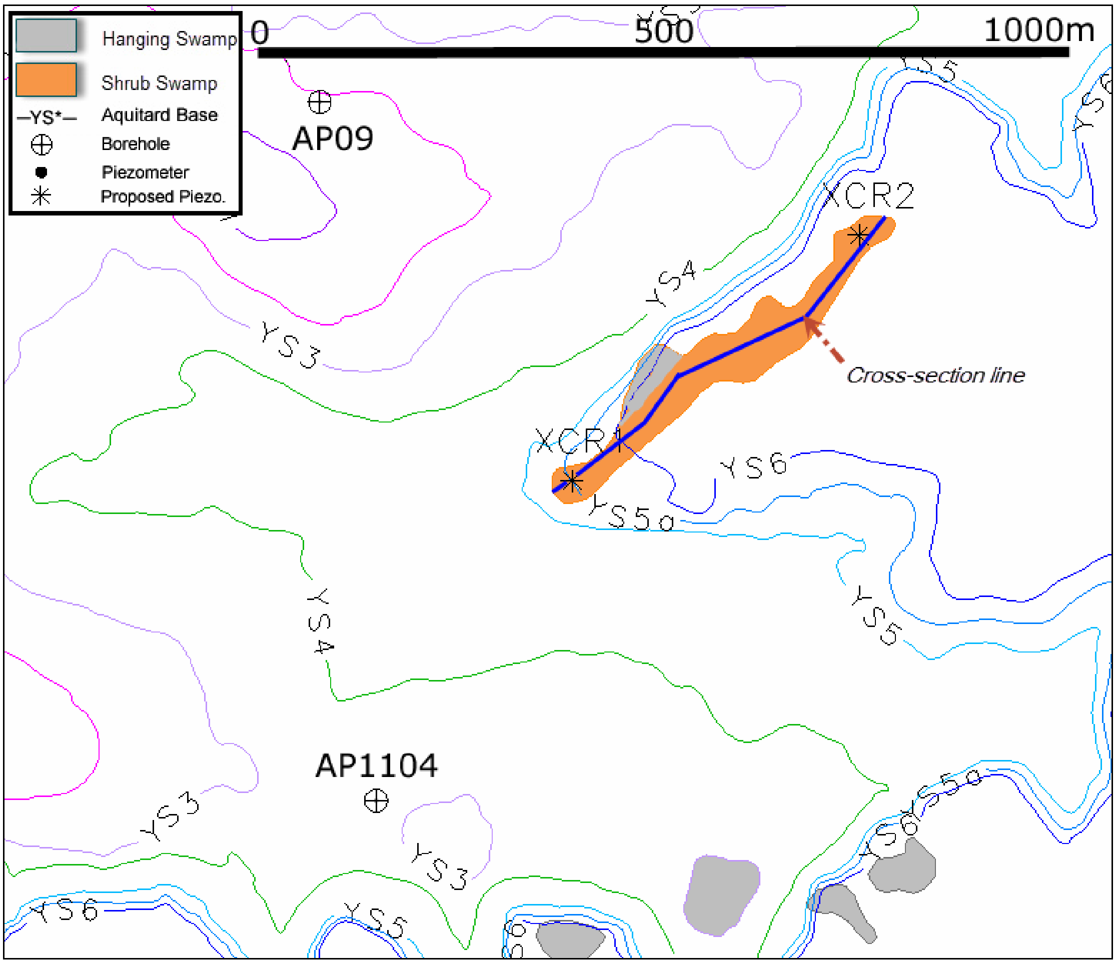


**Figure 42 Plan of Crocodile Shrub Swamp**

Crocodile Shrub Swamp is a "mixed-type" swamp with its upper reaches supported hydrologically by the YS6, YS5a and YS5 aquitards. For the bulk of its length, the swamp relies on valley wall seepage from the above plies plus the YS4 aquitard, all of which crop out along the steep northern flank of this shrub swamp.

Lembit (2010) confirmed the presence of suspected hanging swamps along the northern flank of this shrub swamp and thus this swamp deviates from its previous DEC (2005) classification and Figure 42 represents the updated configuration. The associated hanging swamps are dominated by Coral Fern (*Gleichenia dicarpa*). The presence of hanging swamps illustrates the relatively high groundwater levels at this location due to the virtual coalescence of aquitard plies YS4, YS5, YS5a and YS6 along the northern flank. However, the dominant Banks Wall Sandstone substrate ensures that this swamp is relatively short in length compared to Burralow-type swamps with their associated multiple in-gully aquitard groundwater input.

**Figure 43 Crocodile Shrub Swamp flanked by hanging swamp vegetation**

Figure 43 shows a view of Crocodile Shrub Swamp from the upper reaches looking northwards towards the hanging swamp on the relatively steep northern flank. The photo was taken from 239734E 6306563N GDA. This is the widest portion of the swamp due to the added width of the hanging swamp at this location.

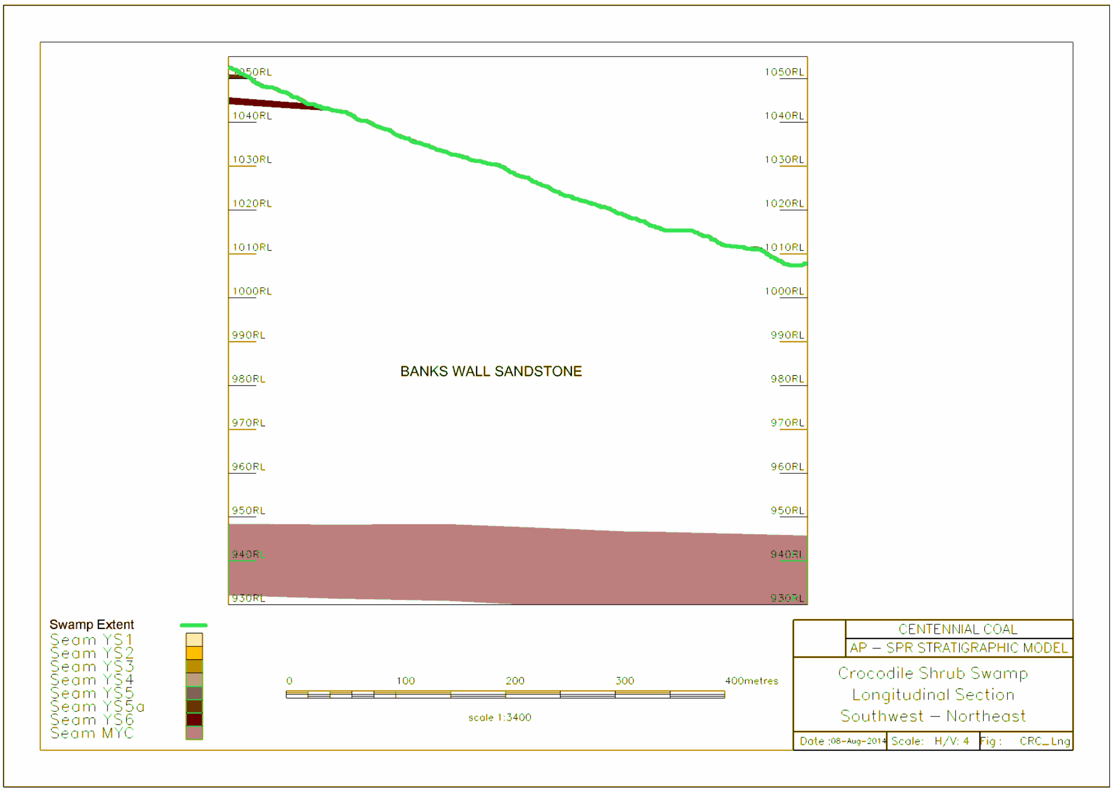


Figure 44 Longitudinal Stratigraphic Section of Crocodile Shrub Swamp

Figure 44 shows a longitudinal stratigraphic section of Crocodile Shrub Swamp. The extreme upper reaches are underpinned by the YS5a aquitard with both the YS5a and YS6 plies supplying direct in-gully groundwater to the upper reaches. The bulk of the swamp consists of a Banks Wall Sandstone substrate, which influences the relatively steep gradient and the limited length of the swamp as compared to those swamps underpinned solely buy the Burralow Formation.

There is no piezometer data for Crocodile Swamp to date and this situation should be addressed prior to mining. Two swamp piezometer monitoring sites have been suggested for this swamp and are labelled XCR1 and XCR2 in Figure 42 above. The former site has been selected to provide upstream groundwater data that will monitor groundwater response to mining. The downstream site was chosen to have pre-mining data reflecting the groundwater regime at this location and to act as a control groundwater monitoring site.

## V. *Rattlesnake Gorge Hanging Swamp Complex*

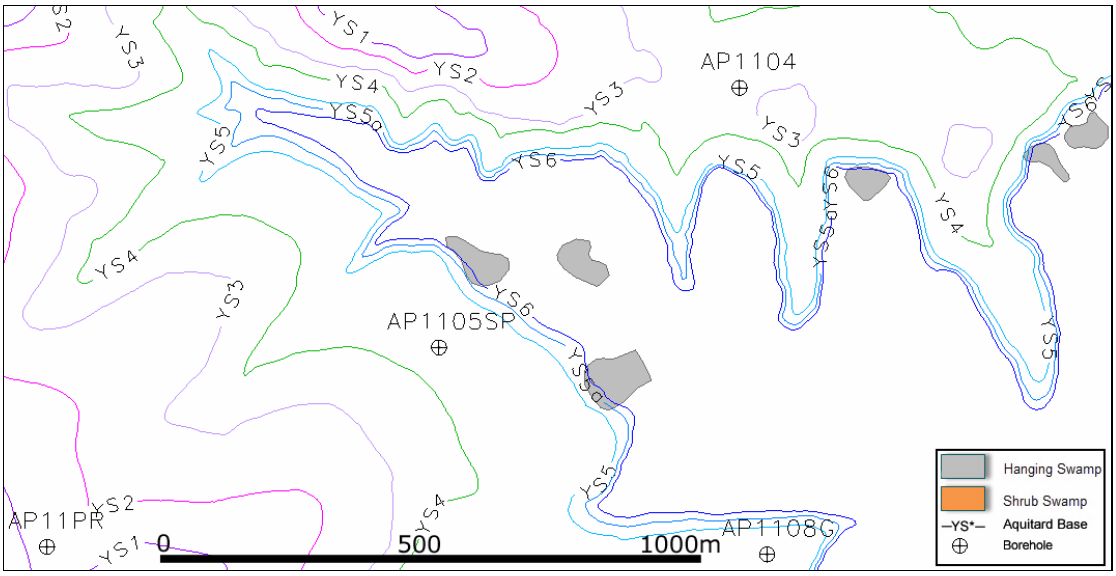


**Figure 45 Hanging Swamp Complex at Rattlesnake Gorge**

The Rattlesnake Gorge Hanging Swamp complex has been included in the current report due to the proximity of the three westerly swamps near AP1105SP (Figure 45) to longwall mining. The hanging swamp to the north-east of AP1105SP will be undermined by proposed longwall LW1002. The western half of the hanging swamp due east also falls within the angle of draw for LW1002. The hanging swamp to the east-south-east of AP1105SP is outside of the predicted angle of draw (P.Corbett pers. comm.). It is recommended that the two former swamps be monitored for changes in vegetation status before and after longwall extraction.

All five of the upper hanging swamps at this location are hydrologically supported by the YS5, YS5a and YS6 aquitards (Figure 45). The kidney-shaped "hanging swamp" north-east of AP1105SP has been observed only from the northern escarpment and has not been formally ground-truthed due to access difficulties (Lembit, 2014).

It can be noted from Figure 42 that the Rattlesnake Gorge suite of swamps is hydrologically contiguous with the hanging swamp system adjoining Crocodile shrub swamp.

## *VI. Smithston Hanging Swamp Complex*

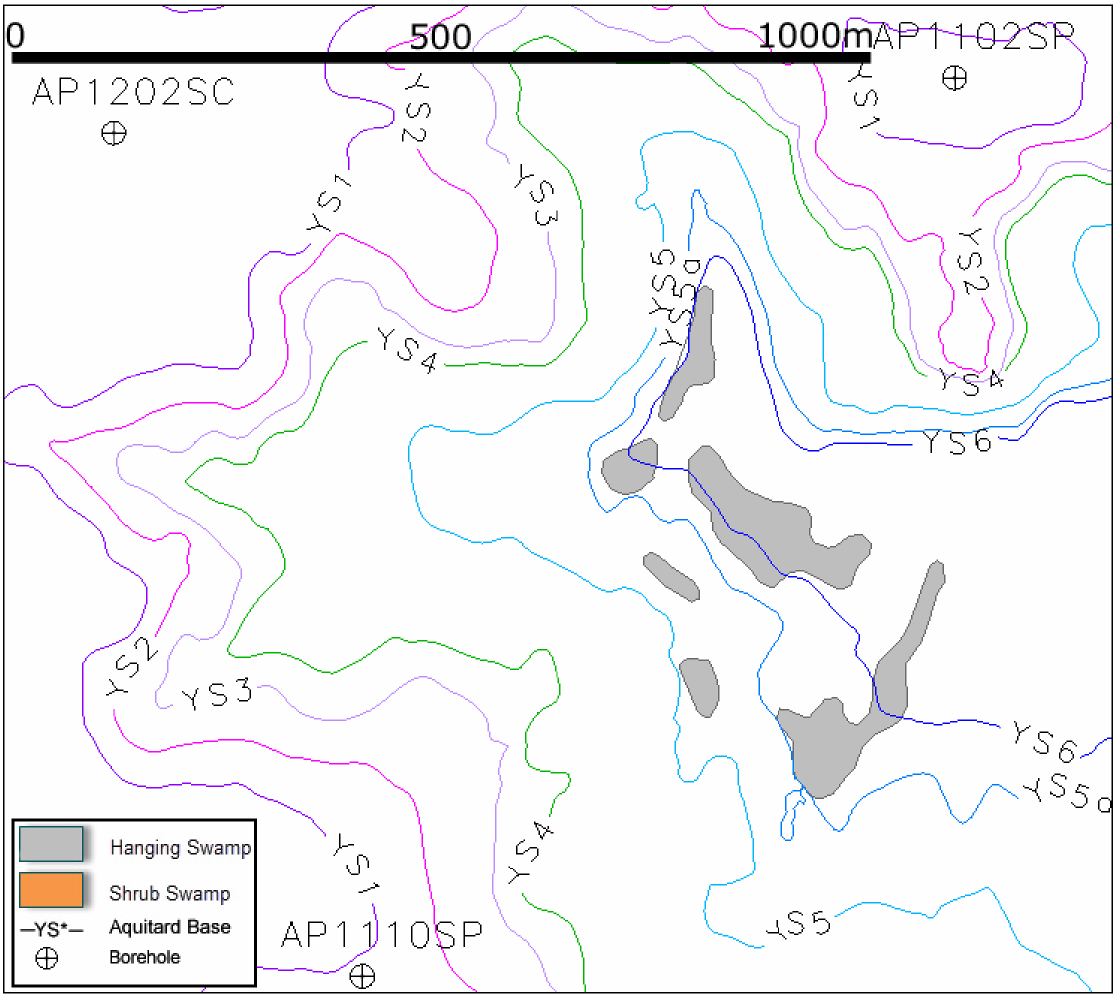


**Figure 46 Smithston Hanging Swamp Complex**

The Smithston Hanging Swamp Complex covers an area of appropriately 18 hectares and is included in the present study of Angus Place East due to its proximity to longwall LW1008. The most northerly hanging swamp overlies the tailgate of LW1009, while the three small western swamps lie within the angle of draw of LW1008 (P.Corbett pers.com). This suite of swamps is hydrologically supported by the YS5, YS5a and YS6 aquitards. The larger swamps drape between 100 and 300 metres down the slopes of this western tributary of Carne Creek.

Figure 47 Hanging Swamp in Smithston Hanging Swamp Complex

Figure 47 shows the view from the northern side of the large central hanging swamp in this complex looking in a westerly direction up the gully wall. This particular swamp has a total drop of 100 metres at its widest point and is supported hydrologically by the YS5a and YS6 aquitards.

SRK (2012) identified a Type 2 structure zone trending east-north-east to the immediate west of this hanging swamp complex (Figure 4). This, together with the more dominant Type 1 NNW-oriented basement to surface structural trend, may account for the composite topographic patterning at this locality and its immediate vicinity.

The hanging swamps of the Newnes Plateau, including their hydrological significance, will be discussed in detail in a subsequent report

# 13. Selected Newnes Plateau Shrub Swamp Descriptions within Springvale South Extension

Springvale South extension consists of longwall panels 424 to 432 and is overlain by those shrub swamps with headwaters surrounding the more elevated areas of Springvale Ridge.

As shown in Figure 48 below, the shrub swamps associated with the Springvale South Extension and its immediate surroundings include Nine Mile Swamp, Pine and Upper Pine Swamp, Paddy's Creek Swamp, Paddy's Creek East Swamp and Marrangaroo Swamp.

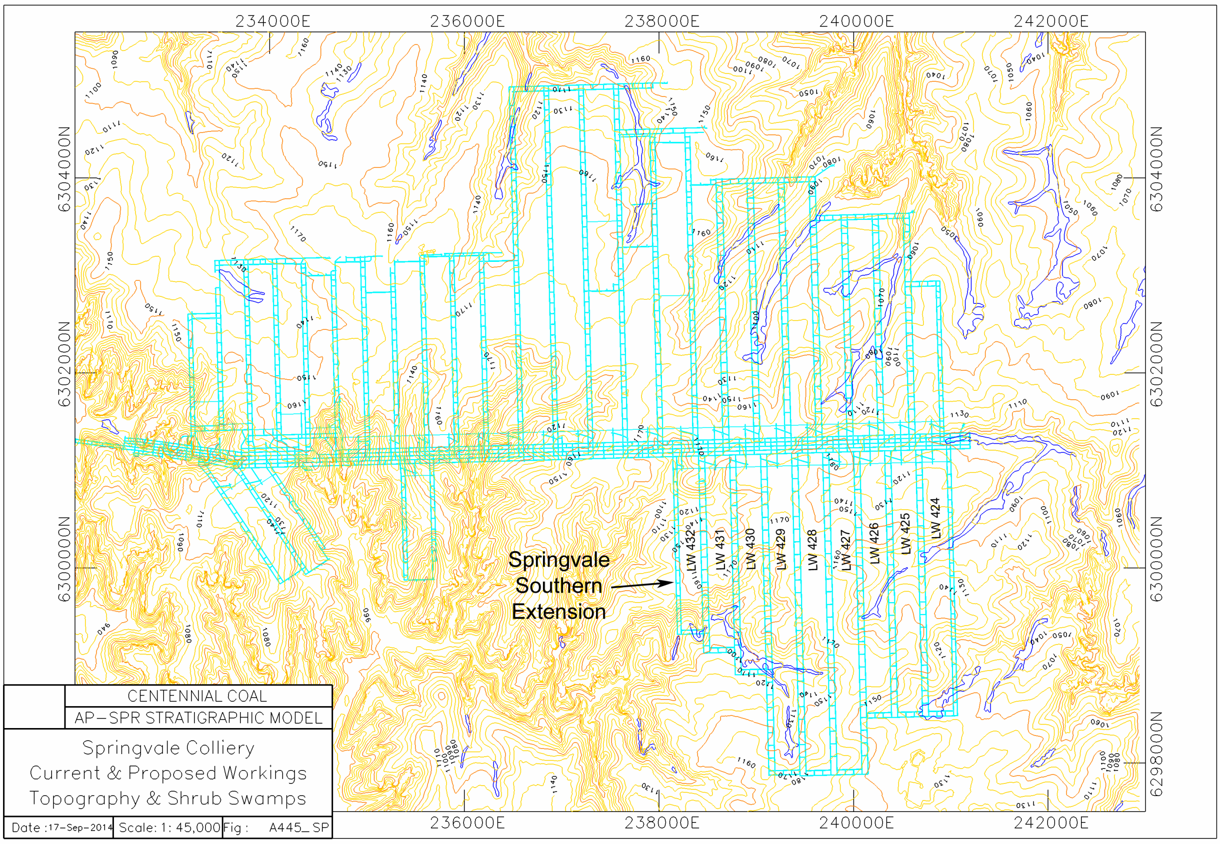


**Figure 48 Springvale and Springvale South Extension Areas showing shrub swamp locations, mine layout and topography**

Figure 49 below shows the location of the shrub swamps within the Springvale South extension area together with a key for swamp abbreviations used throughout the Angus Place and Springvale leases. The Springvale South extension swamps are discussed separately below.

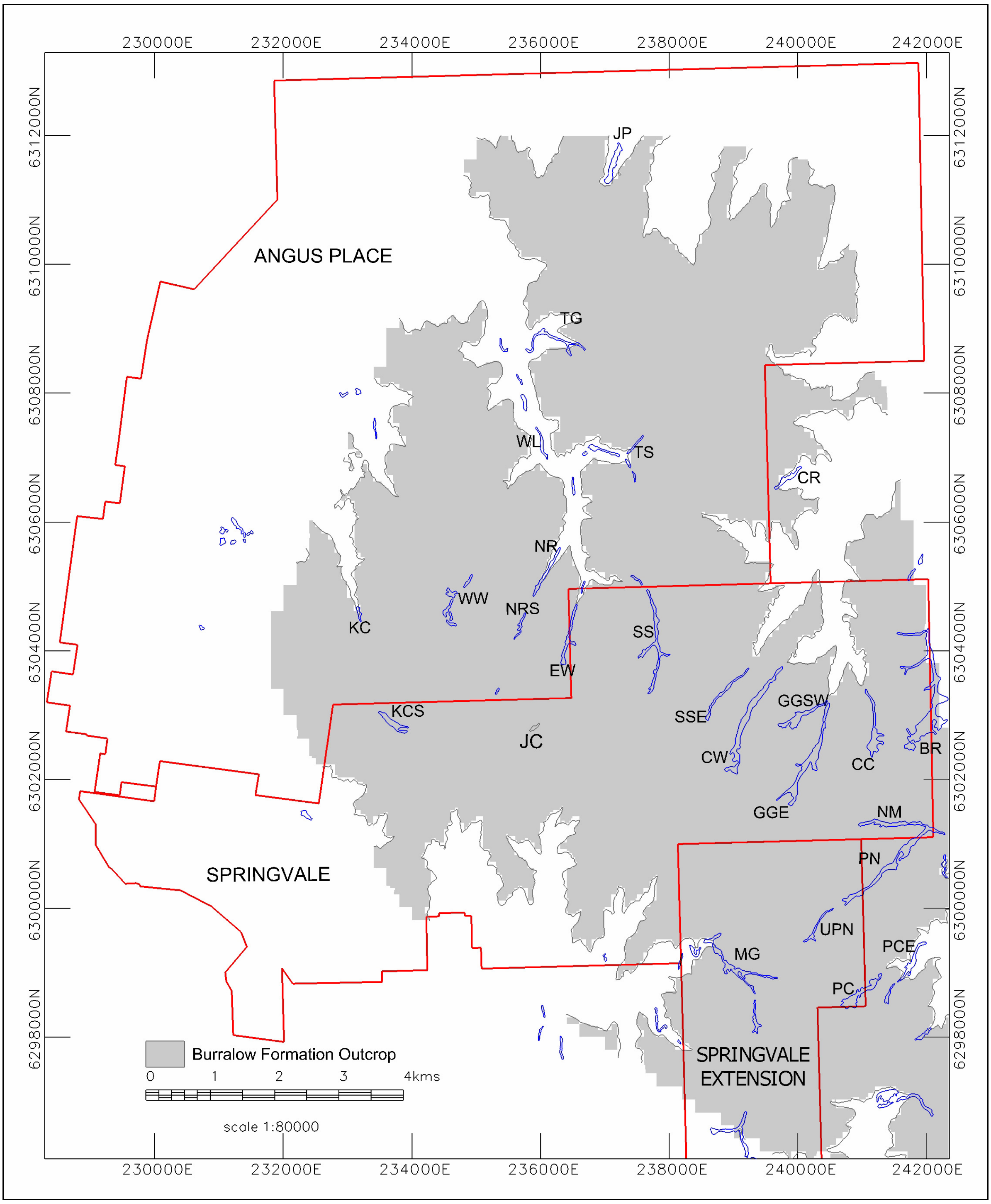


**Figure 49 Shrub Swamp Localities in Angus Place, Springvale and Springvale South Extension**

**Key to swamp abbreviations:**

**JP: Japan (Trail 6), TG: Twin Gully, WL: Wolgan, TS: Tri-star, CR: Crocodile, NR: Narrow, NRS: Narrow South, WW: West Wolgan, EW: East Wolgan, KC: Kangaroo Creek, KCS: Kangaroo Creek South, JC: Junction, SS: Sunnyside, SSE: Sunnyside East, CW: Carne West, GGSW: Gang Gang Southwest, GGE: Gang Gang East, CC: Carne Central, BA: Barrier, NM: Nine Mile, PN: Pine, UPN: Pine Upper, PCE: Paddy's Creek East Swamp, PC: Paddy's Creek Swamp, MG: Marrangaroo**

## *I. Nine Mile Shrub Swamp*

Nine Mile Shrub Swamp trends west-east, with a length of slightly over 1300 metres and a maximum width of 80 metres (Figure 50). It has a fall of 35 metres and is contained wholly within the Burralow Formation. Pine Creek is a tributary of Nine Mile Creek as shown below. Nine Mile Shrub Swamp lies outside the proposed Springvale South extension area, however the upper reaches of this swamp will be affected by proposed development headings although not subject to longwall extraction.

Nile Mile Swamp, in conjunction with Pine Shrub Swamp and Upper Pine Shrub Swamp discussed in subsequent sections, are also collectively known as Bungleboori Swamp.

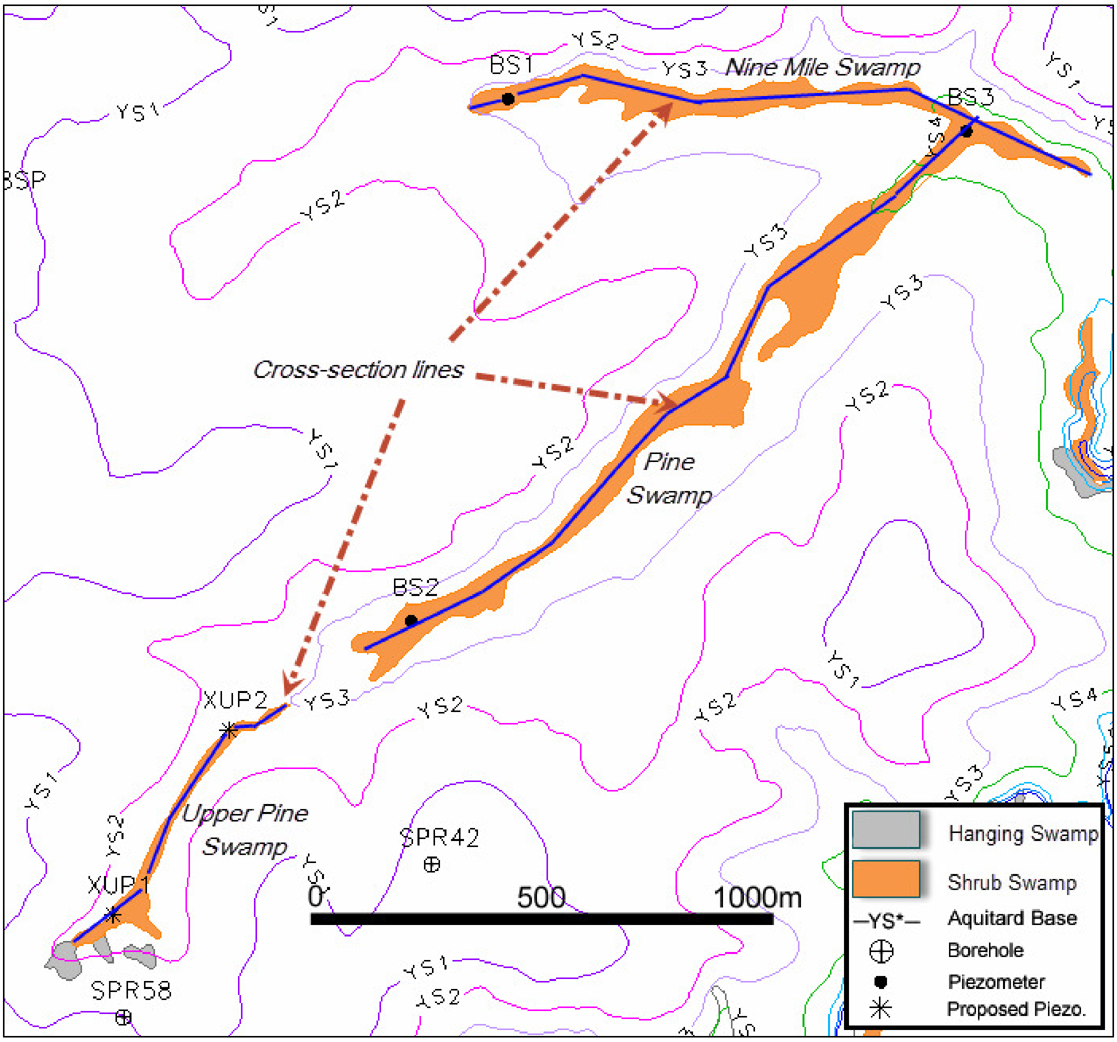


**Figure 50 Plan of Nine Mile, Pine and Upper Pine Shrub Swamps**

Figure 51 shows a west-to-east longitudinal cross section of Nine Mile Shrub Swamp. The upper two-thirds of the swamp is situated between plies YS3 and YS4, while the lower reaches of the swamp lie between the YS4 and YS5 horizons.

The majority of the swamp relies on valley wall seepage from plies YS2 and YS3, with minor input from YS1 and YS4 in the lower reaches along the northerly aspect of this swamp. Although YS4 and YS3 both intersect the gully floor, they are not particularly thick horizons at this location, and YS3 only influences the extreme upper reaches.

The west-east trend of this swamp mimics the topography present. Geological modelling indicates that the upper aquitards present in the vicinity of Nine Mile Swamp are relatively thin, as illustrated in Figure 51 below. These two factors impact on the morphology of Nine Mile Swamp in terms of average width, and contrasts with that of other Burralow-type shrub swamps such as Carne West.

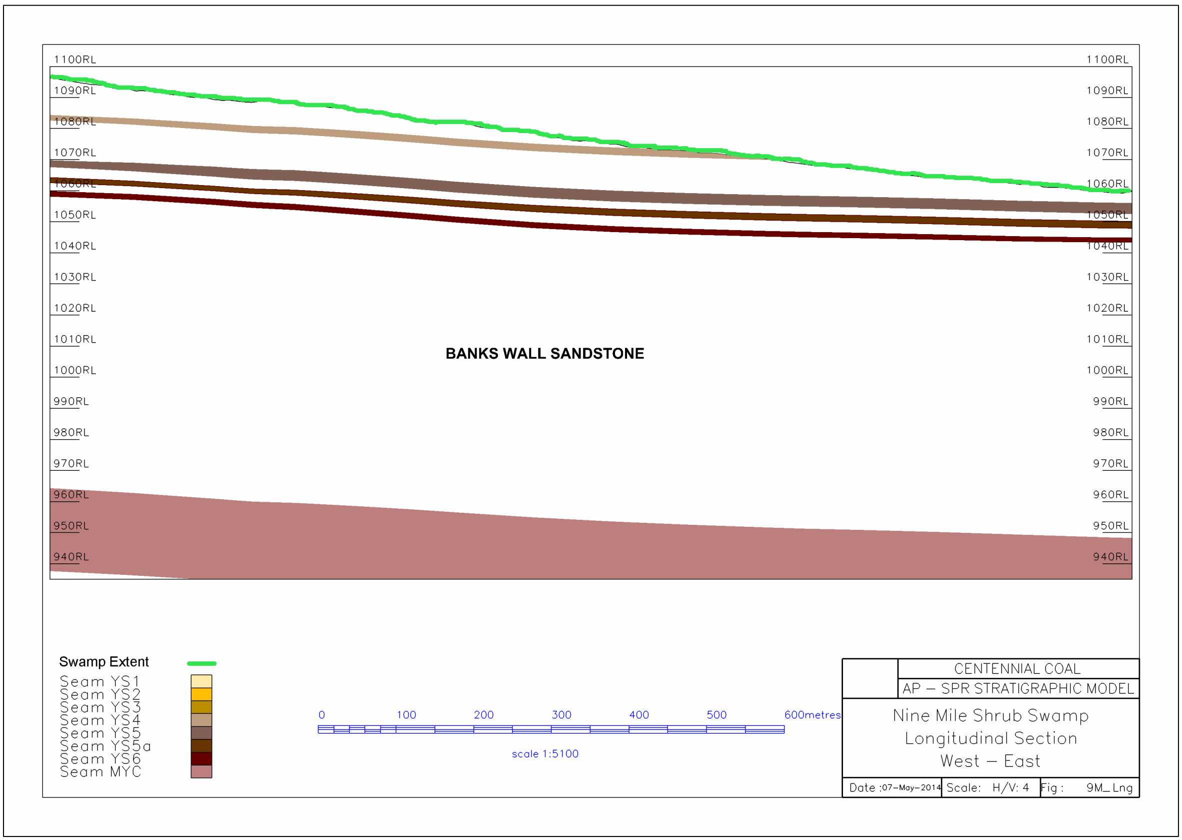


Figure 51 Longitudinal Stratigraphic Section of Nine Mile Shrub Swamp

The above longitudinal section of Nine Mile swamp illustrates that the upper half of the swamp lies stratigraphically between the YS4 and YS3 plies while the remainder of the swamp in the lower reaches is hydrologically supported by the YS5 aquitard.

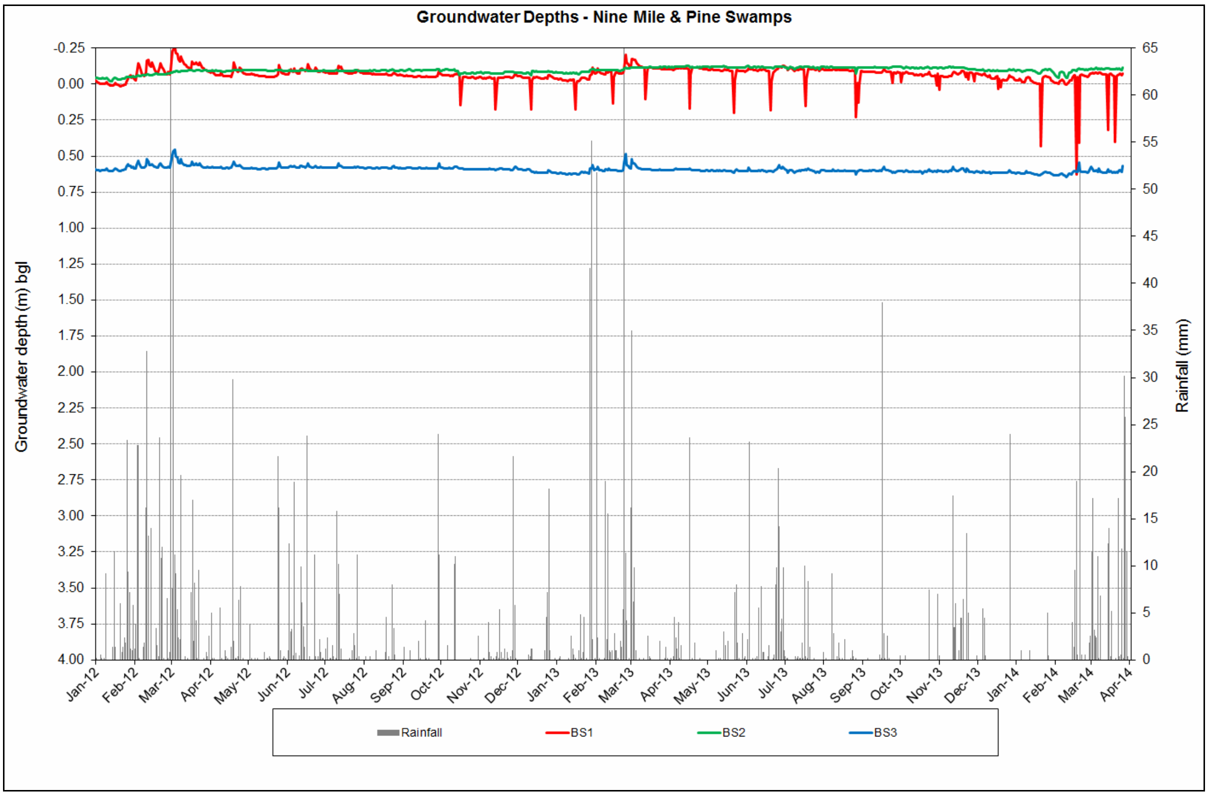


**Figure 52 Hydrograph of the Nine Mile, Pine and Upper Pine Swamp Complex**

Figure 52 shows piezometric data from January 2012 to April 2014 for the Bungleboori group of swamps which are discussed separately for clarity. Piezometer BS1 (red) is situated in the upper reaches of Nine Mile swamp and overlies the development headings for Springvale and Springvale South (Figure 48). It displays a consistent surface groundwater level and is permanently saturated. At times throughout the monitoring period, groundwater is recorded above ground level, within the casing. The negative spikes from October 2012 onwards represent regular water sampling. Hence the upper reaches of Nine Mile Swamp display typical groundwater-dependent shrub swamp characteristics.

## *II. Pine Shrub Swamp*

Pine Shrub Swamp trends SW-NE with a length of approximately 1750 metres and a maximum width of 140 metres near the lower third of its length (Figure 50). It has a fall of approximately 85 metres and is contained wholly within the Burralow Formation. Pine Creek is a tributary of Nine Mile Creek also shown in Figure 50 above. The upper reaches of Pine Shrub Swamp overlie proposed longwall 424.

Pine Shrub Swamp is stratigraphically situated within the unconfined aquifer above the YS4 horizon. However, for the majority of the length of the swamp, additional groundwater is supplied by valley wall seepage from the YS3 ply (Figure 50). Towards the lower reaches of this swamp, the YS4 horizon influences the morphology of the swamp, as shown in Figure 50, where the YS4 subcrop coincides with a widening of the swamp to a maximum width of 150m.

As with other Burralow-type shrub swamps, the occurrence of valley wall seepage as a source of consistent groundwater is supplemented by the intersection of aquitard horizons as the gully floor erodes downstream, supplying a direct input of groundwater to the above swamps at specific locations. These locations as per geological modelling commonly coincide with wider sections of individual swamps. However, it should be noted that boreholes used for the correlation of Burralow Formation plies are sparse in the vicinity of Pine Shrub Swamp (Figure 50) and the model at this location is largely determined by interpolated data from surrounding deep boreholes.

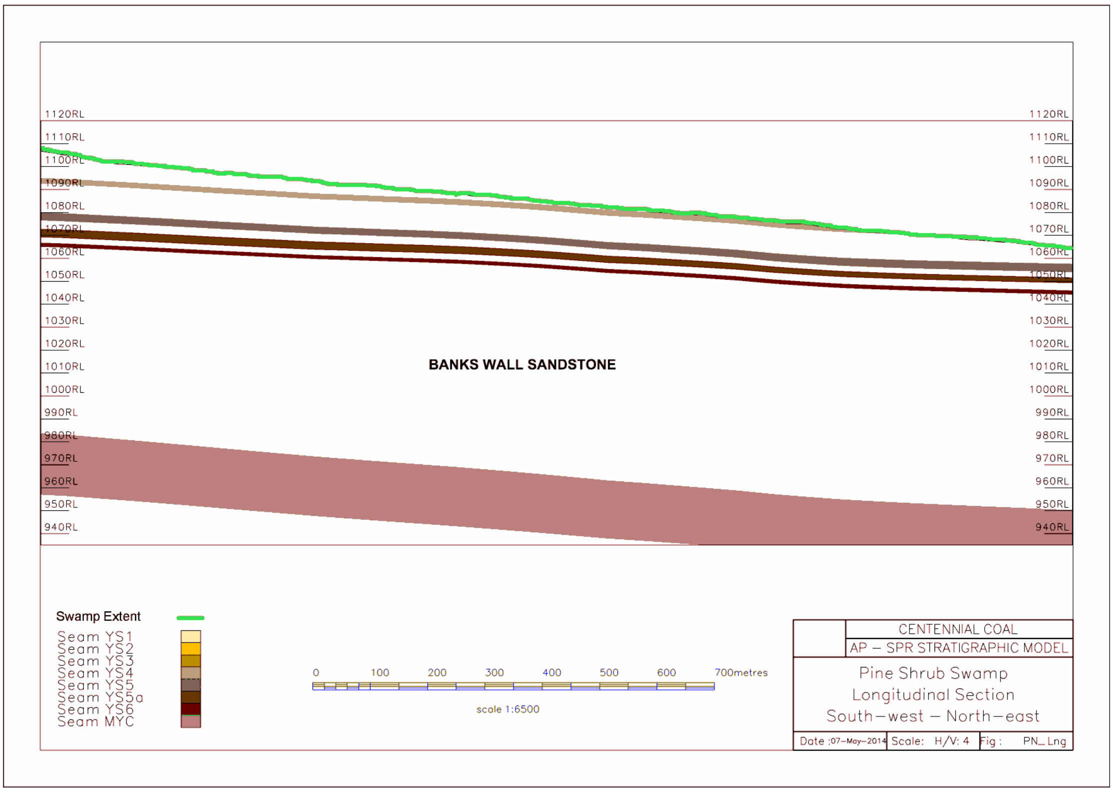


**Figure 53 Longitudinal Stratigraphic Section of Pine Shrub Swamp**

Figure 53 illustrates the stratigraphic profile along the gully floor of Pine Shrub Swamp. The majority of the swamp is hydrologically supported by the YS4 aquitard with additional supplementation from the YS5 aquitard in the lower reaches of the swamp.

Figure 52 above shows the hydrological status for piezometer BS2 (green) which is situated in the upper reaches of Pine Shrub Swamp (Figure 50). As with monitoring station BS1 in Nine Mile swamp, the groundwater level has been consistently high since installation despite significant variations in rainfall, and displays a consistent pattern typical of groundwater-dependency for the upper reaches of this shrub swamp.

## *III. Upper Pine Shrub Swamp*

Upper Pine Shrub Swamp also trends SW-NE and occupies the same watercourse as its downstream equivalent. Upper Pine has a length of approximately 700 metres and a maximum width of 100 metres near its upper extremity (Figure 50). It has a fall of 18 metres and is contained wholly within the Burralow Formation. Upper Pine Creek is essentially a tributary of Nine Mile Creek as shown in Figure 50. Upper Pine Shrub Swamp overlies proposed longwalls 425 and 426.

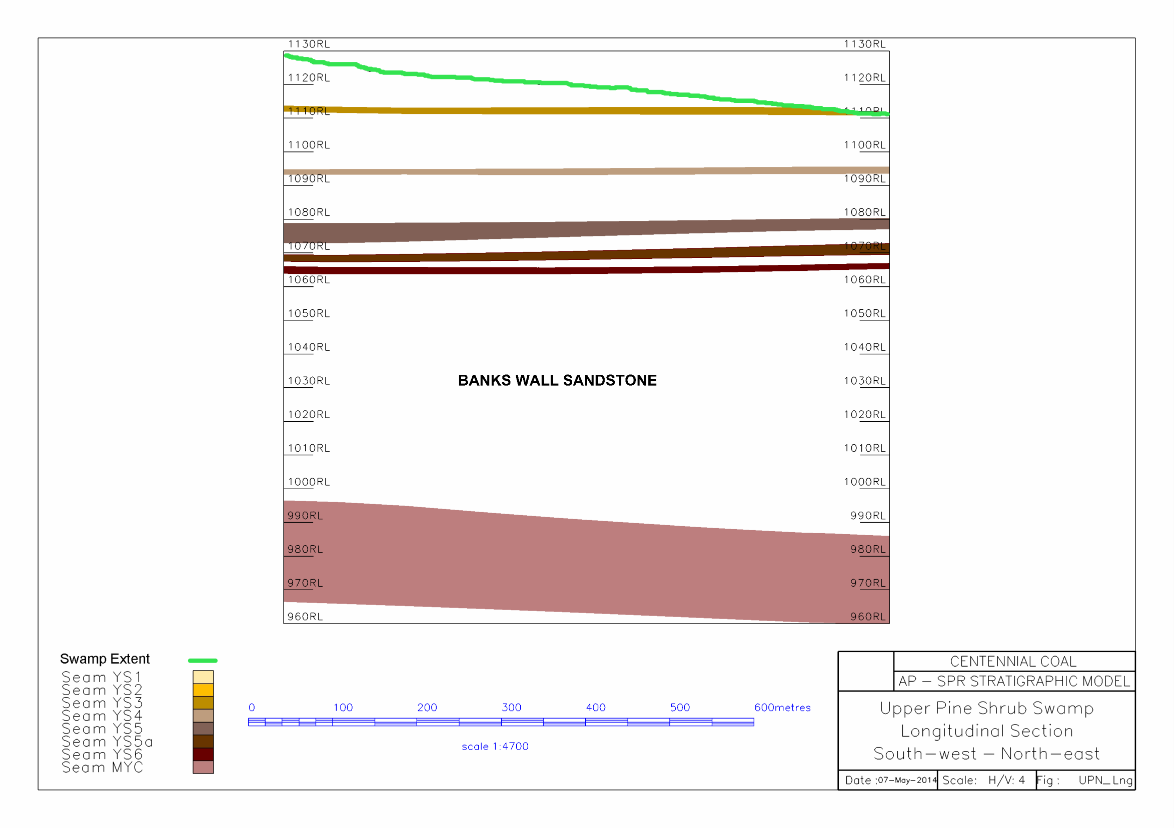


**Figure 54 Longitudinal Stratigraphic Section of Upper Pine Shrub Swamp**

Figure 54 shows a longitudinal section of Upper Pine Shrub Swamp. The entire length of the swamp is stratigraphically located within the unconfined aquifer above YS3. There are no gully-aquitard intersections present within Upper Pine and hence this swamp is reliant on valley seepage flow from aquitards YS2 and YS1 in addition to the groundwater confined by the YS3 aquitard which is located beneath the entire length of the host gully.

However a cluster of hanging swamps is present at the extreme upper reaches of this shrub swamp which are supported by the presence of the YS2 aquitard. The presence of these groundwater-supplied hanging swamps confirms the theory of groundwater-dependence of shrub swamps which will be discussed in a subsequent report. In addition, the accuracy of the stratigraphic model at this location can be observed by the positioning of the YS2 aquitard and its relationship to the three hanging swamps which the latter ply supports.

A break of approximately 200 metres exists between Upper Pine Shrub Swamp and Pine Shrub Swamp to the north-east. As this area forms part of the proposed Springvale southern extension, it is recommended that this zone be assessed pre-mining for pre-existing surface or subsurface anomalies, including pre-mining slumping.

There is no piezometer data for Upper Pine Shrub Swamp to date and this situation should also be addressed prior to mining. Two swamp piezometer monitoring sites have been suggested for this swamp and are labeled XUP1 and XUP2 in Figure 50. The latter site has been selected to provide downstream groundwater data which may indicate the presence of a periodically waterlogged groundwater regime at this location.

Piezometer BS3 (Figure 52 in blue) is located at the junction of Nine Mile and Pine Creeks and is outside of the proposed Springvale southern extension mining area. Very muted responses to rainfall input are evident, however groundwater is consistently high, with near-surface groundwater levels and minimal groundwater level variation. Hence the hydrograph pattern is typical of that of a permanently saturated groundwater-dependent swamp.

## *IV. Paddy's Creek East Shrub Swamp*

Paddy's Creek East Shrub Swamp trends roughly SW-NE, with an approximate length of 1200 metres and a maximum width in its middle reaches of 100m (Figure 55). It has a fall of 73 metres. This swamp is outside of the Springvale South Extension area but falls within the Clarence Colliery lease.

As shown in Figure 55, this shrub swamp is divided into two sections separated by a break in continuity of approximately 50 metres. The larger northern segment of this swamp is located within the Banks Wall Sandstone with the exception of the southernmost 60 metres which is located within the Burralow Formation. Hence the swamp in its entirety is a "mixed-type" shrub swamp.

However, it is important to note that, as with Pine Shrub Swamp, boreholes used for the correlation of Burralow Formation plies are comparatively sparser in the vicinity of Paddy's Creek East Swamp and the model at this location is largely determined by interpolated data from surrounding deep boreholes. The nearest borehole to the east of the downstream section of Paddy's Creek East swamp which contains correlatable data of Burralow Formation plies is CLRP05 at a distance of 1.5km to the southeast.

Hence the delineation between the outcrop of the Banks Wall Formation and the overlying Burralow Formation is expected to differ slightly from Figure 55, particularly in the lower reaches of Paddy's Creek East swamp, as further borehole data became available within the Clarence lease.

However, large volumes of groundwater are present in the strata surrounding the lower Paddy's East complex as evidenced by the size and number of hanging swamps in the immediate vicinity. It is predicted from the study of shrub swamps in both

Angus Place and Springvale that, given the location of hanging swamps in this location, including the hanging swamp to the east of the lower reaches of Paddy's East swamp, that the subcrop of the Burralow Formation may actually include all hanging swamps and possibly lower Paddy's East swamp in its entirety. The proposed piezometer XPCE2 (Figure 55) at Clarence Colliery would assist in determining groundwater levels at this site in the absence of appropriate drilling data, however without the latter the classification of this swamp remains undetermined.

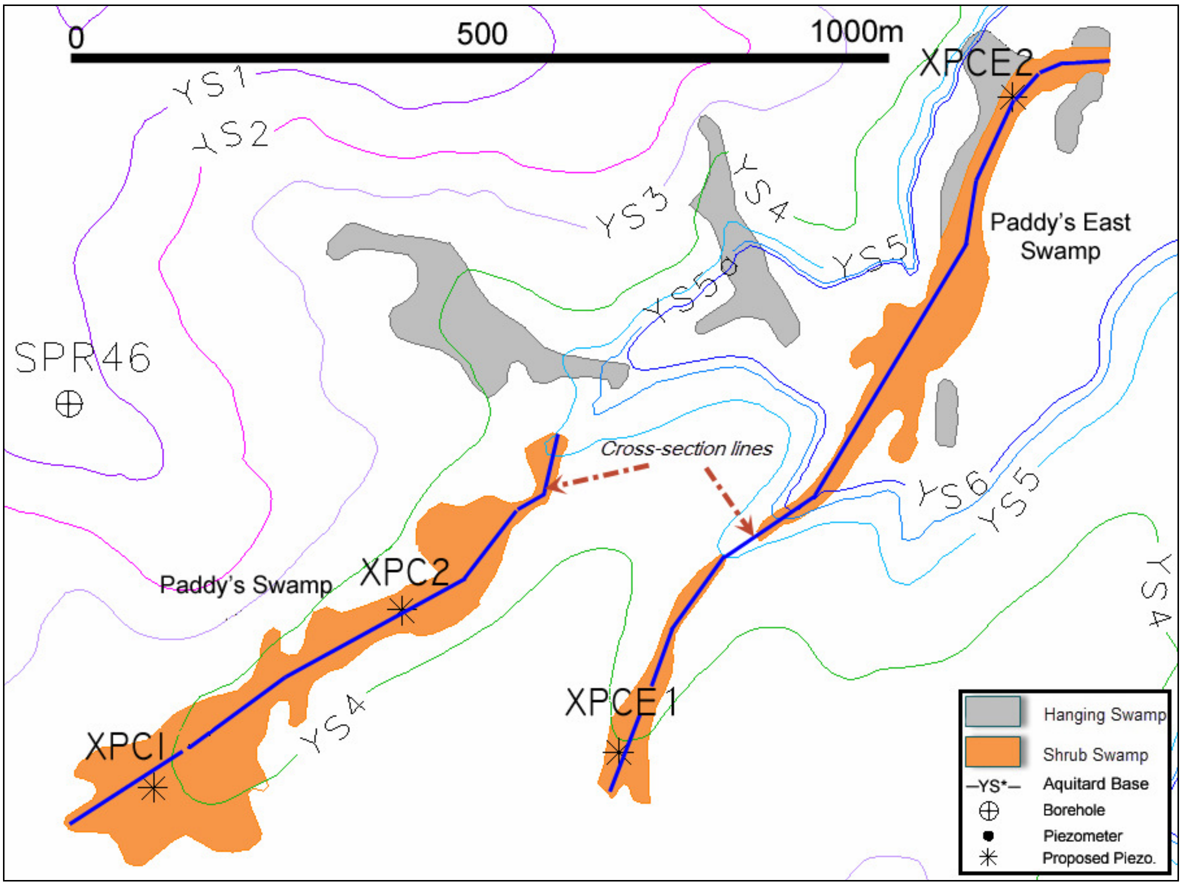


**Figure 55 Plan of Paddy's Creek and Paddy's Creek East Shrub Swamps**

Figure 55 also shows the southernmost section of Paddy's Creek East Shrub Swamp. The upper reaches of this section are underpinned by the YS4 aquitard, with the majority of the upper swamp situated stratigraphically between the YS4 and the YS5 plies. Just upstream of the break between the upper and lower Paddy's East swamp sections, the swamp is located stratigraphically between the YS5 and YS5a horizons. The presence of the YS4 aquitard has a significant effect on the morphology of the upper reaches of Paddy's East Swamp, and reinforces the importance of in-gully groundwater input on the hydrology of Newnes Plateau shrub swamps.

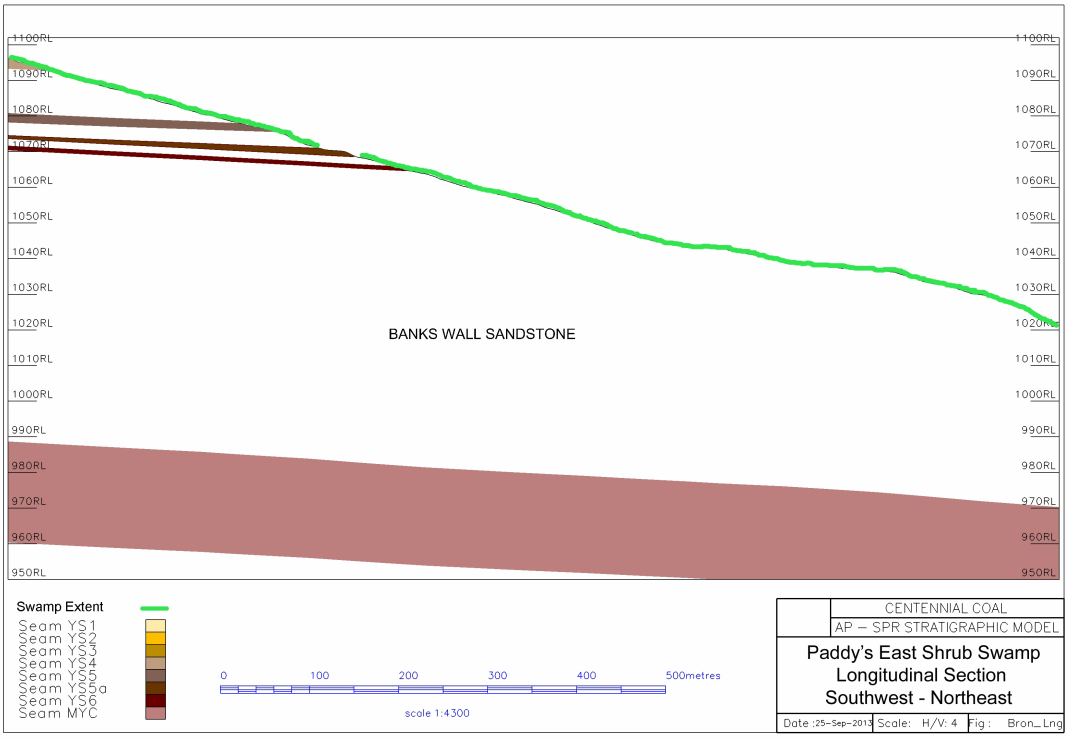


**Figure 56 Longitudinal Stratigraphic Section of Paddy's East Shrub Swamp**

Figure 56 is a longitudinal section of Paddy's Creek East Shrub Swamp. The break between the upper and lower swamps is shown by the break in the swamp extent, marked in green, the model indicating the YS5a crops out at this point. This diagram clearly illustrates the stratigraphic positioning of this swamp from the Burralow Formation and into the Banks Wall Sandstone below. From limited current data and interpolation as noted above, the upper reaches of Paddy's East Swamp represent a Burralow-type swamp, while the lower two-thirds appear to lie stratigraphically within the Banks Wall Sandstone. Extensive hanging swamps (Figure 55) are present within the lower reaches of this shrub swamp and are associated with the YS6, YS5a, YS4 and YS3 plies.

As Paddy's Creek East Shrub Swamp overlies Clarence Colliery, it is recommended that this area be assessed pre-mining for pre-existing surface or subsurface anomalies. There is no piezometer data for this swamp to date and this situation should also be addressed prior to mining. To that effect, two piezometric monitoring sites, XPCE1 and XPCE2 have been selected as indicated in Figure 55. XPCE1 has been chosen to determine groundwater levels in the upper reaches of this swamp and to observe the effects on groundwater levels of the YS4 aquitard. By contrast, XPCE2 has been selected to observe the effects of a possible Banks Wall Sandstone substrate combined with the confounding influence of the groundwater input from the extensive hanging swamp complexes at the northern extent of this shrub swamp.

## *V. Paddy's Creek Shrub Swamp*

Paddy's Creek Shrub Swamp trends approximately SW-NE with an approximate length of 800 metres and a maximum width in its upper reaches of 200 metres. This swamp overlies longwall 424 of the Springvale South Extension area, has a fall of 35 metres and is wholly contained within the Burralow Formation.

Figure 57 is a plan of Paddy's Creek Shrub Swamp showing subcrops of the aquitards in the vicinity. The extreme upper reaches are located in the unconfined aquifer above the YS4, and the broad southern expanse of the swamp is underpinned by the subcrop of the YS4 ply and demonstrates the importance of direct in-gully groundwater input to the morphology of shrub swamps. The YS4 ply also provides a source of indirect groundwater via valley wall seepage for most of the length of the swamp. The YS3 and YS4 aquitards also hydrologically support the two hanging swamps to the immediate north of this shrub swamp. The majority of Paddy's Creek Shrub Swamp lies stratigraphically between the YS4 and the YS5 aquitards. The extreme northern extremity is hydrologically supported by the YS5a aquitard.

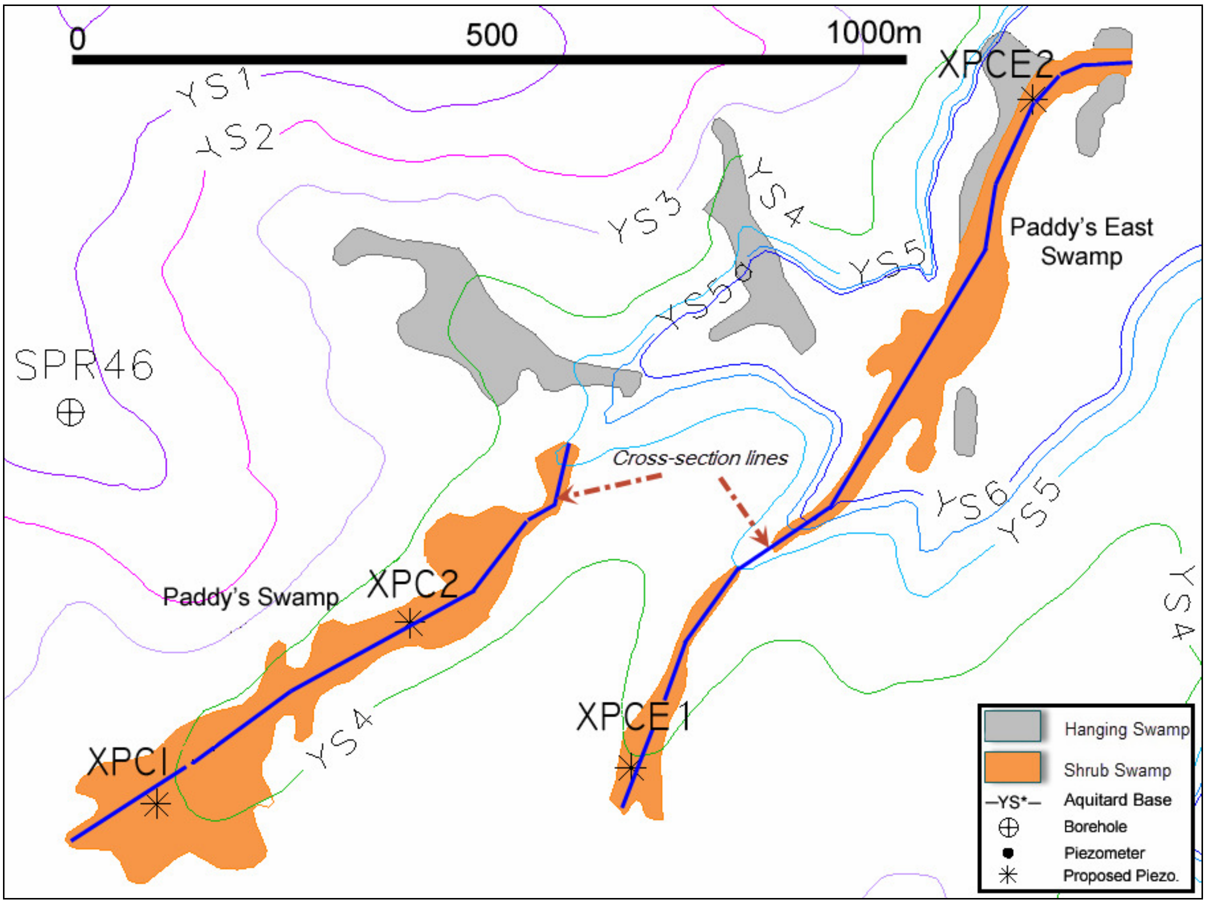


**Figure 57 Plan of Paddy's Creek Shrub Swamp**

Figure 58 shows a longitudinal stratigraphic section of Paddy's Creek swamp and highlights the role of the YS4 in the upper reaches, the presence of the YS5 aquitard as the principal retainer of groundwater and the relatively steep gradient at the northern end of the swamp where the aquifer between the YS5 and the YS5a crops out.

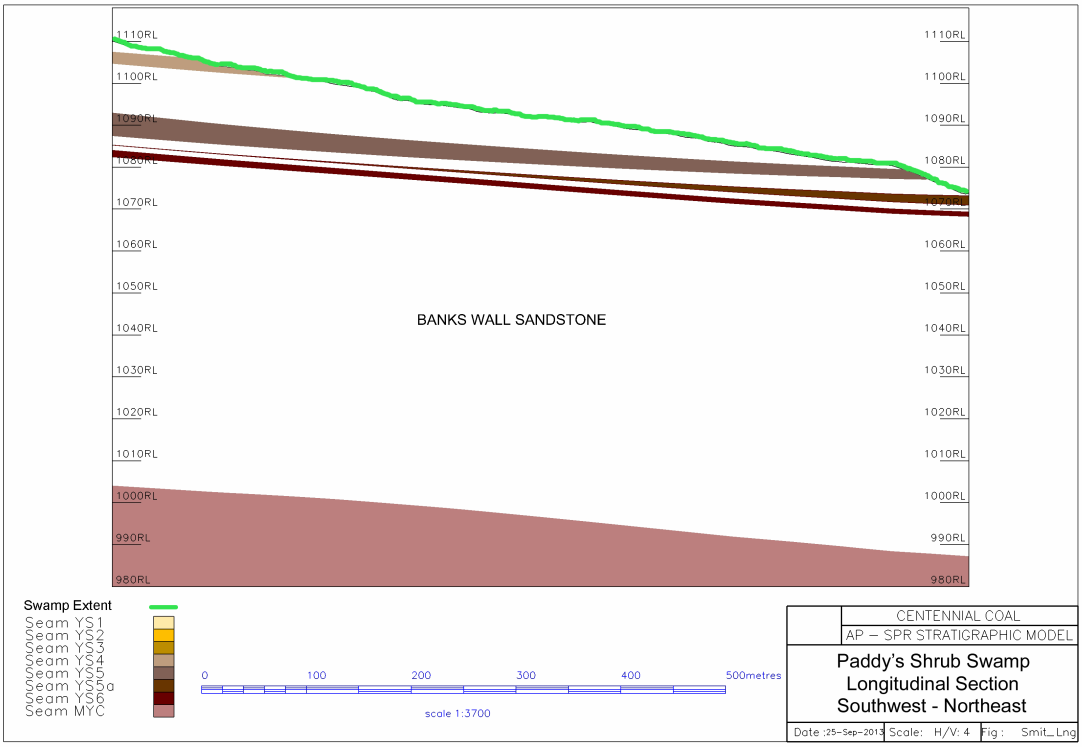


**Figure 58 Longitudinal Stratigraphic Section of Paddy's Shrub Swamp**

As Paddy's Creek swamp forms part of the Springvale South extension lease, it is recommended that this area be assessed pre-mining for pre-existing surface or subsurface anomalies. There is no piezometer data for this swamp to date and this situation should also be addressed prior to mining.

To that effect, two piezometric monitoring sites, XPC1 and XPC2, have been selected as indicated in Figure 57. XPC1 has been chosen to determine groundwater levels in the upper reaches of this swamp and to observe the effects on groundwater levels of the YS4 aquitard. XPC2 has been selected to capture groundwater levels in a comparatively drier area of the swamp but still within the angle of draw of the current proposed mine plan.

## *VI. Marrangaroo Shrub Swamp*

Marrangaroo Shrub Swamp trends approximately SW-NE, with an approximate length of over 1700 metres and a maximum width of 150 metres. It has a fall of 67 metres and is mostly contained within the Burralow Formation, with the exception of the extreme lower reaches where it is underpinned by the Banks Wall Sandstone. Hence this swamp which drains into the Cox's River and thence into the Warragamba

Dam catchment area is a “mixed-type” swamp. It currently overlies longwalls 428, 429, 430 and 431 of the Springvale South extension area and has a gradient of 3.8%.

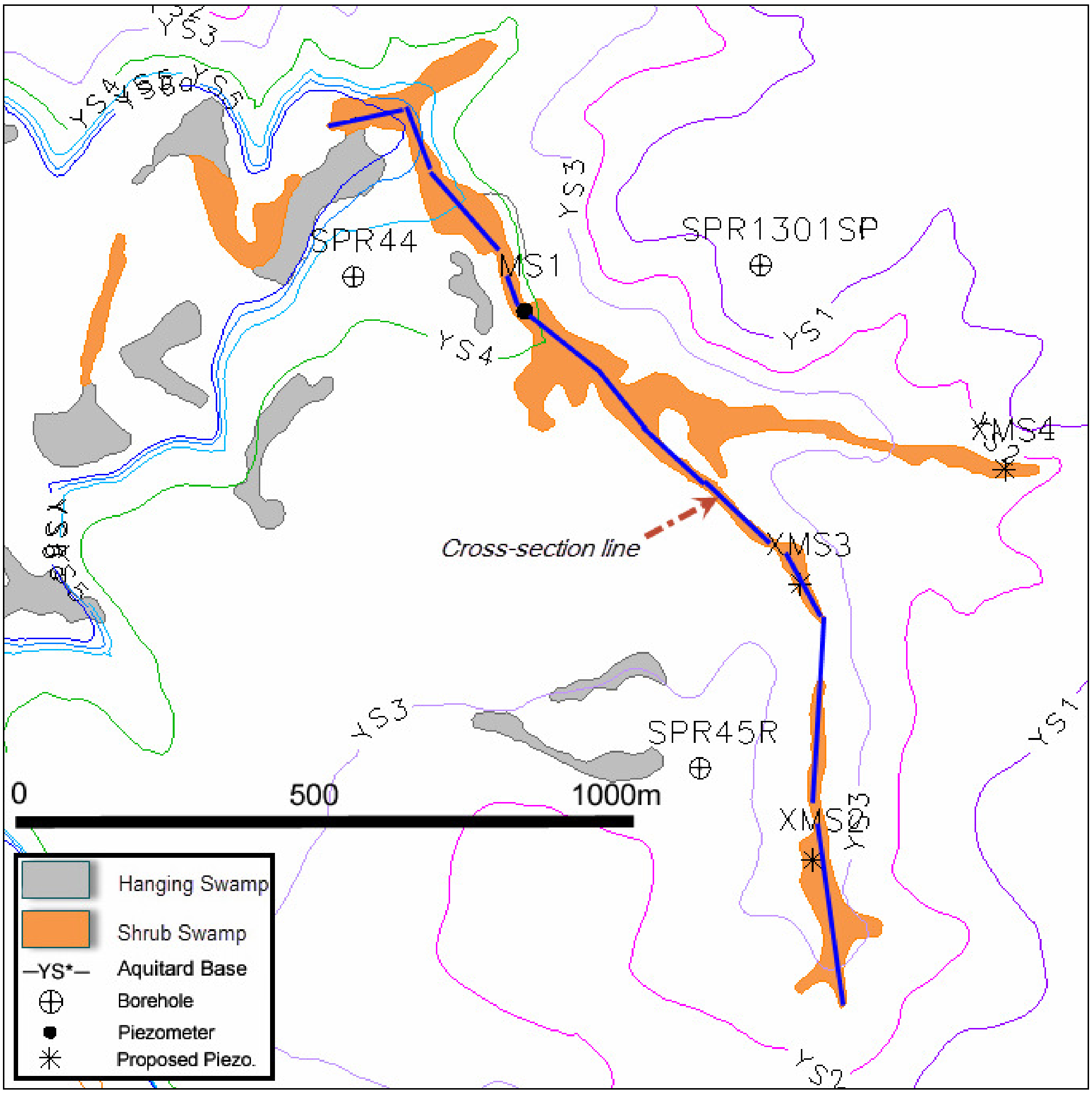


**Figure 59 Plan of Marrangaroo Shrub Swamp**

Figure 59 is a plan of the Marrangaroo Shrub Swamp and associated Marrangaroo Hanging Swamp complexes. The extreme upper reaches of the southern extension of the Marrangaroo Shrub Swamp is intersected by the YS3 aquitard, providing an in-gully groundwater source to this relatively wider section of the southern arm of the Marrangaroo swamp system. The YS3 ply also provides valley seepage along the length of the southern course of the host creek. The eastern upper reaches also receive valley wall seepage and direct in-gully input from the YS3 ply, in addition to minor valley seepage from the YS2 aquitard.

Hanging swamps in the general area of Marrangaroo shrub swamp are supported by the YS2 and YS3 aquitards to the south, and the YS4, YS5, YS5a and YS6 aquitards adjacent to the lower reaches of the shrub swamp, where the Burralow Formation conformably overlies the Banks Wall Sandstone. The hydrogeology of the hanging swamps throughout the Angus Place, Springvale and Clarence leases is discussed in the subsequent report, *The Geology and Hydrogeology of the Hanging Swamps of the Newnes Plateau.*

Near the confluence of the southern and the eastern reaches of Marrangaroo Creek, the base of the YS4 aquitard intersects the gully floor and it is at this location that the creek widens to its maximum width as a result of both direct and indirect input of groundwater, in additional to topographic influences.

The YS5 and YS6 plies are relatively thick in the vicinity of this shrub swamp and supply additional in-gully and valley wall seepage to the lower reaches of this creek, which accounts for the widening of Marrangaroo Swamp at this location, as well as the presence of its north-eastern tributary in the extreme lower reaches (Figure 59). Here the stream bed and accompanying shrub swamp progress lithologically from the Burralow Formation into the Banks Wall Sandstone due to erosion.

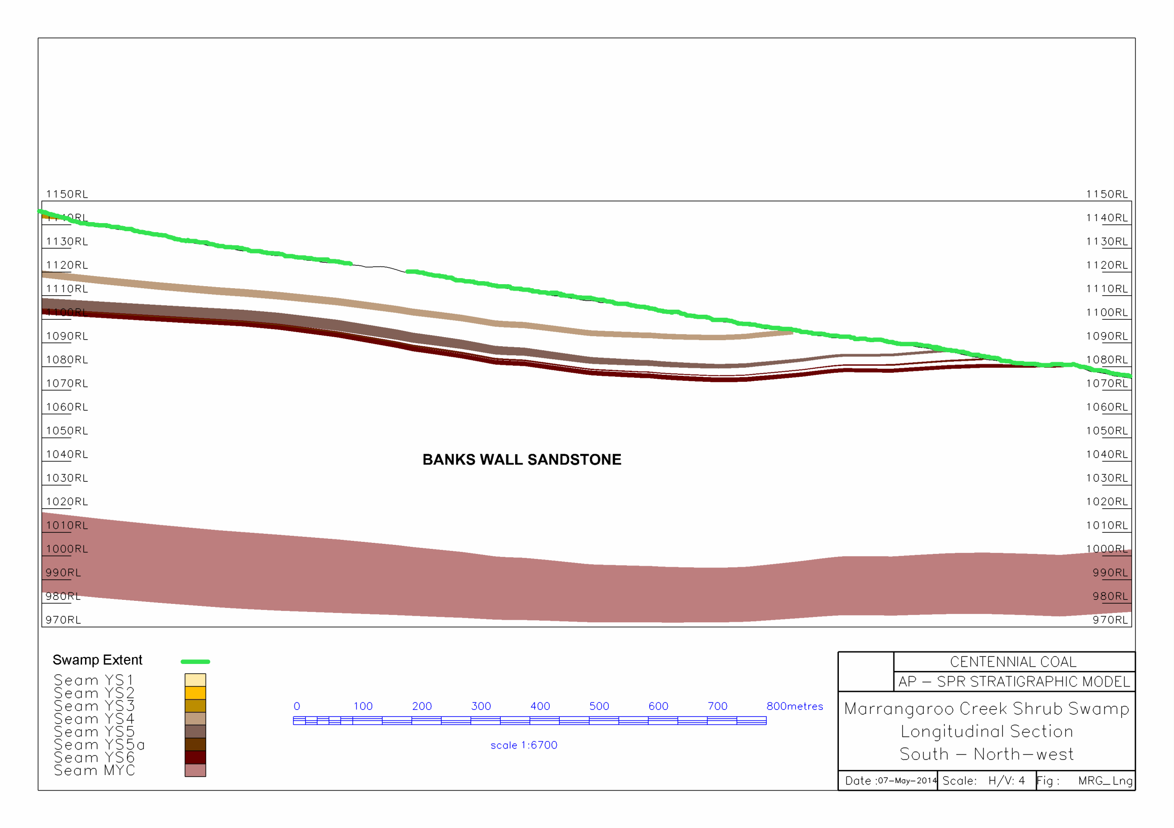


**Figure 60 Longitudinal Stratigraphic Section of Marrangaroo Shrub Swamp**

Figure 60 shows a longitudinal section of Marrangaroo Shrub Swamp from the southern tributary to the north-eastern extent of the swamp. YS3 underpins the extreme upper extent of this swamp, with YS4 intersecting the gully floor approximately 1300 metres downstream.

Figure 60 also displays the breach in continuity between the main body of this shrub swamp and its southernmost extremity. It is recommended that this area be ground-truthed for pre-mining slumping or other surface anomalies prior to longwalling. As this figure demonstrates, the swamp is underlain by the aquifer between YS4 and

YS3, followed sequentially in the lower reaches by the aquifer between the YS4 and the YS5, and ultimately the aquifer between the YS5 and YS6. The YS5a is essentially non-existent at this location and forms part of the YS5 ply and subcrops only in the extreme lower reaches of this swamp.

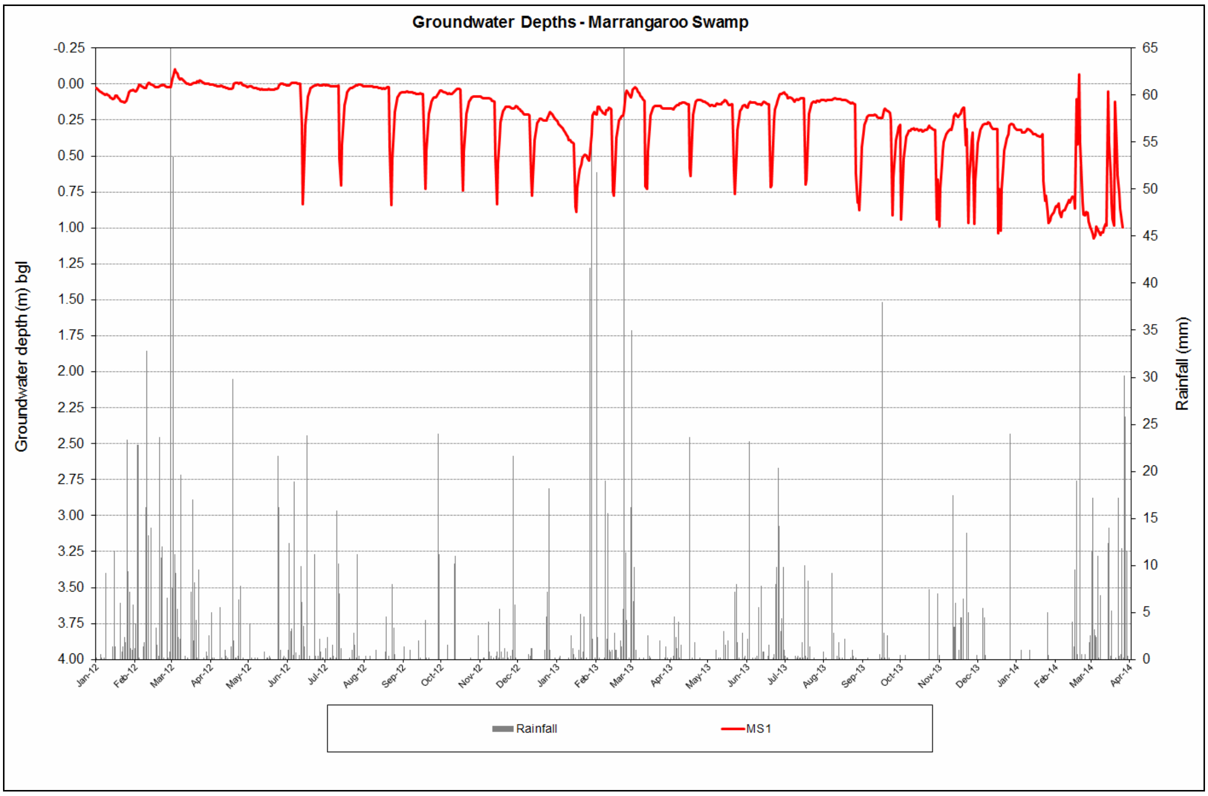


**Figure 61 Hydrograph of Marrangaroo Shrub Swamp**

Figure 61 shows recorded groundwater levels for piezometer MS1. Piezometer MS1 is located above the projected subcrop of the YS5 ply (Figure 59). This piezometer was installed in November 2011 and the above graph shows data from January 2012 to mid-April 2014. Although piezometer MS1 in general displays a pattern of a permanently waterlogged swamp at this location, there is a significant and consistent lowering of groundwater levels from November 2012 through to January 2013, although only between 0.12 to 0.5 mbgl. High rainfall in February – March 2013 has increased groundwater levels briefly for that time period, and groundwater levels remain consistently high (approximately 0.12mbgl) until mid-October 2013 when the swamp was burned out.

The hydrograph above indicates that the October 2013 fire and the accompanying changes to vegetation and peat conditions in this swamp have had an effect on the consistently high groundwater levels at this location within Marrangaroo swamp, with an apparent change to an atypical periodically-saturated profile. It is expected that the typical groundwater-saturated pattern will prevail in time as peat formation and shrub swamp vegetation reestablish. Installation of additional piezometers at the locations suggested below would add significant value to understanding the groundwater regime in this “mixed-type” shrub swamp.

Marrangaroo Shrub Swamp is hydrologically a “mixed-type” swamp, that is, it contains both a Burralow and a Banks Wall substrate. However, at the location of piezometer MS1, this shrub swamp displays an essentially groundwater dependent profile, unlike the mixed-type swamps described previously, such as Twin Gully and the upper tributaries of Tri-Star shrub swamps. This is due to the Burralow/Banks Wall substrate ratio along the fall of the gully floor and the lack of additional piezometers in the upper (potentially drier) reaches of this extensive shrub swamp.

As discussed previously, the presence of a Banks Wall substrate within a Burralow-type shrub swamp creates a different lithological regime for groundwater movement whereby the Banks Wall Sandstone acts as an efficient vertical conduit for relocating water from the swamp system. This is in comparison to a Burralow-type lithological profile, where a sequence of major and minor aquitards within the Burralow Formation serves to maintain high groundwater levels within the upper sequences.

While the majority of Marrangaroo Swamp is located within the Burralow Formation, the extreme lower reaches are situated in the Banks Wall Sandstone. The intersection of aquitards YS2, YS3, YS4, YS5, YS5a and YS6 with the gully floor indicates the importance of direct in-gully input in maintaining the relatively high water levels in this swamp, together with its extensive length.

Marrangaroo Shrub Swamp is one of the longer shrub swamps in the Angus Place/ Springvale area and it is proposed that its length is related to the number of aquitards the gully encounters, either directly or indirectly, as is passes down through the lithological sequence. However, the presence of the Banks Wall Sandstone at the lower reaches, as determined by the stratigraphic model, also likely contributes to the differing morphology of this swamp as compared to Carne West swamp, for example. This concept will be further discussed in *Geological and Hydrogeological Influences on Shrub Swamp Types.*

As Marrangaroo Shrub Swamp forms part of the proposed Springvale southern extension, it is recommended that this zone be assessed pre-mining for pre-existing surface or subsurface anomalies. It is strongly suggested that swamp piezometers be installed at XMS2 and XMS3 (Figure 59) to capture the hydrological response in the southern section of this shrub swamp. In addition, a piezometer at XMS4 would determine groundwater levels at eastern extent of this shrub swamp.

# 14. Conclusions

Newnes Plateau Shrub Swamps (NPSS), Newnes Plateau Hanging Swamps (NPHS), and Newnes Plateau Rush Sedge Snow Gum Hollow Wooded Heath Grassy Woodlands (NPRSSG) are present within the Angus Place/Springvale lease areas. The present study focuses primarily on the Newnes Plateau Shrub Swamps. Not all shrub swamps in the Angus Place/Springvale lease have been included in the current study.

The occurrence and sustainability of the Newnes Plateau Shrub Swamps are multifactorial, involving a complex interplay between topography, hydrological regimes and geology.

The formation and persistence of the Newnes Plateau Shrub Swamps and the Newnes Plateau Hanging Swamps are intrinsically associated with the Burralow Formation, that is, without the presence of the latter, the presence of both swamp types would not occur in the study area.

The Burralow Formation with its suite of aquitards decreases the hydraulic gradient and thus reduces the degree of percolation of groundwater through the varying lithologies of this formation to the units below. Instead, much of the groundwater present within the Burralow Formation is redirected laterally down-dip to discharge points in nearby gullies. Precipitation is thus supplemented by moisture from groundwater sources to form several discharge horizons along the course of the host creek in which a shrub swamp is located.

In the Burralow Formation, where aquitard units are relatively plentiful, the opportunity for groundwater supplementation via valley wall seepage is common. Groundwater supplementation also occurs when aquitards outcrop within the floor of creeks, thus providing a direct means of groundwater input into the host creek. Valley wall seepage together with direct in-gully input of groundwater via aquitards permits continuity of hydration during periods of drought.

The presence of numerous hanging swamps throughout the study area is also an important indicator of the amount of water contained within the aquifer/aquitard strata within the Burralow Formation.

The Newnes Plateau Shrub Swamps are reliant on the Burralow Formation for their presence and development, although the study area does contain shrub swamps which are stratigraphically located solely within the Banks Wall Sandstone. This latter shrub swamp subtype displays an areally restricted morphology and occurs primarily in steep-sided, narrow gullies due to the underlying Banks Wall Sandstone substrate, which is less easily eroded than the lithologies which comprise the overlying Burralow Formation.

In general, shrub swamps occurring wholly within the Banks Wall Sandstone have less access to seepage at discharge points along creek beds due to the absence of aquitard horizons. Consequently this restricts the size and breadth of this shrub swamp type. Significantly, however, with the exception of shrub swamps in the

Wolgan River, the Banks Wall-type shrub swamps are invariably adjacent to subcrops of the lower Burralow Formation aquitard sequence and therefore receive substantial groundwater seepage from these horizons.

Burralow-type shrub swamps are typically more areally extensive than the Banks Wall equivalents, with generally longer and broader morphologies. This is due not only to the presence of the Burralow aquitards, but the lithological differences between the Burralow Formation and the Banks Walls Sandstone. The former promotes more areally extensive swamps while the latter, with its predominantly sandstone-based lithology, results in steeper-sided gullies due to its relative resistance to erosion.

In Banks Wall and “mixed-type” swamps, the lack, or partial lack, of aquifers respectively, inhibits the potential groundwater input and results in smaller, drier and narrower swamps. However, it is important to note that Banks Wall-type shrub swamps and the “mixed-type” swamps which occur at subcrop boundaries between the Burralow Formation and the Banks Wall Sandstone, still receive seepage from the aquitard/aquifer sequences located stratigraphically above them.

Even in shrub swamps located solely within the Burralow Formation, the thickness of the latter can influence the extent of the size of the resultant shrub swamp. High elevation Burralow-type shrub swamps, that is, those in the upper reaches of a particular swamp, may gain groundwater solely from an unconfined aquifer and may be generally smaller in size, unless they are located adjacent to a large recharge area.

Hence, the extensive 1150+ metre ridge system in the Springvale lease, where the Burralow Formation is at its thickest, provides both a substantial precipitation recharge zone plus an array of aquitards to promote groundwater retention in the streams which flow from this watershed area, both to the north and south of the ridge line. It is for this reason that shrub swamps in the south-east of the Springvale lease are, in general, wetter and broader than those in the remainder of both leases.

Floristic differences are also apparent between the upper reaches of Burralow-type shrub swamps, where there is less opportunity for sequential aquifers to supply seepage as the gully moves lithologically downwards, as compared to the lower reaches of these swamps which are typically permanently waterlogged. Similarly, vegetation species differ between Burralow-type and Banks Wall-type shrub swamps due to varying availabilities of groundwater. This, along with hydrological inputs into the shrub swamps and hanging swamps will be discussed in a subsequent report.

Finally, the presence of the Newnes Plateau Shrub Swamps is dependent on topographic, lithological and hydrological factors, which are subsequently reflected in the morphology, floristics and hydrology of the resultant shrub swamp. The manifestation of these complex interacting factors is most readily observable in the change in swamp appearance and swamp vegetation from the northern extension of the Angus Place lease through to the south and east of the Springvale Colliery lease.

# 15. References

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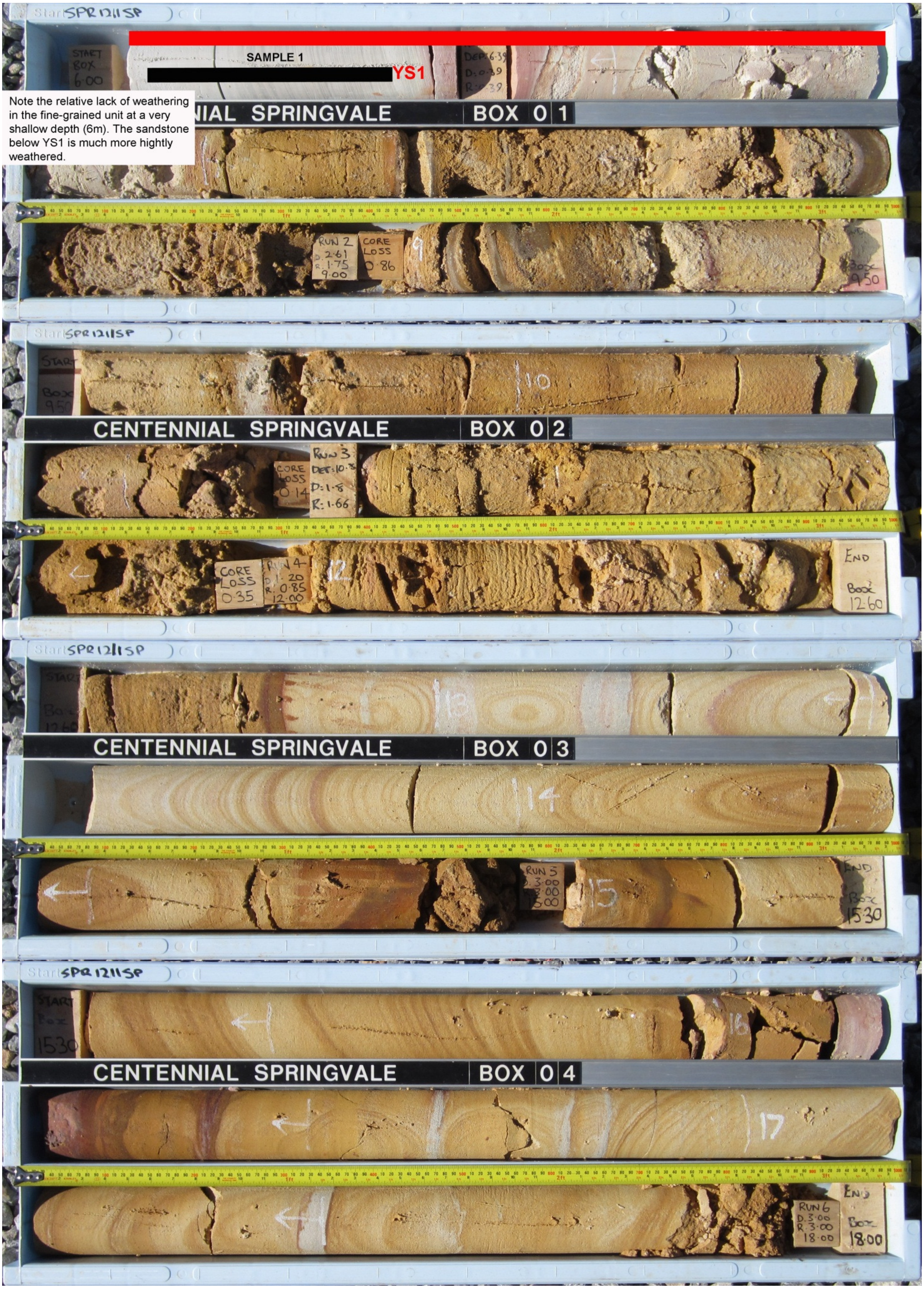
# Appendix A

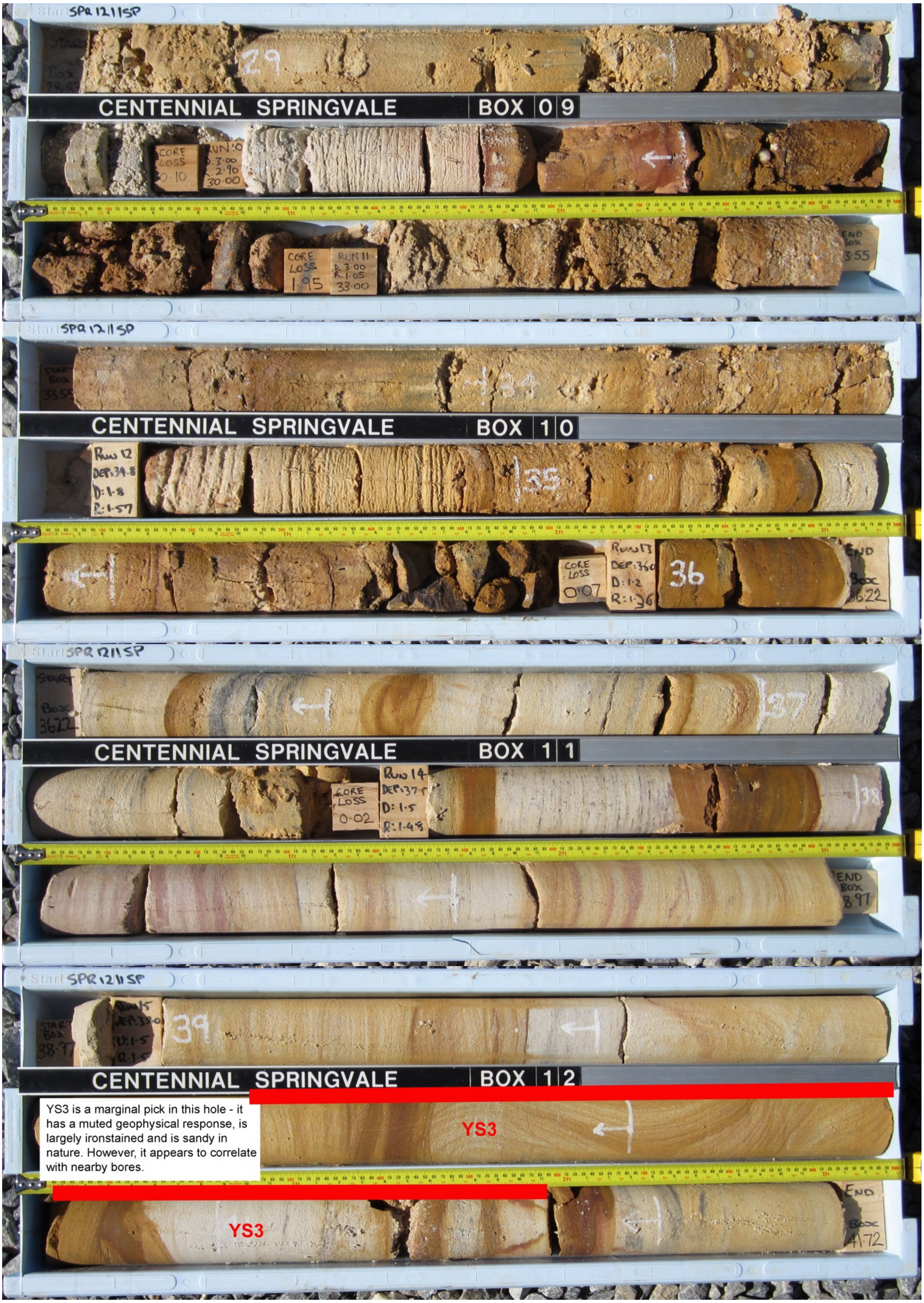
Core Photographs of SPR1211SP

Note: Red bar indicates region of relatively high gamma response in downhole geophysics – see above graphic log.

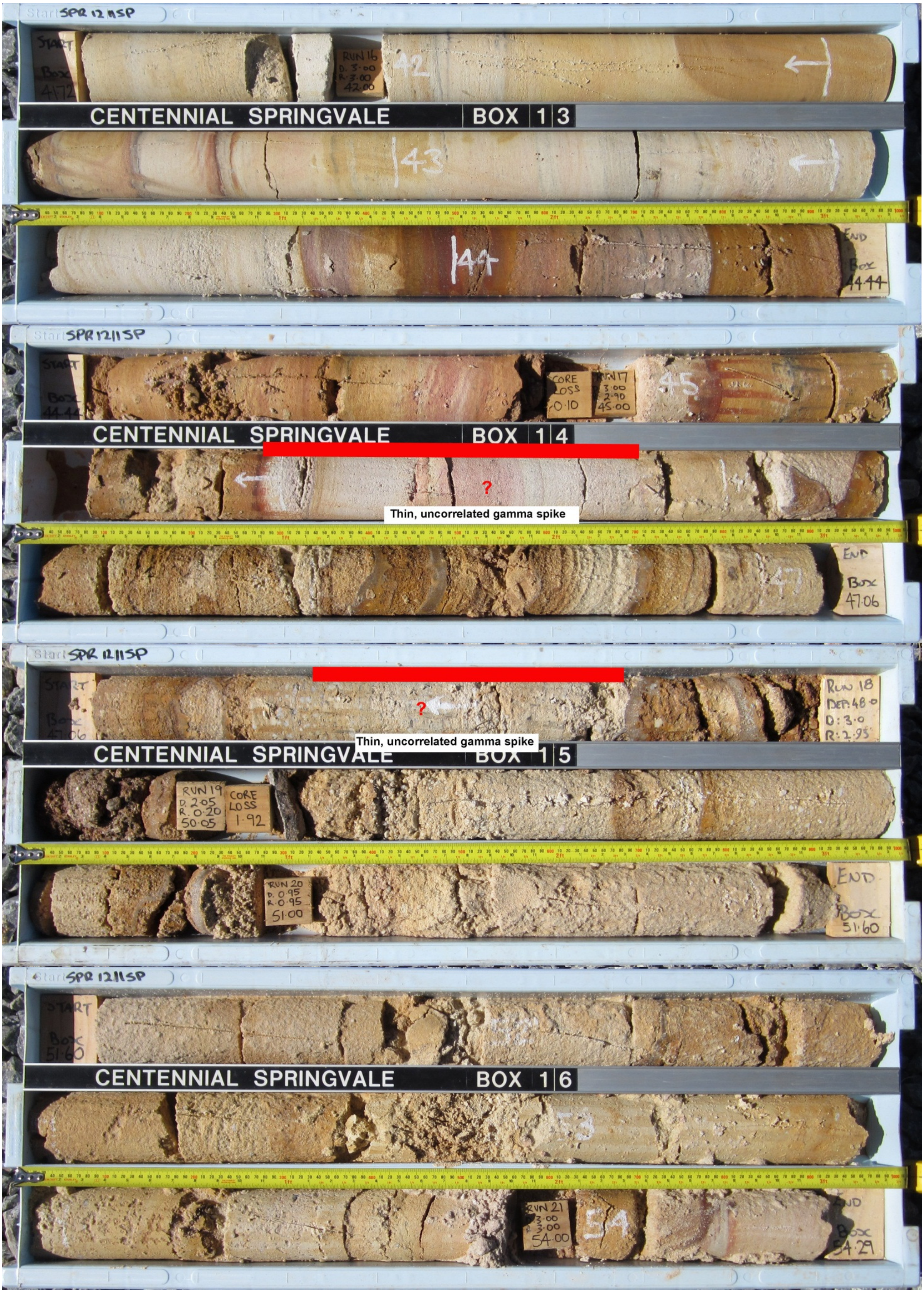


Note the relative lack of weathering in the fine-grained unit at a very shallow depth (6m). The sandstone below YS1 is much more hightly weathered.

YS2 has a 'muted' geophysical response, probably because it is laminated sandstone/siltstone. However, it is relatively unweathered.

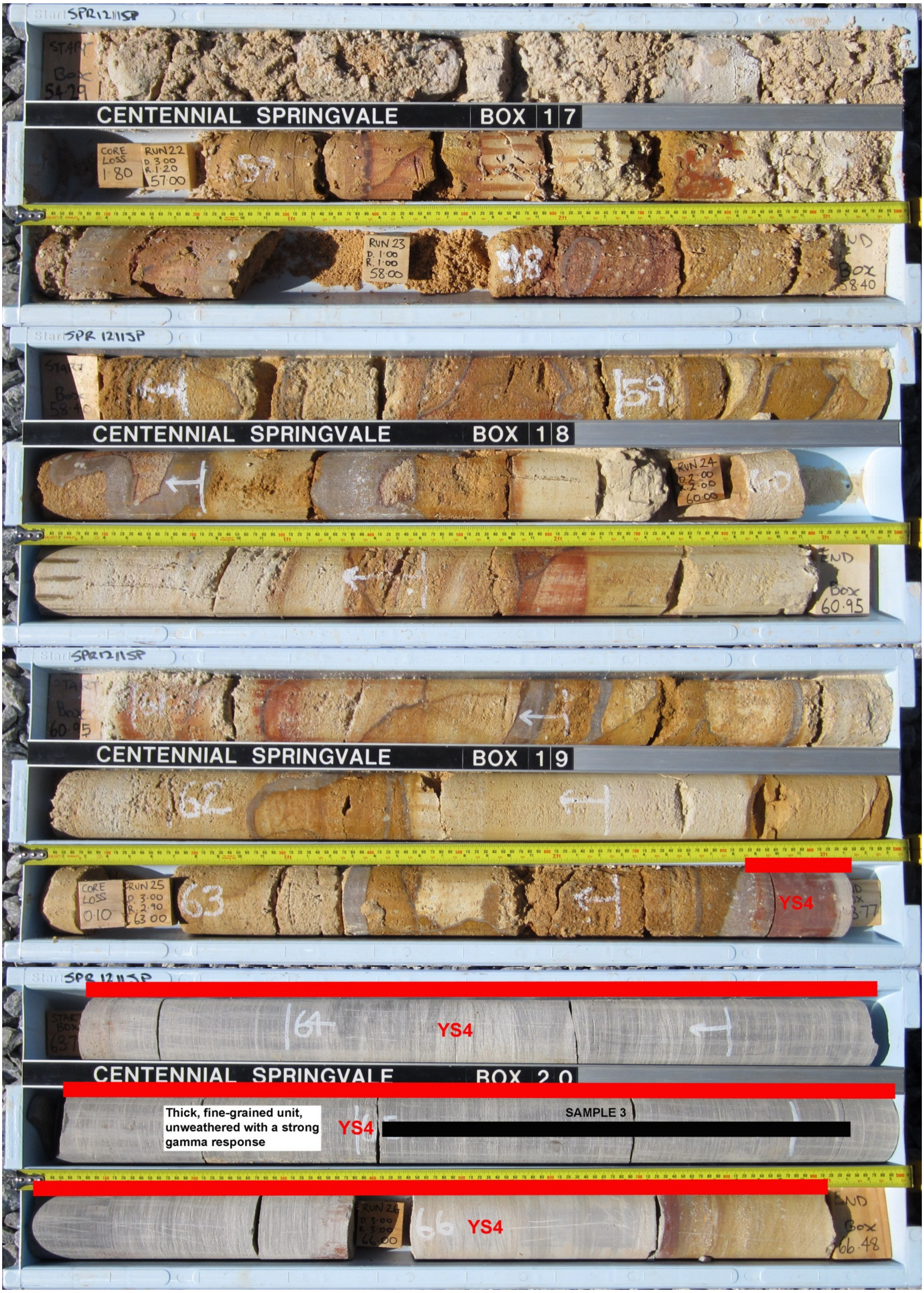


YS3 is a marginal pick in this hole - it has a muted geophysical response, is largely ironstained and is sandy in nature. However, it appears to correlate with nearby bores.

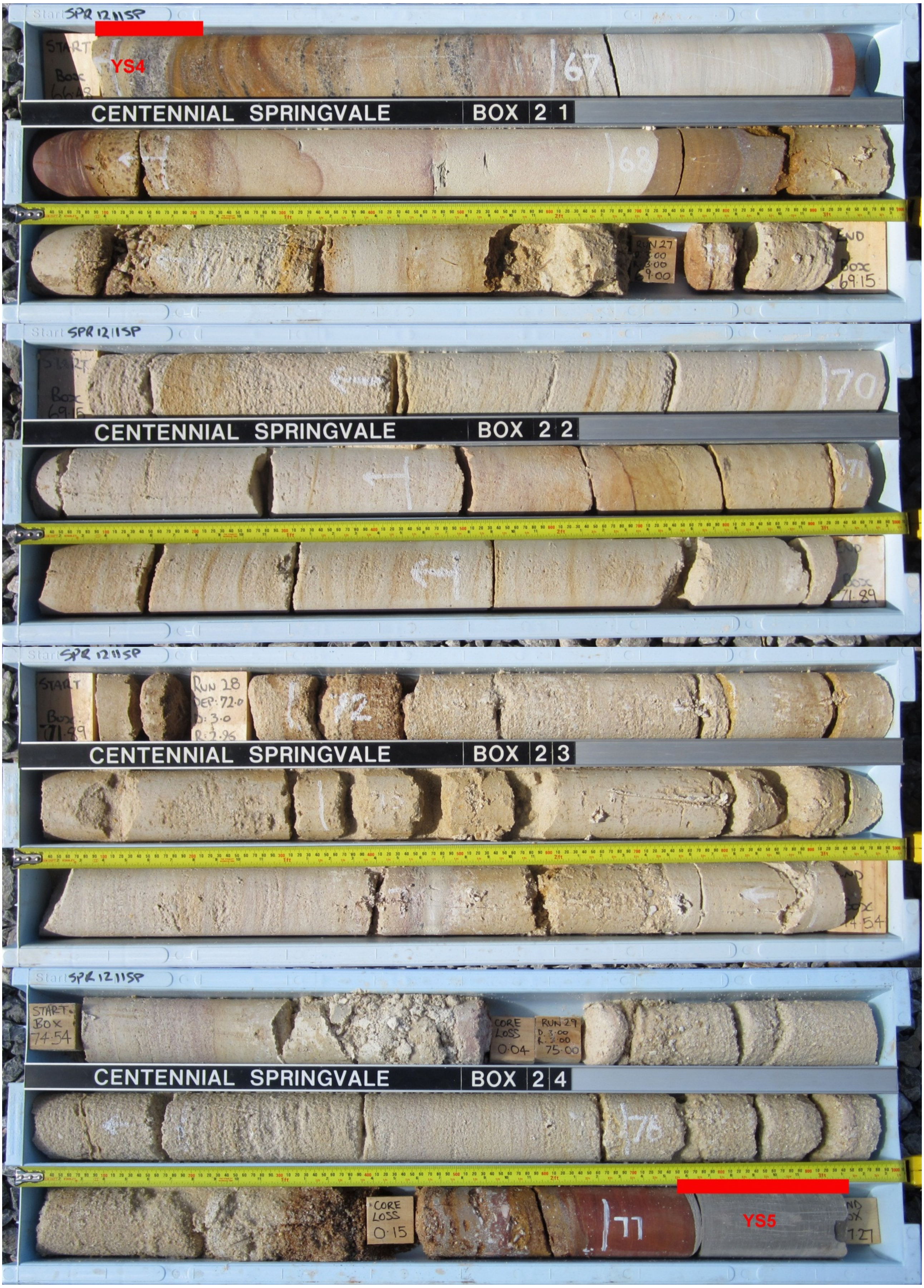


Thin, uncorrelated gamma spike

Thin, uncorrelated gamma spike



Thick, fine-grained unit, unweathered with a strong gamma response


Start SPR 1211SP
YS4
START Box 66.48
67
CENTENNIAL SPRINGVALE BOX 21
68
RUN 27
END Box 69.15
Start SPR 1211SP
START Box 69.15
70
CENTENNIAL SPRINGVALE BOX 22
71
END Box 71.89
Start SPR 1211SP
START Box 71.99
RUN 28 DEP: 72.0 D: 3.0 R: 2.96
72
CENTENNIAL SPRINGVALE BOX 23
END Box 74.54
Start SPR 1211SP
START Box 74.54
CORE LOSS 0.04
RUN 29 D 3.00 R 3.00 75.00
CENTENNIAL SPRINGVALE BOX 24
76
CORE LOSS 0.15
77
YS5
END BOX 77.27

Very thick, fine-grained unit, unweathered with a strong gamma response. Unusually thick ply, which may be due to convergence of YS5, 5a and possibly 6

This sandstone unit has a similar gamma response to the fine-grained material above. It is also unweathered.

YS6 nominally picked at the base of the extended high-gamma interval; basal 0.15m is finer grained. It also marks the end of the non-weathered interval.

Top of Banks Wall Sandstone - weathered to a considerable depth, and lacking in gamma spikes.