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.

[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

[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

[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.

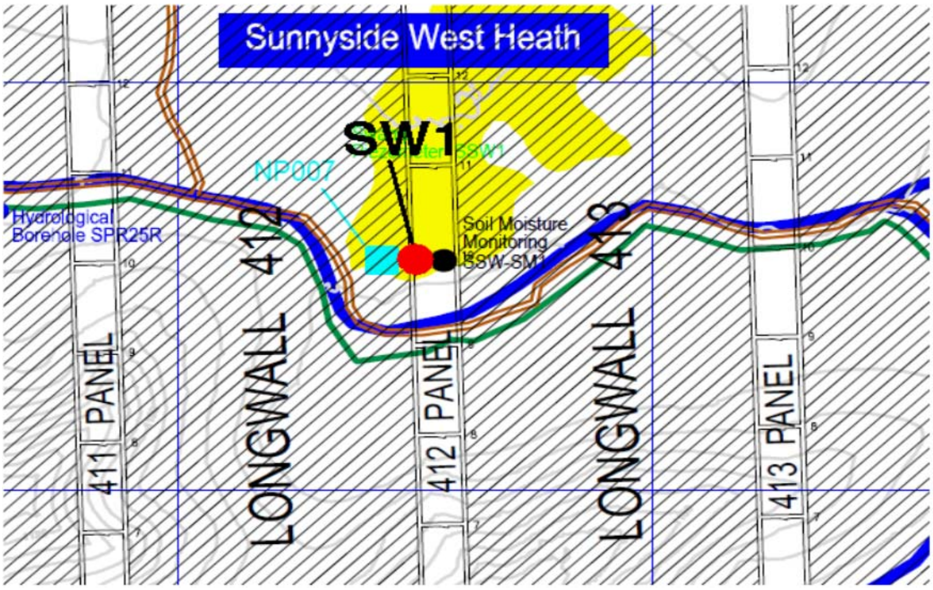


Figure 9 - Sunnyside West Swamp Heath - location of piezometer

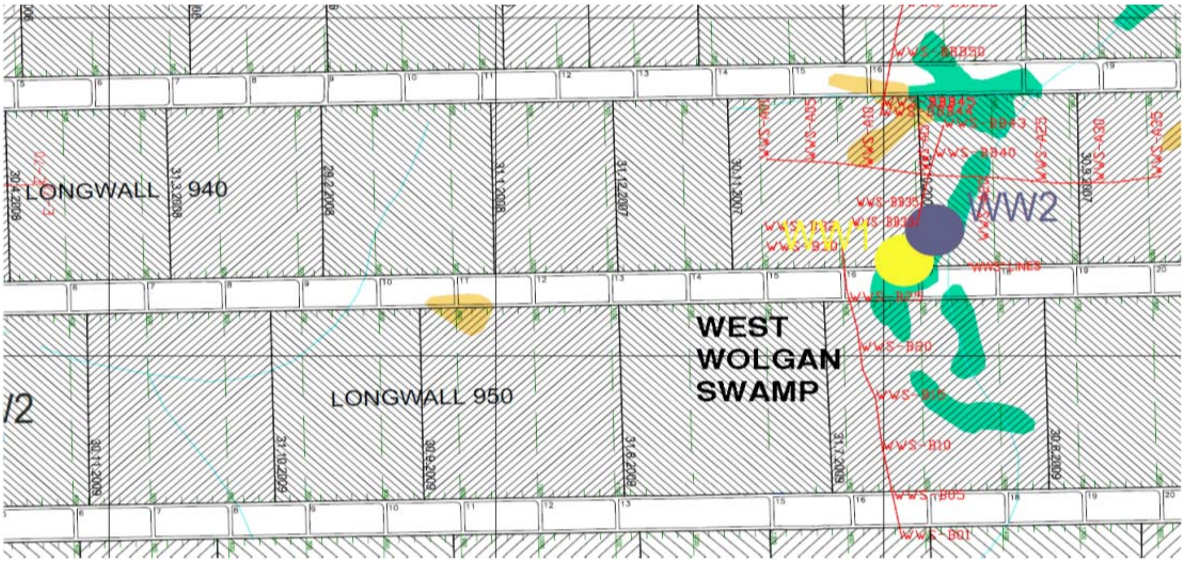


Figure 10 - West Wolgan Swamp - location of piezometers

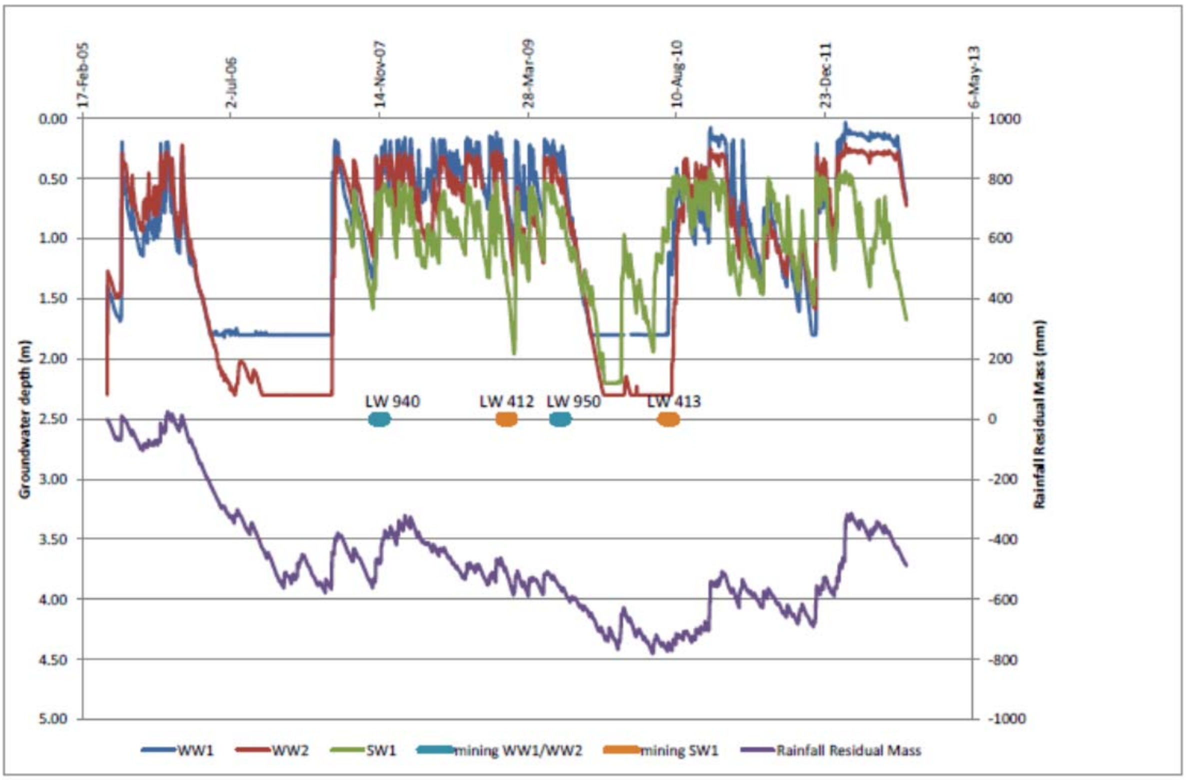


Figure 11 – West Wolgan Swamp and Sunnyside West Swamp Heath – groundwater levels

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.

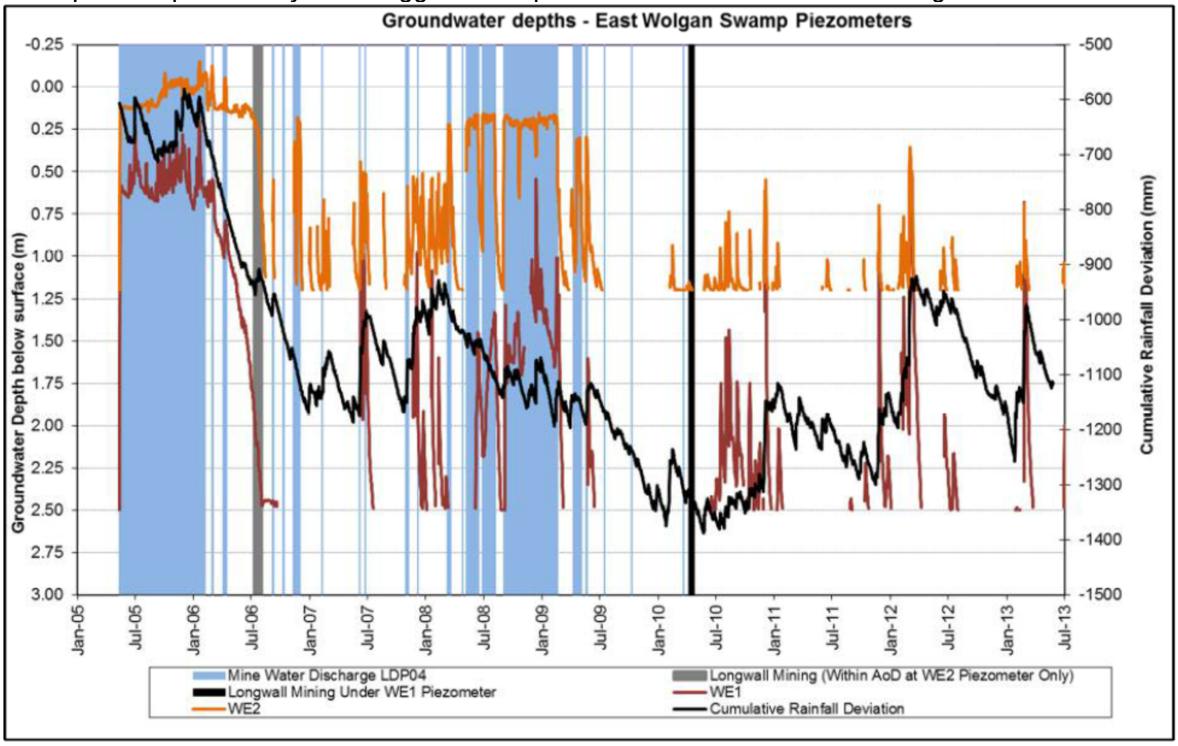
A factual timeline of events and impacts related to East Wolgan Swamp is included below.

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.

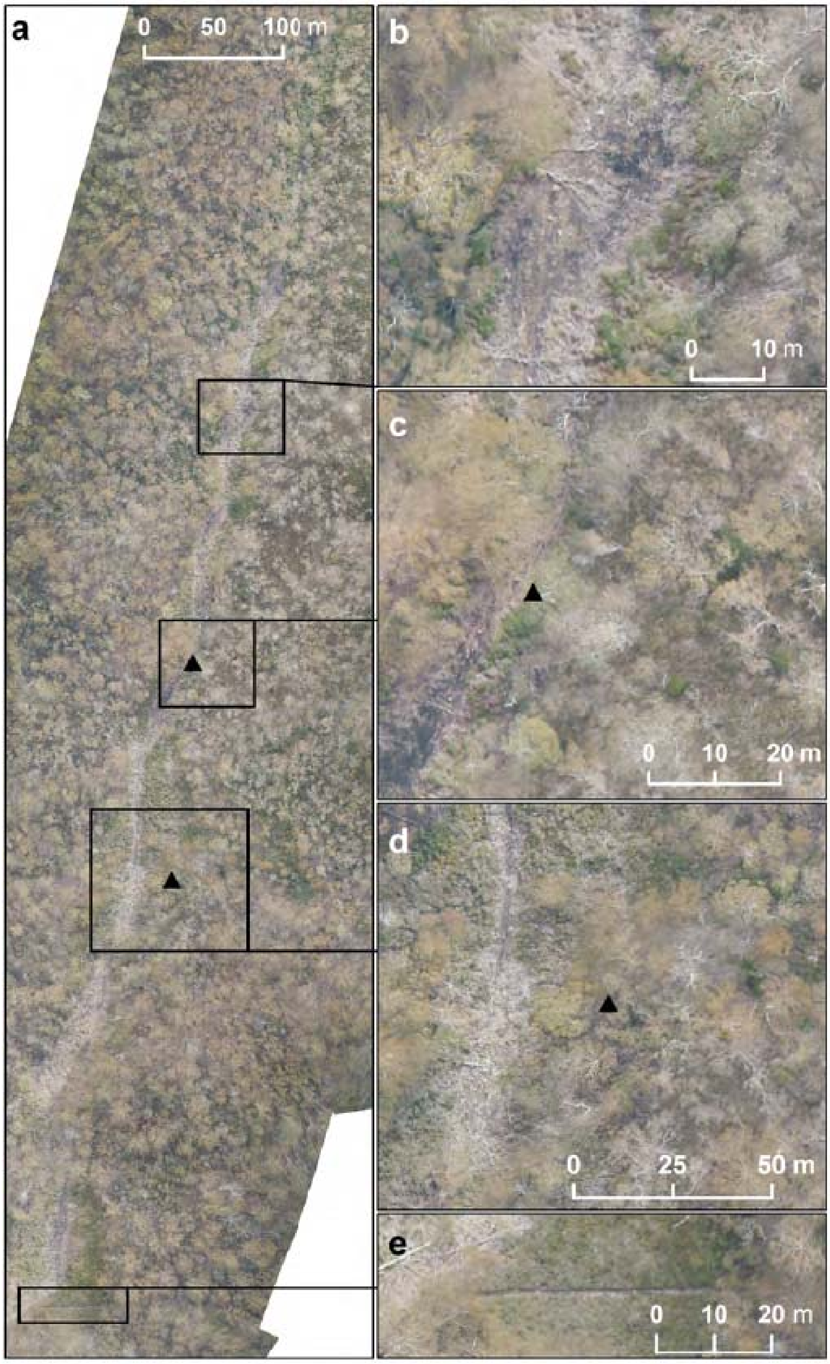


Figure 21: (a) UAS orthophoto mosaic of a shrub swamp collected in June 2013 showing outline of community as described in VISmap 2231 by New South Wales Office of Environment and Heritage. (b). Detail of slump towards downstream end of swamp caused by preferential flow of mine discharge water to below 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.

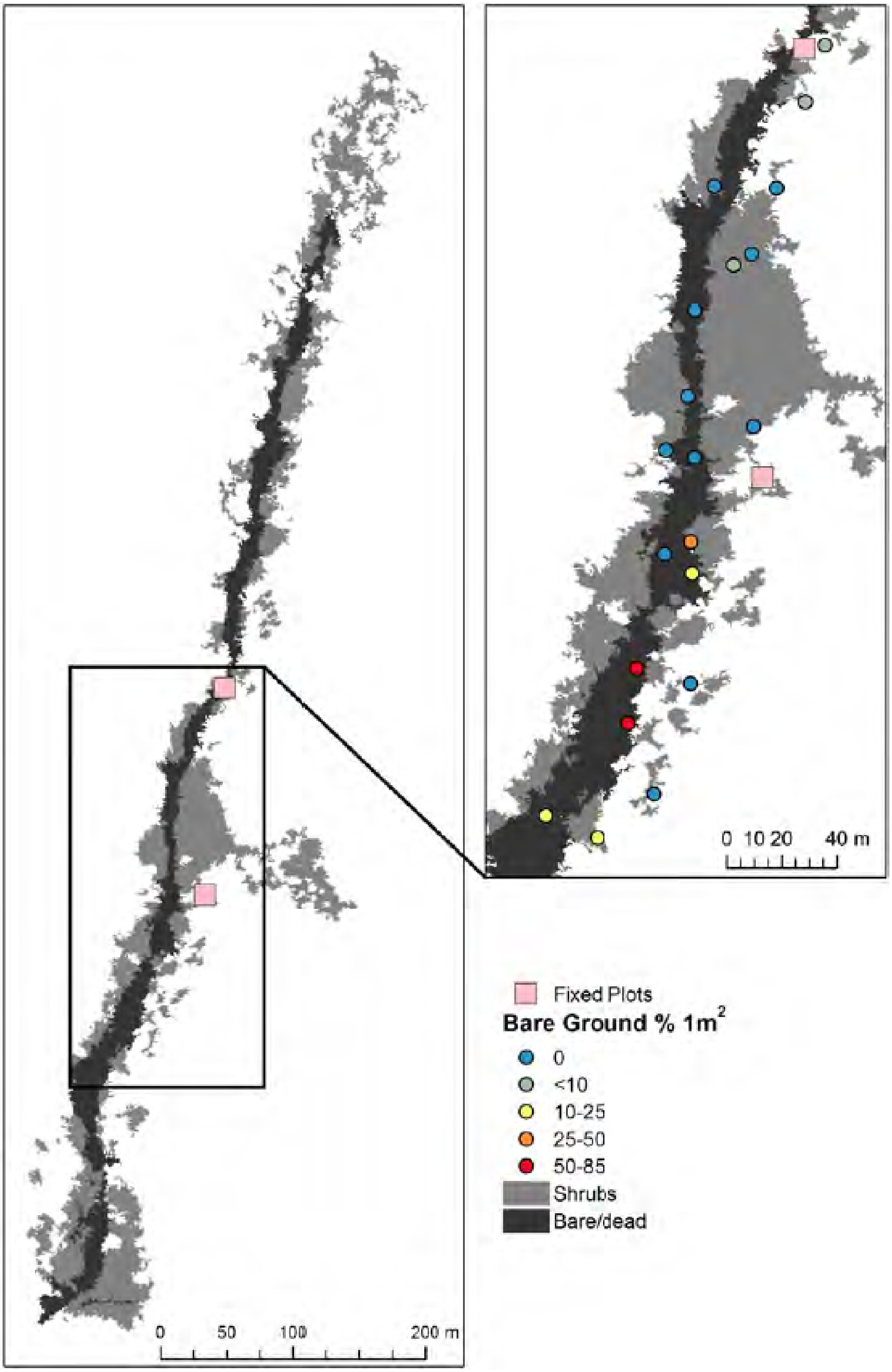


Figure 22: (main) Thematic map of a shrub swamp describing shrub vegetation and dead or bare ground. (inset) Area of mini-plot vegetation assessment ranked by proportion of bare ground identified in 1m2 plot.”

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:

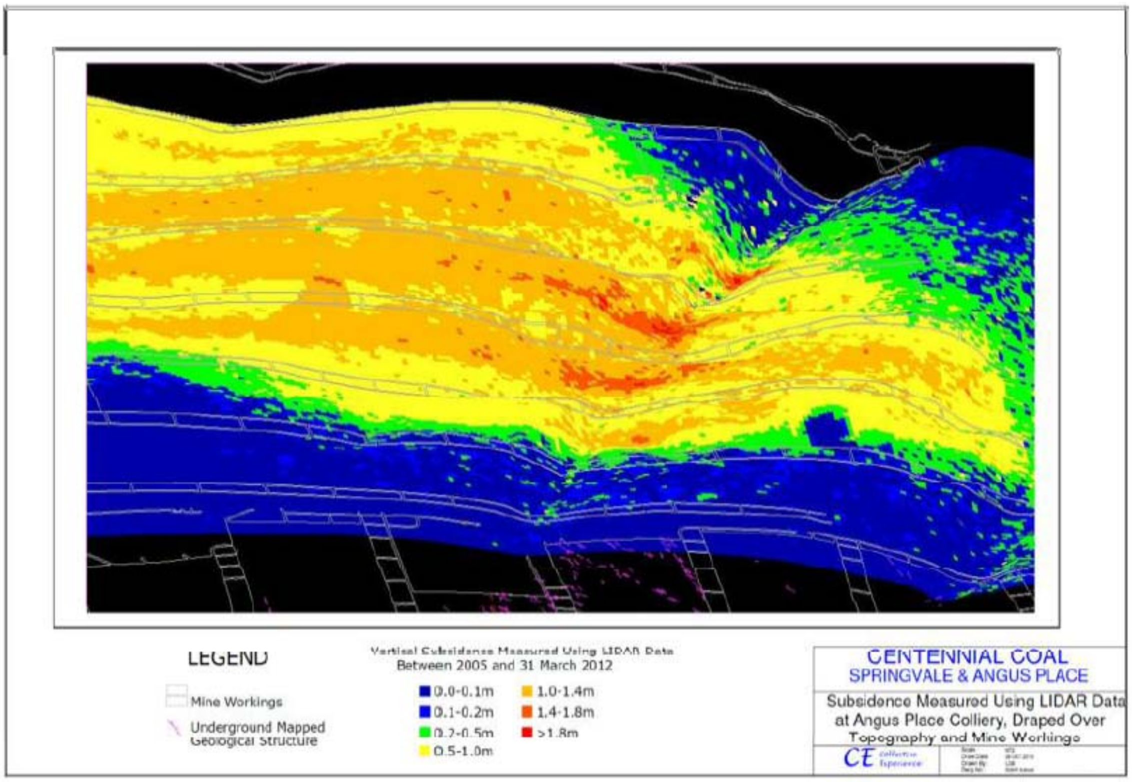
- licensed mine water discharge at rates of up to 12Ml/day;
- intersection of major geological fault structures;
- orientation of the longwall panel subparallel to the major structures;
- steepness and depth of East Wolgan Swamp valley at northern end;
- prevailing in-situ stress direction and magnitude (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)

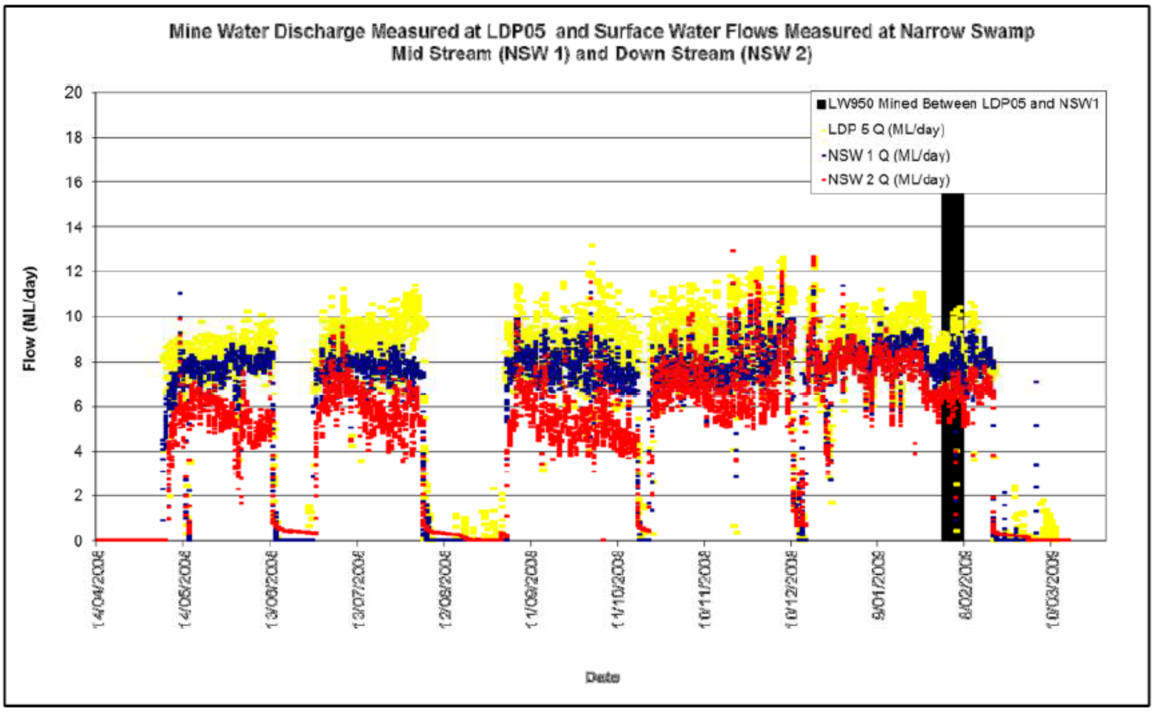
Narrow Swamp was undermined by Longwall 920 in March 2004, Longwall 940 in May 2007 and Longwall 950 in February 2009.

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.

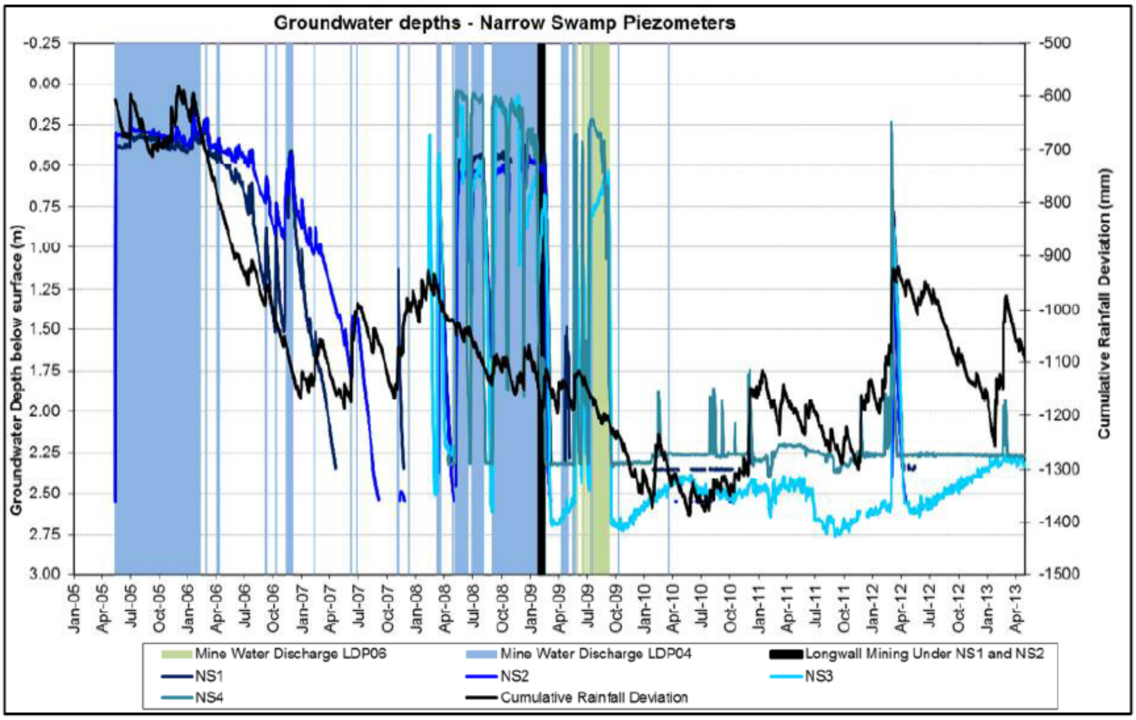
Flow monitoring carried out in this swamp prior to the extraction of LW950 has shown that approximately 91% of the discharge from Angus Place Colliery LDP005 reached a weir (NSW1) in the centre of the Narrow Swamp. After undermining by LW950 in February 2009, the monitoring indicated no change in the 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)

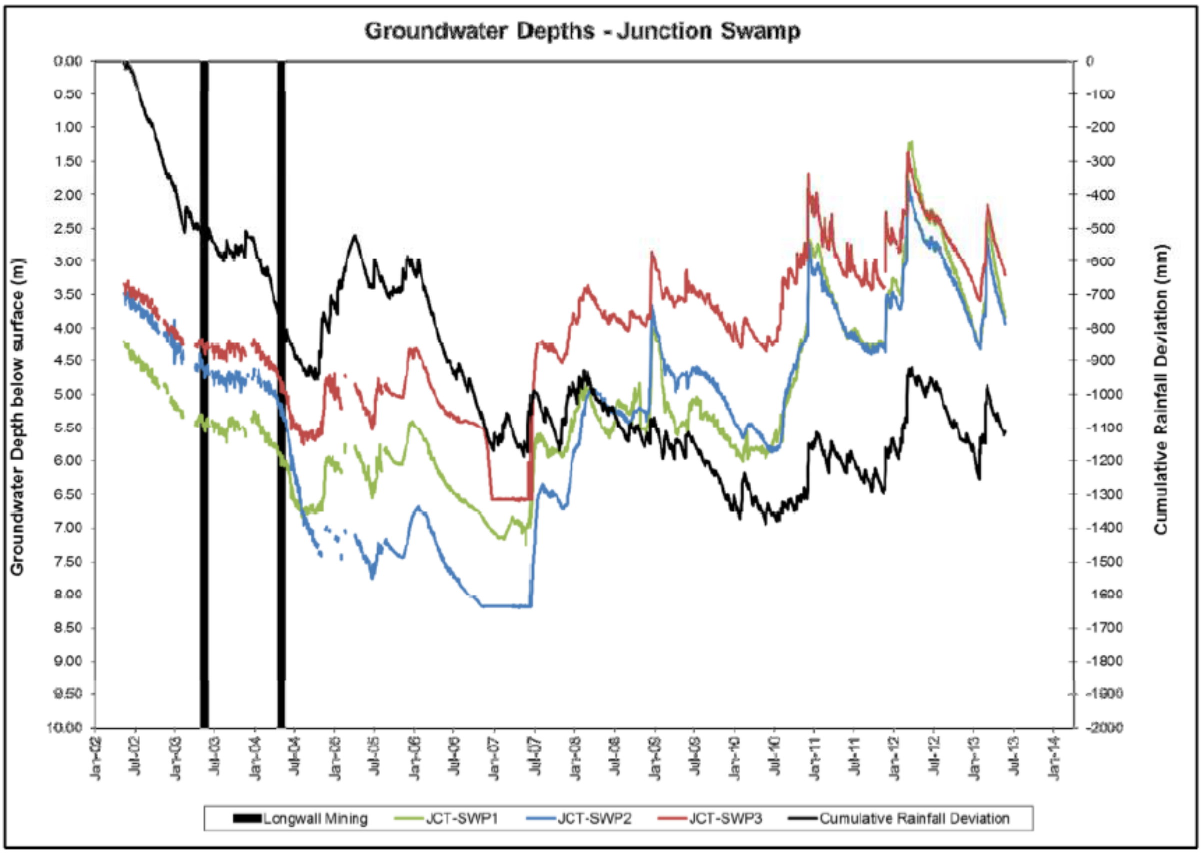
Table 3.5 Junction Swamp: timeline and impact information from available references. (pp47)

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.

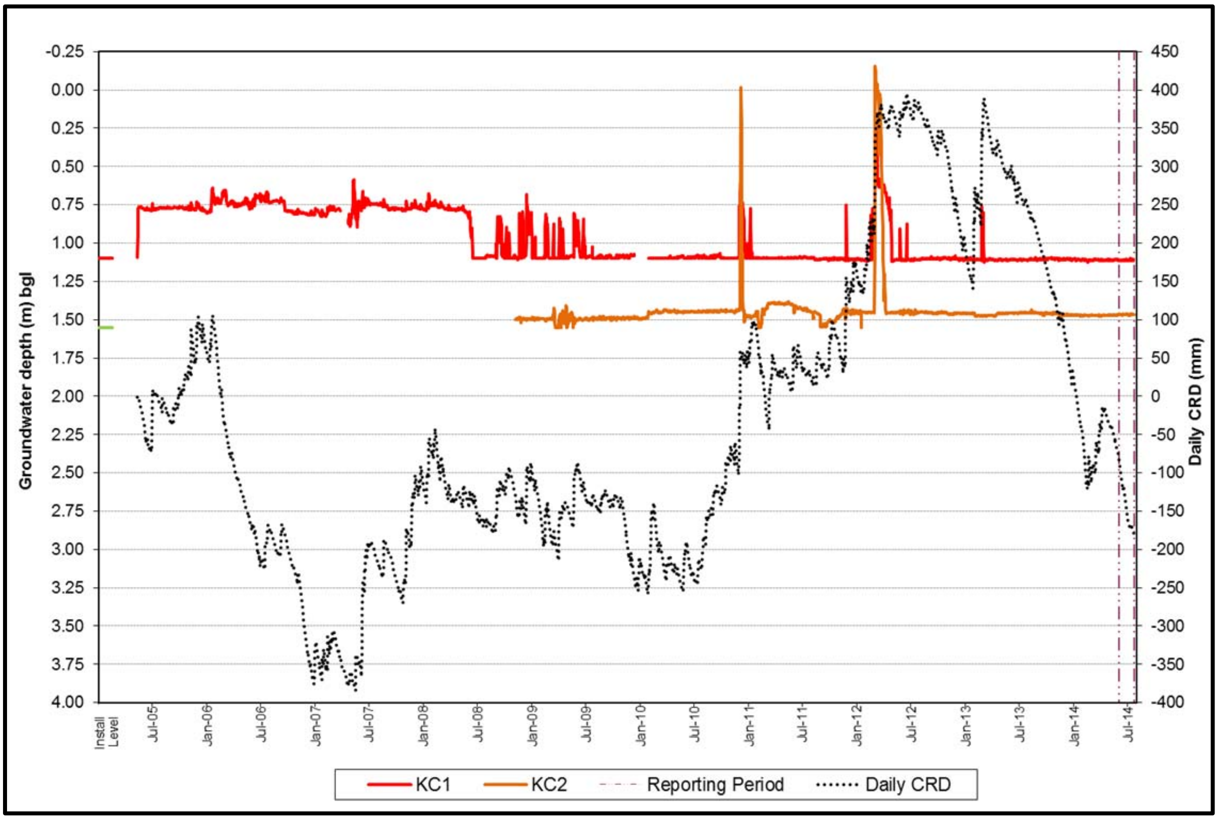


Figure 1 – Kangaroo Creek Piezometer Monitoring Data and Cumulative Rainfall Deviation

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.

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.

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

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.

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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.

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.

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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

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.

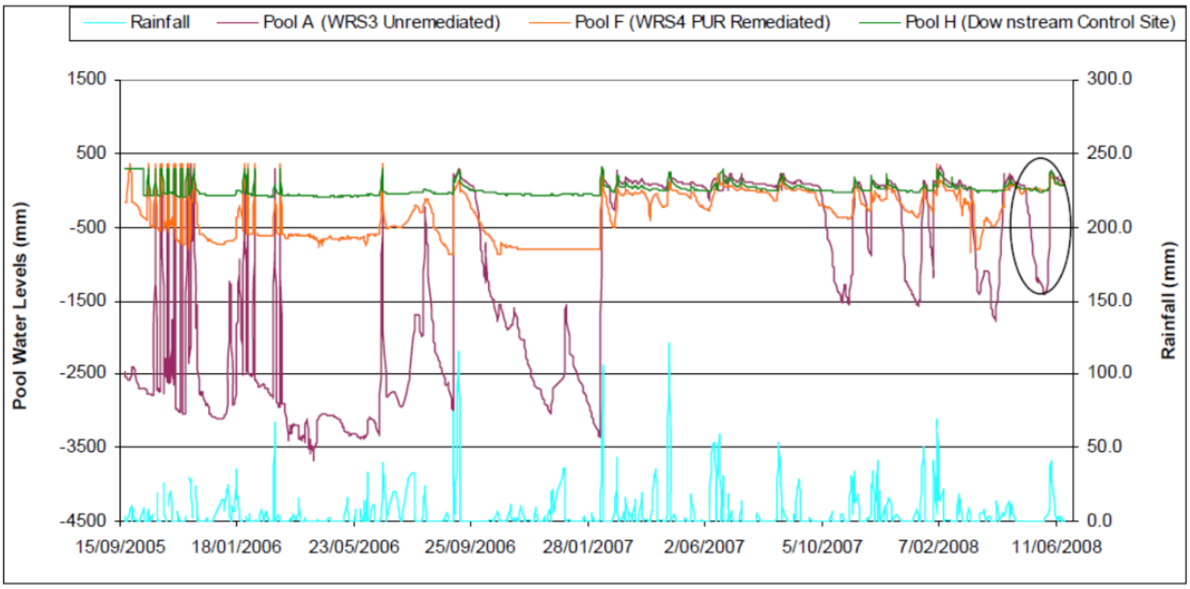
Pool H is located downstream of Pool F and approximately 120m downstream of previous longwall mining activities. The hydrological characteristics of Pool H have not been affected by subsidence. Pool H is a similar size to Pool F and has a similar pool/rock bar morphology.

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

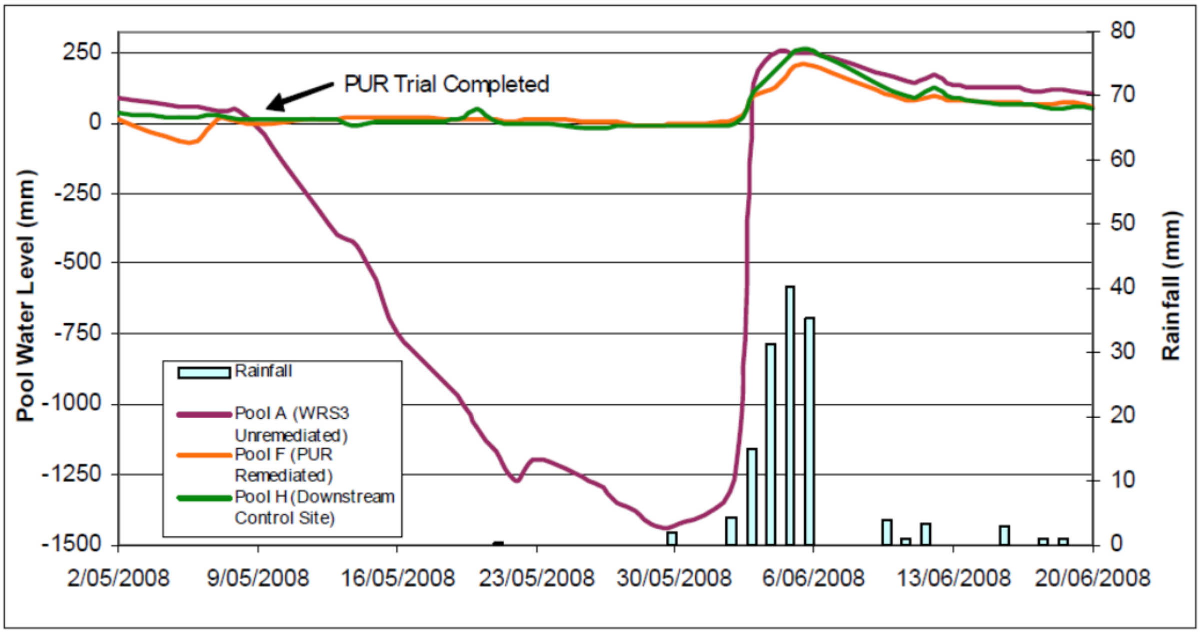


Note: See Graph 2 for further detail of circled data.

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.

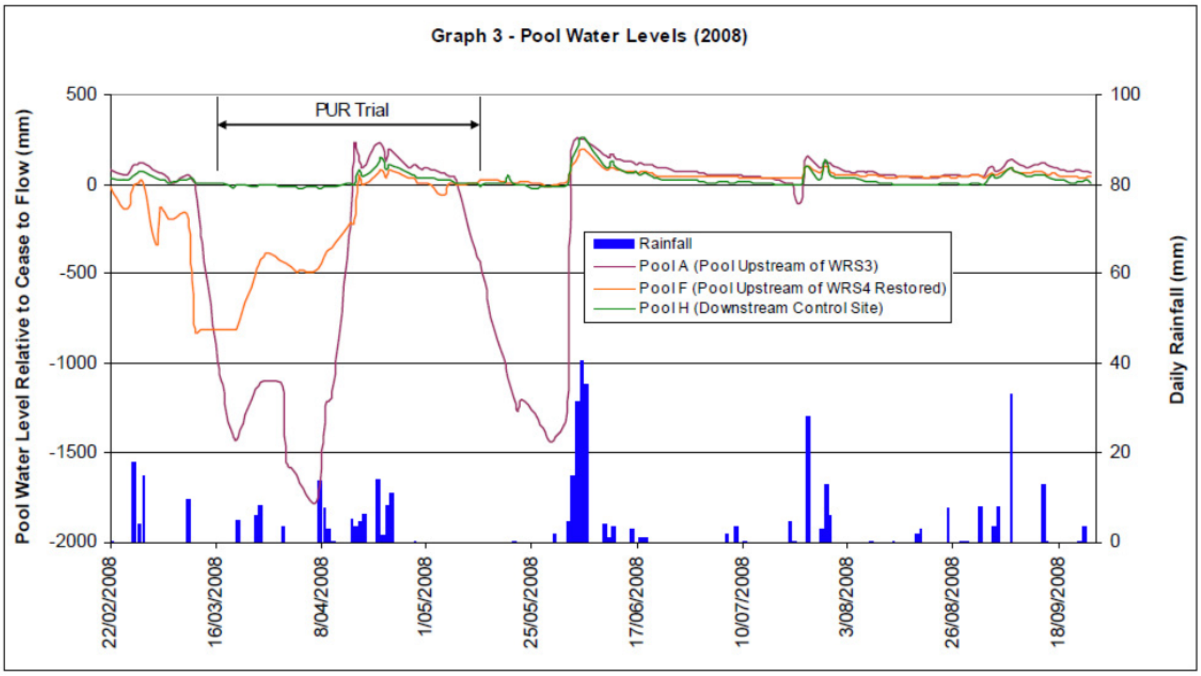
Graph 2 Pool Water Level Responses to PUR Trial



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.

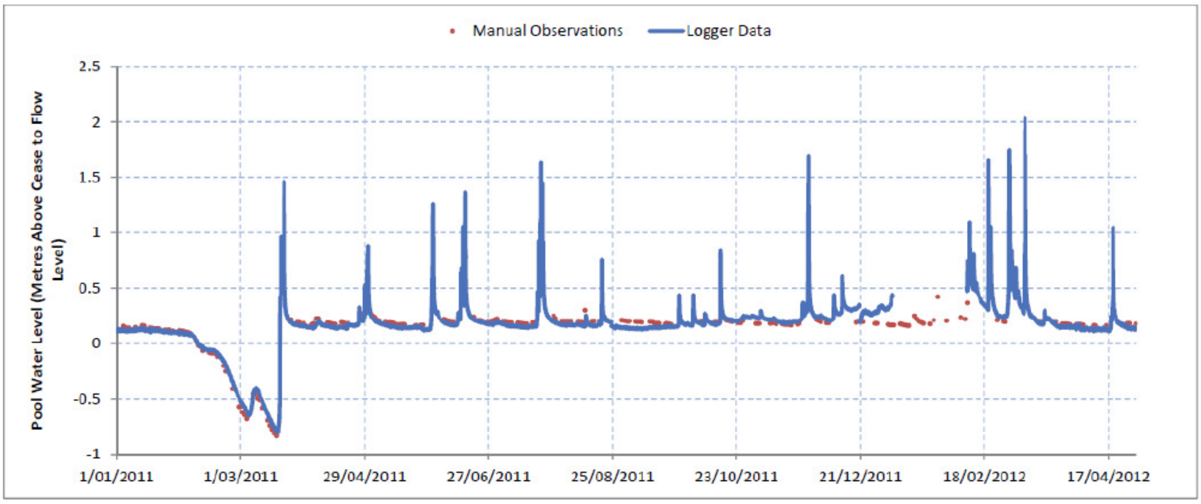


Figure 2 Observed and Recorded Water Level Data for Pool A (1 January 2011 to 3 May 2012)

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.

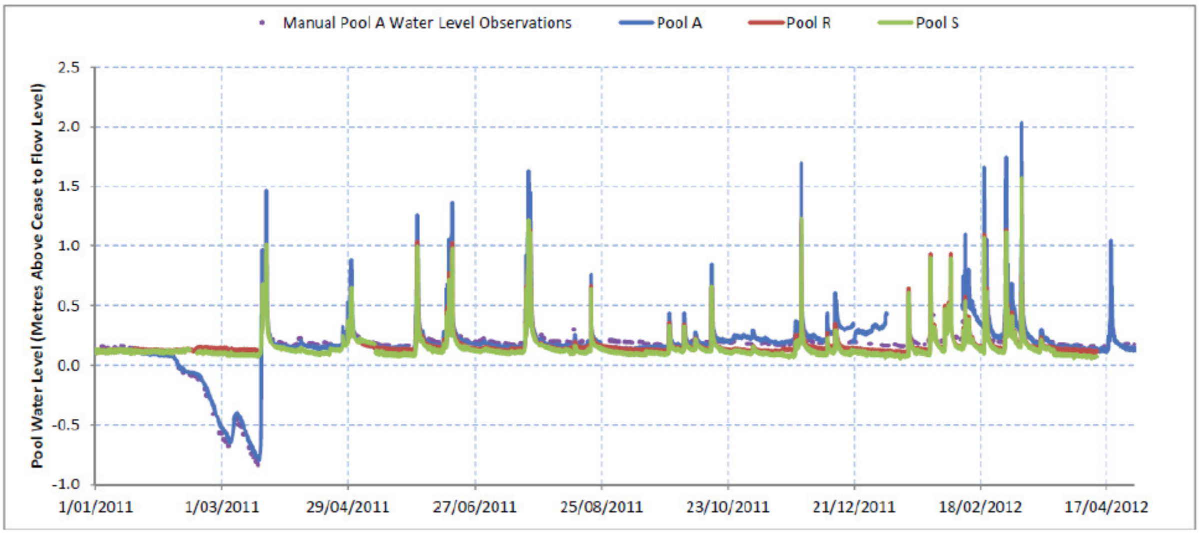


Figure 3 Comparison of Pool A Water Level Hydrograph with Downstream Pools R and S – Waratah Rivulet

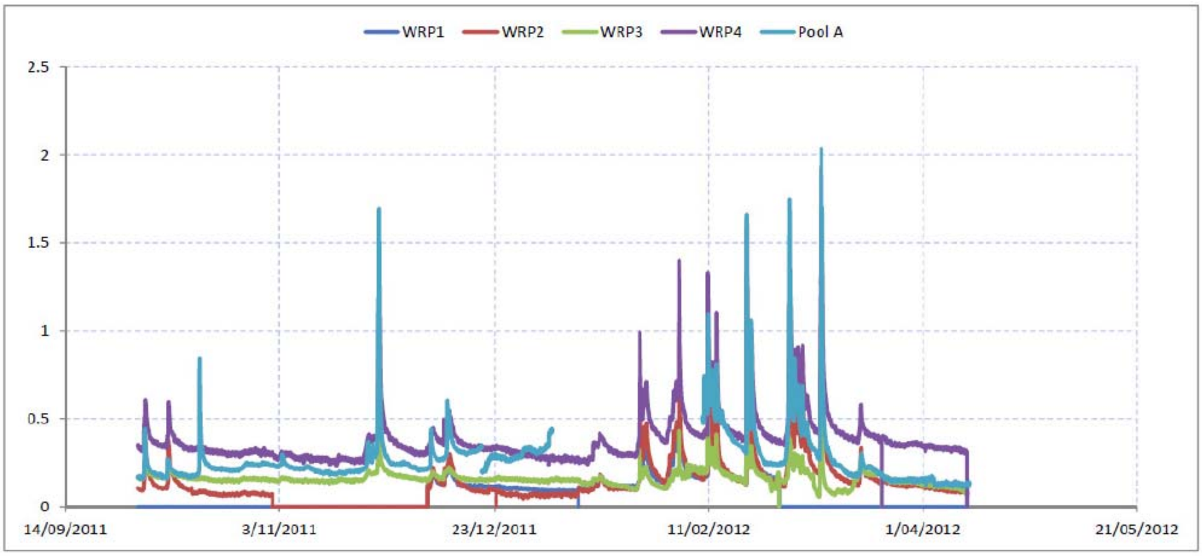


Figure 4 Comparison of Pool A Water Level Hydrograph with Pools WRP1, WRP2, WRP3 and WRP4 on Woronora River"

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)