TAHMOOR UNDERGROUND

GLENCORE

Tahmoor Colliery Longwall 31 Environmental Management Plan

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Authorisation of Management Plan

Authorisation on behalf of Tahmoor Colliery	
Name	Belinda Treverrow
Position	Approvals and Community Coordinator
Signature	
Date	2 November 2017

Approval History

Longwall	Document	Approval Date	Approval Parameters
Longwall 31	Tahmoor Colliery Longwalls 27 to 30 Environmental Management Plan *Revision D*	26 June 2017	Interim approval to 200m
Longwall 31	Tahmoor Colliery Longwalls 27 to 30 Environmental Management Plan *Revision D*	26 July 2017	Interim approval to 400m
Longwall 31	Tahmoor Colliery Longwalls 27 to 30 Environmental Management Plan *Revision D*	30 August 2017	Interim approval to 800m
Longwall 31	Tahmoor Colliery Longwall 31 Environmental Management Plan Revision B	Approval pending	-

1 Introduction

1.1 Background

Tahmoor Colliery is managed and operated by Tahmoor Coal Pty Limited (Tahmoor Colliery). Tahmoor Colliery holds coal and mining leases CCL 716, ML 1539 and ML 1376 encompassing the proposed longwall extraction.

Tahmoor Colliery is located approximately 80 kilometres south-west of Sydney in the township of Tahmoor NSW. It is managed and operated by Glencore Coal Assets Australia. Tahmoor Colliery has previously mined 30 longwalls to the north and west of the mine's current pit top location and it is currently mining Longwall 31 in accordance with current Subsidence Management Plan Approval for the extraction of Longwall 31.

Table 1 Tahmoor Colliery mine schedule

Longwall	Start Date	Completion Date
Longwall 31	July 2017	July 2018

Longwall 31 is a continuation of a series of longwalls that extend into the Tahmoor North Lease area, which began with Longwall 22. The longwall panels are located between the Bargo River in the south-east, the township of Thirlmere in the west and Picton in the north.

A number of natural features have been identified in the active subsidence zone of Longwall 31. In particular Redbank Creek, with pre mining data identifying numerous ferruginous seeps prior to undermining of the Creek.

Redbank Creek flows above Longwalls 31 and towards the north-east, where it joins Stonequarry Creek approximately 830 metres (m) east of proposed Longwall 32, it then drains to the Nepean River. The creek falls approximately 30 metres over a total length of approximately 2,300m, with an average gradient of 13mm/m.

1.2 Objectives

The Environmental Management Plan (EMP) provides detailed information about how Tahmoor Colliery will manage the risks associated with subsiding natural features during the extraction of Longwall 31 and will be updated in consultation with key Government agencies and landowners prior to the influence of future longwalls.

The objectives of this Management Plan are to establish procedures to measure, manage, mitigate and repair potential impacts that might occur to natural features include:

a) Minimising or avoiding impact on the natural environment.

b) Minimising the risk to public safety to within tolerable limits, and;

c) Minimising the level of public disruption and inconvenience.

These objectives will be met by using the following methods:

a) Assessing the potential subsidence impacts to natural features resulting from the proposed mining.

b) Monitoring natural features during mining.

c) In the event that the impacts due to the extraction of Longwall 31 are greater than predicted, implement contingent measures as recommended for natural features

d) Mitigate, remediate and / or compensate potential significant impacts if recommended by qualified consultant.

e) A developed protocol for notification in the event that the impacts of mine subsidence exceed trigger levels.

f) Preparation of a contingency plan for natural features, and

g) Consultation with key landowners and Government agencies.

This Management Plan has been prepared in accordance with the requirements of Condition 12 (Environmental Management Plan) of the *Subsidence Management Plan Approval for Tahmoor Colliery Longwall 31*, dated 3 May 2017.

Figure 1 shows the layout of the current Longwall 31.

Figure 1 Aerial photograph and mine plan

1.3 Scope

The EMP will be used to protect, monitor, remediate and report the condition of natural features identified in the active subsidence zone of Longwall 31. The components covered by this Management Plan addresses subsidence impacts on:

a) Surface Water
   i. Redbank Creek
b) Groundwater
   i. Piezometers
   ii. Mine water
c) Flora and fauna
   i. Aquatic
   ii. Terrestrial
d) Archaeological sites
   i. Aboriginal Cultural Heritage
   ii. European Historical Heritage
e) Any other significant environmental features that may be effected by subsidence resulting from the proposed longwall extraction.

The EMP covers the specified features located within the general active subsidence zone of Longwall 31 as outlined in Section 1.4., but does not include areas outside the extent of the Longwall 31 active subsidence zone.

The EMP applies to all personal employed or engaged by Tahmoor Colliery for the purpose of any item outlined in this Management Plan.

1.4 Definition of Active Subsidence Zone

As a longwall progresses, subsidence begins to develop at a point in front of the longwall face and continues to develop after the longwall passes. The majority of subsidence movement typically occurs within an area 150 metres in front of the longwall face to 450 metres behind the longwall face.

This is termed the “active subsidence zone” for the purposes of this Management Plan.

The active subsidence zone for each longwall is defined by the area bounded by the predicted 20 mm subsidence contour for the active longwall and a distance of 150 metres in front and 450 metres behind the active longwall face, as shown by Figure 2.

Figure 2 Diagrammatic representation of 'active subsidence zone'

1.5 Consultation, Co-operation, Co-ordination

Substantial consultation, co-operation and co-ordination has taken place between Tahmoor Colliery various landowners and Government agencies prior to and during the development of the EMP.

Archaeological site 52-2-3254 Redbank Creek 1 is a shelter with art and deposit located directly above Longwall 29. Tahmoor Colliery received an Aboriginal Heritage Impact Permit (AHIP) Approval on 19 December 2014 from the Office of Environment and Heritage (OEH) and during the preparation of the AHIP Aboriginal stakeholders were consulted throughout the process and are consulted prior to and at the end of each longwall, until written notice is provided to OEH to advise the completion of actions authorised in the AHIP.

Koorana Homestead Complex is a Heritage listed property located above Longwall 32. Tahmoor Colliery, Niche Environment and Heritage (Niche), Mine Subsidence Engineering Consultants (MSEC) and John Matheson and Associates (JMA) have been consulting with the property owner since 2014, during the development of the *Koorana Homestead Statement of Heritage Impact Longwall 31 Structural Investigation Report* and *Tahmoor Colliery Longwall 31 Management Plan for Potential Impacts to the Koorana Homestead Complex.*

Surface Water Remediation in Myrtle Creek is outlined in Section 5 of this Management Plan. A *Corrective Management Action Plan* has been submitted to the Department of Resource and Geoscience (DRG) for a Myrtle Creek remediation Trial Project Site. On approval of the Project Tahmoor Colliery will consult with key Government agencies prior to execution of Stage 1 Trial Project Site works. . For further details refer to *Tahmoor Colliery Corrective Management Action Plan Revision B dated 16 June 2017.*

1.6 Compensation

The Mine Subsidence Compensation Act 1961 (MSC Act) is administered by Subsidence Advisory NSW (Mine Subsidence Board). Currently, under the Mine Subsidence Compensation Act 1961, any claim for mine subsidence damage needs to be lodged with Subsidence Advisory NSW. Subsidence Advisory NSW staff will then assess the damage to determine the cause. If the damage is determined to be attributable to mine subsidence, a scope will be prepared and compensation will be assessed.

Claims lodged with the Subsidence Advisory are for built structures.

2 Subsidence Predictions

2.1 Maximum Predicted Systematic Parameters

Predicted mining-induced conventional subsidence movements were provided in Report No. MSEC647, which was prepared in support of Tahmoor Colliery's SMP Application for Longwalls 31 to 37, and includes predictions due to the extraction of Longwall 31.

A summary of the maximum predicted incremental conventional subsidence parameters, due to the extraction of Longwall 31 only, is provided in Table 2. A summary of the maximum predicted total conventional subsidence parameters, after the extraction of Longwall 31, is provided in Table 3.

Table 2 Maximum Predicted Incremental Conventional Subsidence Parameters Due to Extraction of Longwall 31

Longwall	Maximum predicted incremental subsidence (mm)	maximum predicted incremental tilt (mm/m)	Maximum predicted incremental hogging curvature (1/km)	Maximum predicted incremental sagging curvature (1/km)
Due to LW31	725	5.5	0.06	0.12

Table 3 Maximum Predicted Total Conventional Subsidence Parameters after Extraction of Longwall 31

Longwall	Maximum predicted total subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (1/km)	Maximum predicted total sagging curvature (1/km)
After LW31	1225	6.0	0.09	0.13

The values provided in the above table are the maximum predicted cumulative conventional subsidence parameters which occur within the general longwall mining area, including the predicted movements resulting from the extraction of Longwalls 22 to 31.

2.2 Observed Subsidence during Mining Longwalls 22 to 30

The extraction of longwalls at Tahmoor Colliery has generally resulted in mine subsidence movements that were typical of those observed above other collieries in the Southern Coalfield of NSW at comparable depths of cover.

However, observed subsidence was greater than the predicted values over Longwalls 24A and the southern parts of Longwalls 25 to 27. Monitoring during the mining of Longwalls 28 to 30 has found that subsidence behaviour has returned to normal levels.

Ground surveys will continue to be undertaken above Longwall 31. The survey results will be checked against predictions to confirm whether subsidence continues to develop in a normal manner during the mining of Longwall 31.

2.3 Predicted Strain

The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. The reason for this is that strain is affected by many factors, including curvature and horizontal movement, as well as local variations in the near surface geology, the locations of pre-existing natural joints at bedrock, and the depth of bedrock. Survey tolerance can also represent a substantial portion of the measured strain, in cases where the strains are of a low order of magnitude. The profiles of observed strain, therefore, can be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

In previous MSEC subsidence reports, predictions of conventional strain were provided based on the best estimate of the average relationship between curvature and strain. Similar relationships have been proposed by other authors. The reliability of the strain predictions was highlighted in these reports, where it was stated that measured strains can vary considerably from the predicted conventional values.

Adopting a linear relationship between curvature and strain provides a reasonable prediction for the conventional tensile and compressive strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Southern Coalfield, it has been found that a factor of 15 provides a reasonable relationship between the maximum predicted curvatures and the maximum predicted conventional strains.

At a point, however, there can be considerable variation from the linear relationship, resulting from non-conventional movements or from the normal scatters which are observed in strain profiles. When expressed as a percentage, observed strains can be many times greater than the predicted conventional strain for low magnitudes of curvature. In this Report, therefore, we have provided a statistical approach to account for the variability, instead of just providing a single predicted conventional strain.

The data used in an analysis of observed strains included those resulting from both conventional and non-conventional anomalous movements, but did not include those resulting from valley related movements, which are addressed separately in this Report. The strains resulting from damaged or disturbed survey marks have also been excluded.

A number of probability distribution functions were fitted to the empirical data. It was found that a *Generalised Pareto Distribution (GPD)* provided a good fit to the raw strain data. Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during a longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay).

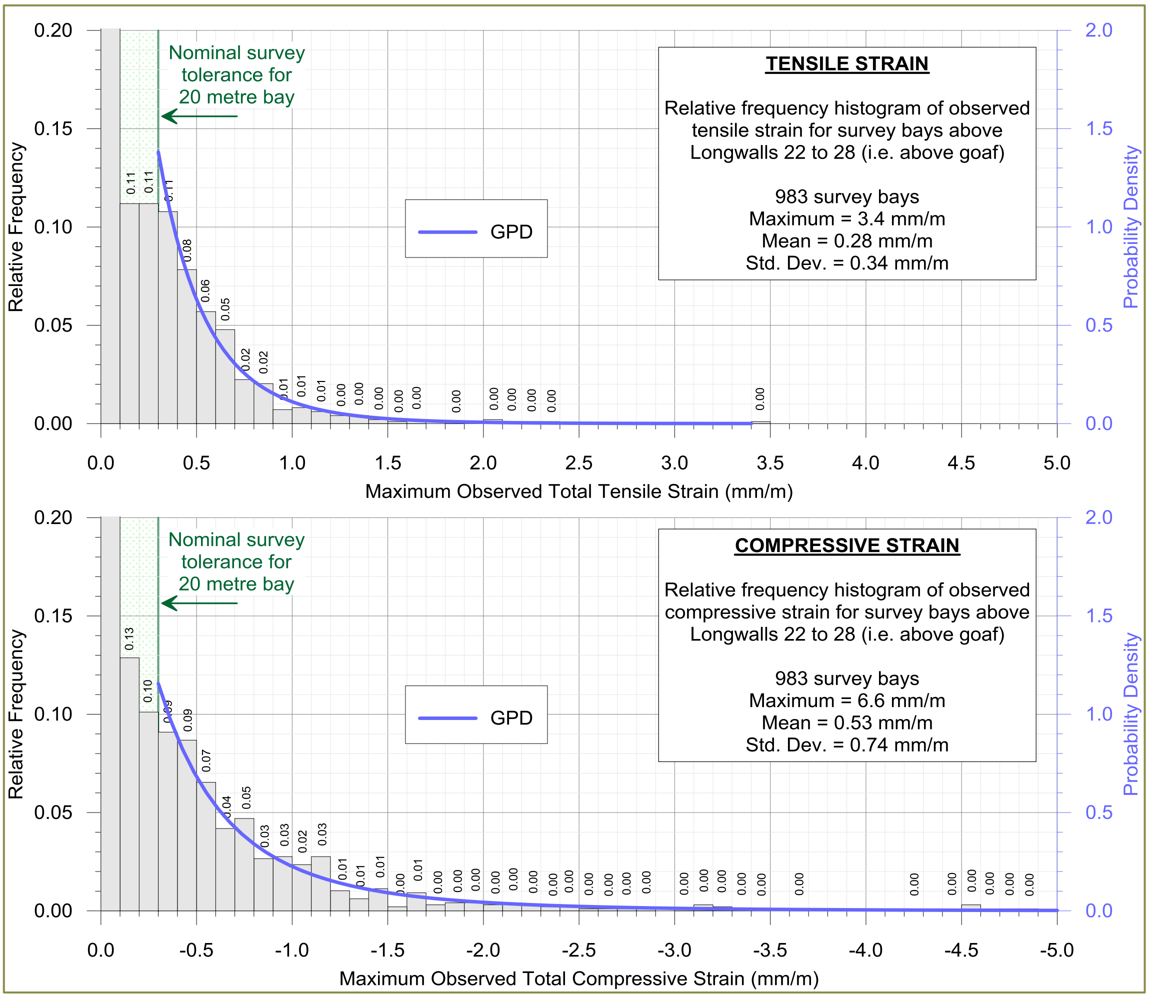

Figure 3 Distributions of the measured maximum tensile and compressive strains for surveys bays located above goaf

The 95 % confidence levels for the maximum total strains that the individual survey bays *above goaf* experienced at any time during mining are 0.9 mm/m tensile and 1.8 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays *above goaf* experienced at any time during mining are 1.5 mm/m tensile and 3.5 mm/m compressive.

2.4 Predictions of Strain above Solid Coal

The survey database has also been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of Longwalls 22 to 28 at Tahmoor Colliery, for survey bays that were located outside and within 200 metres of the nearest longwall goaf edge, which has been referred to as "*above solid coal*".

The histogram of the maximum observed tensile and compressive strains measured in survey bays above solid coal at Tahmoor Colliery is provided in Figure 4. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

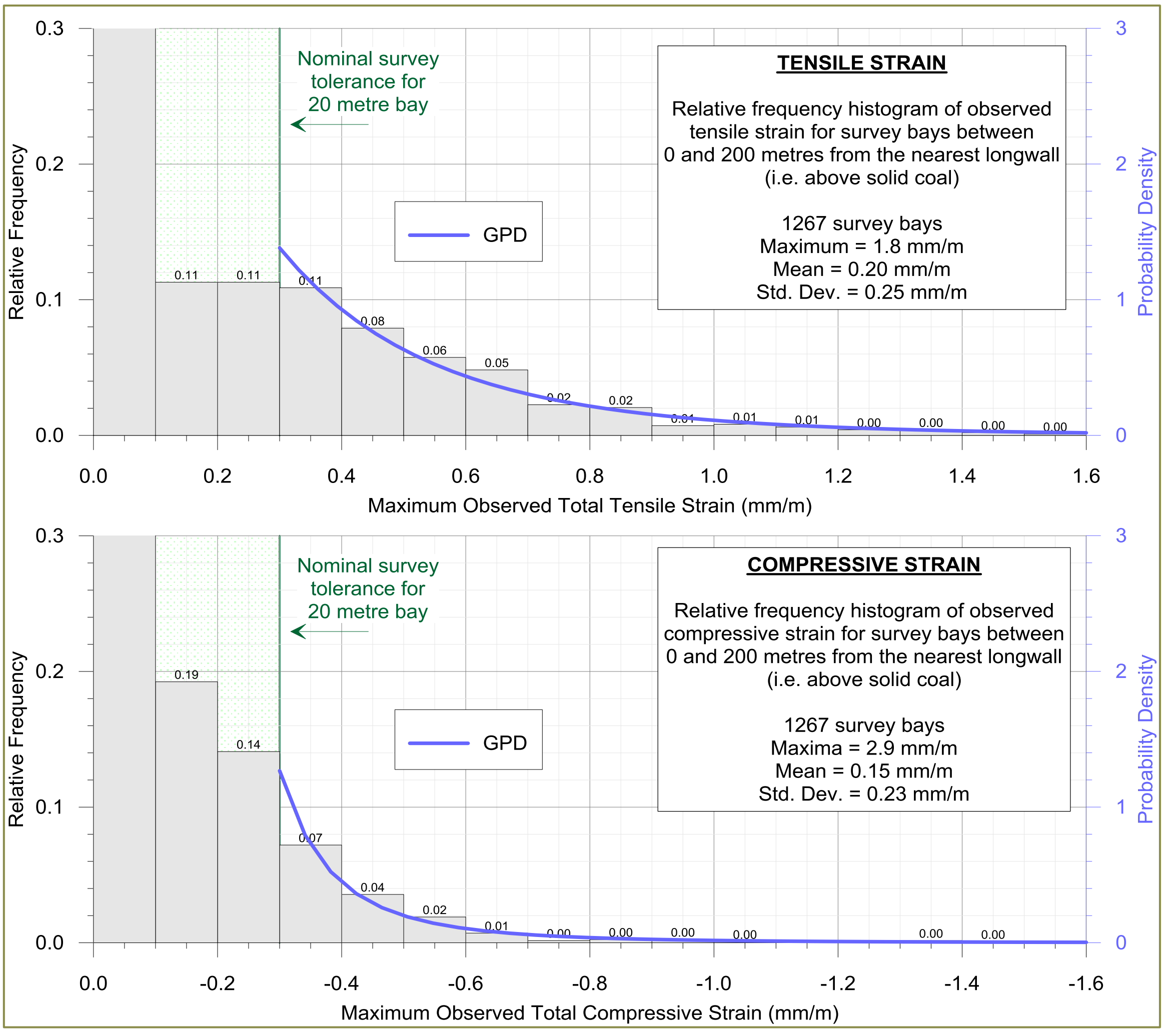

Figure 4 Distributions of the measured maximum tensile and compressive strains for survey bays located above solid coal

The 95% confidence levels for the maximum total strains that the individual survey bays *above solid coal* experienced at any time during mining are 0.6 mm/m tensile and 0.5 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays *above solid coal* experienced at any time during mining are 1.1 mm/m tensile and 0.9 mm/m compressive.

2.5 Analysis of Strains Measured Along Whole Monitoring Lines

For linear features such as roads, cables and pipelines, it is more appropriate to assess the frequency of the maximum observed strains along whole monitoring lines, rather than for individual survey bays. That is, an analysis of the maximum strains measured anywhere along the monitoring lines, regardless of where the strain actually occurs.

The histogram of maximum observed total tensile and compressive strains measured anywhere along the monitoring lines, at any time during or after the extraction of Longwalls 22 to 28 at Tahmoor Colliery, is provided in Figure 5.

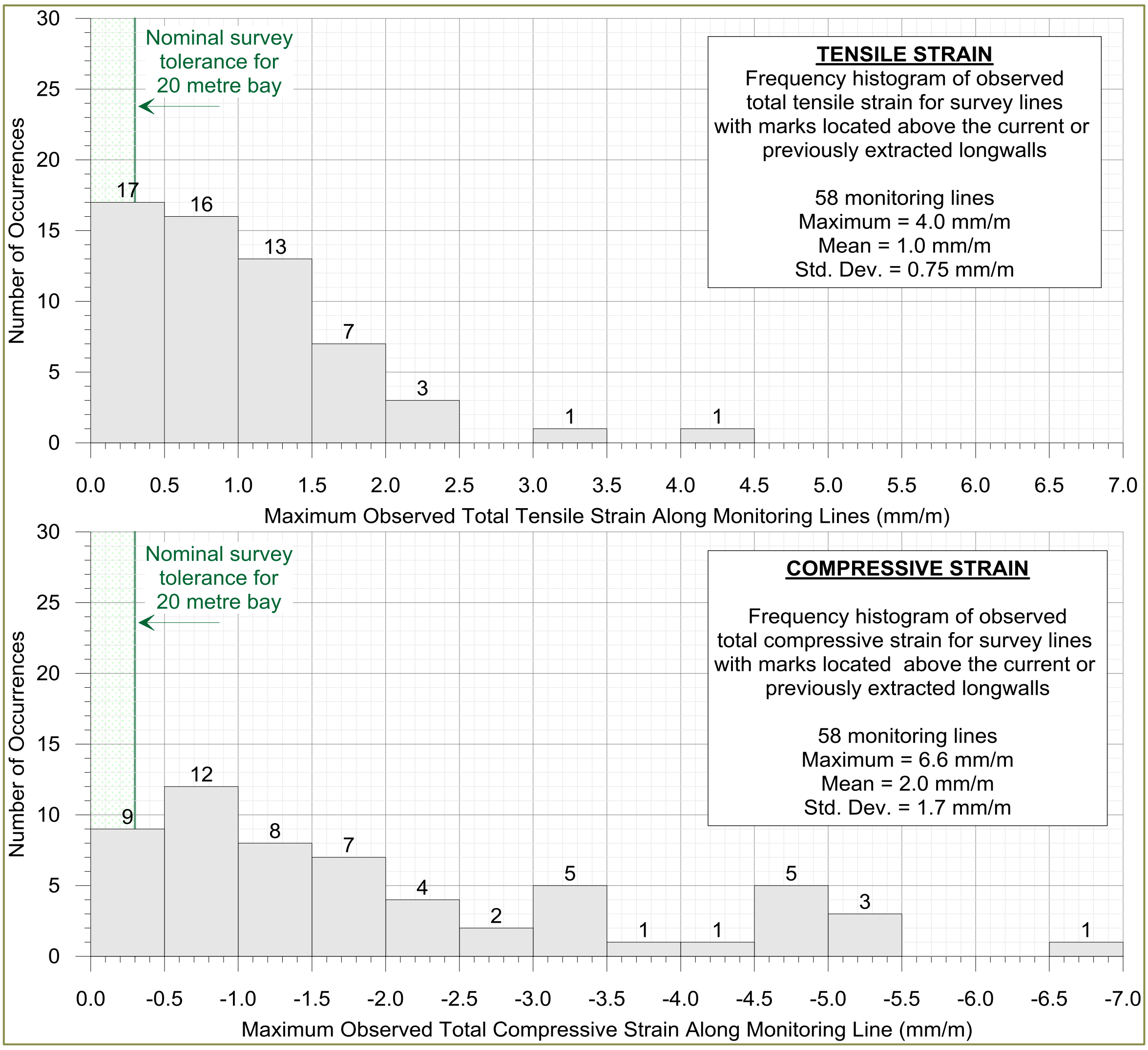

Figure 5 Distributions of measured maximum tensile and compressive strains anywhere along the monitoring lines

It can be seen from Figure 5, that 33 of the 58 monitoring lines (i.e. 57 %) had recorded maximum total tensile strains of 1.0 mm/m, or less, and that 53 monitoring lines (i.e. 91 %) had recorded maximum total tensile strains of 2.0 mm/m, or less. It can also be seen from this figure, that 36 of the 58 monitoring lines (i.e. 62 %) had recorded maximum compressive strains of 2.0 mm/m, or less, and that 48 of the monitoring lines (i.e. 83 %) had recorded maximum compressive strains of 4.0 mm/m, or less.

2.6 Predicted and Observed Valley Closure across Creeks

The valley related movements for the streams have been predicted using the empirical method outlined in ACARP Research Project No. C9067 (Waddington and Kay, 2002), referred to as the 2002 ACARP method. The predicted upsidence and closure movements for Redbank Creek are provided in Chapter 4.

The valley closure movements along Redbank Creek due to the extraction of Longwalls 26 to 30 have been measured using the two 3D ground monitoring lines that are located along the alignment and on either side of the creek. The BC-Line follows Bridge Street on the western side of Redbank Creek and the RK-Line is located on the eastern side of the creek. The locations of these two monitoring lines are shown in Figure 6.

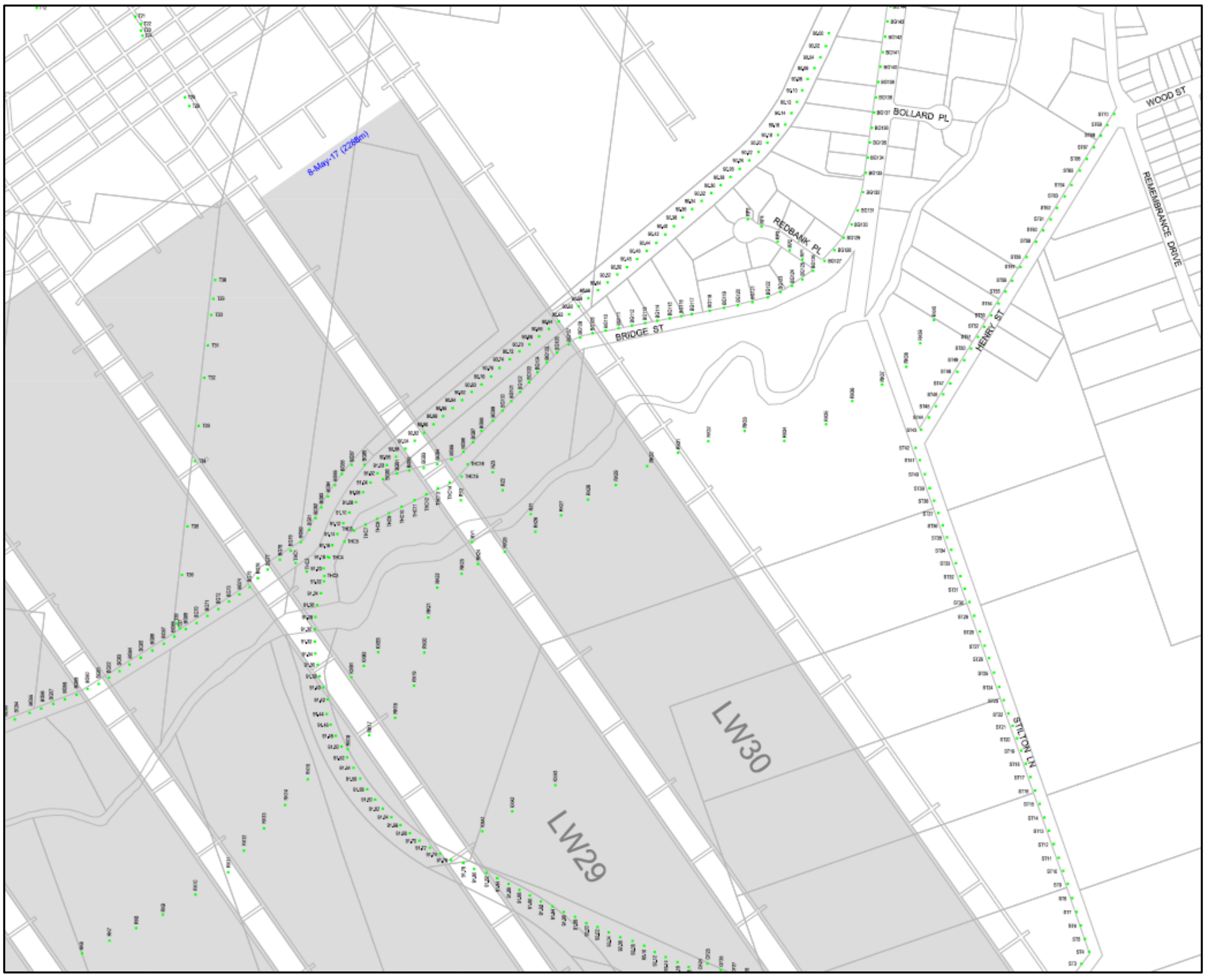

Figure 6 Ground monitoring lines adjacent to Redbank Creek

The valley closure movements along Redbank Creek have been determined from the changes in distance between the corresponding survey marks along the two survey lines located either side of the creek. The comparison between the measured and predicted total closure for Redbank Creek due to the extraction of Longwalls 26 to 30 is shown at the top of Figure 7. The measured and predicted incremental closure for the creek due to Longwall 30 only is shown at the bottom of this figure.

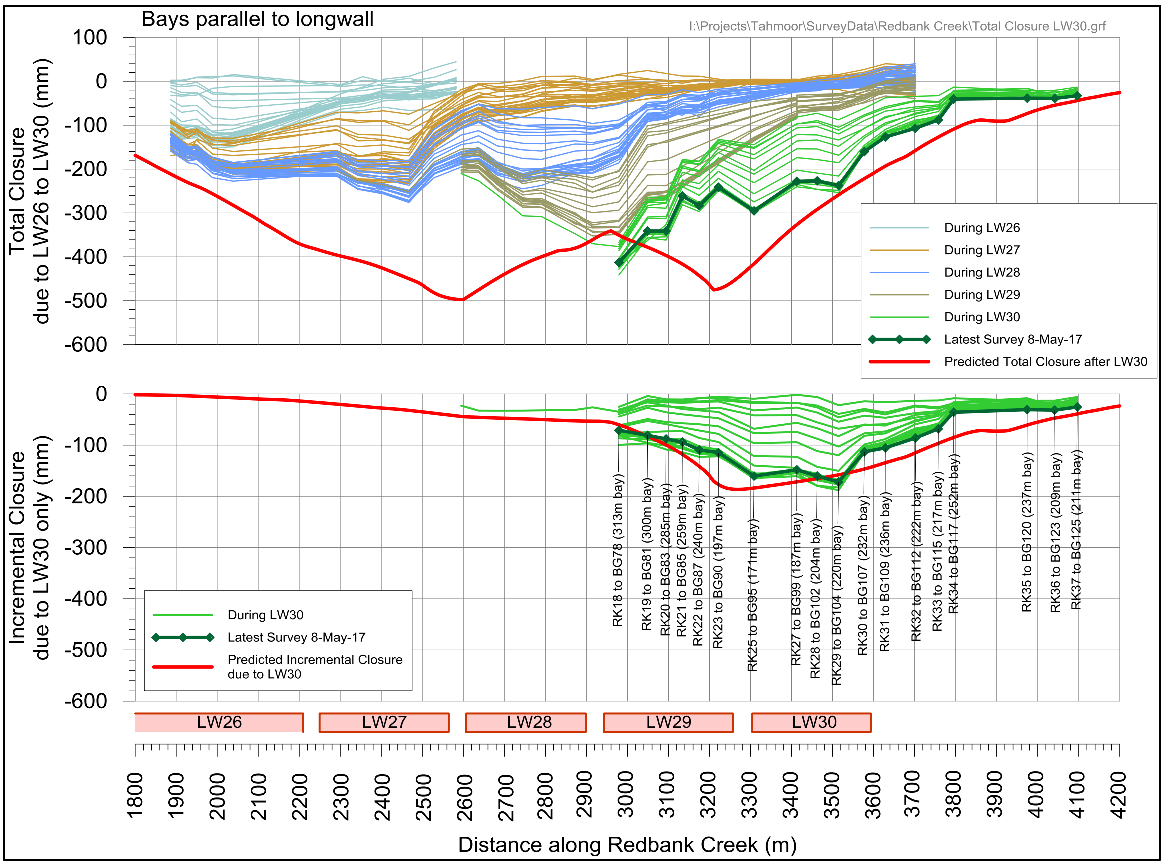

Figure 7 Measured and predicted valley closure along Redbank Creek

The maximum measured total and incremental closure movements are less than the maximum predicted values along Redbank Creek. The profiles of the measured total and incremental closure movements above Longwalls 29 and 30 reasonably match the predicted profiles. The total closure measured above the chain pillar between Longwalls 28 and 29 is slightly greater than the predicted total closure in that location, however, it is less than the maximum predicted values above the two adjacent chain pillars.

It is considered, therefore, that the valley closure movements measured along Redbank Creek are consistent with the predicted valley closure movements obtained using the 2002 ACARP method.

3 Risk Management Method

3.1 NSW Work Health & Safety Legislation

All persons conducting a business or undertaking (PCBUs), including mine operators and contractors, have a primary duty of care to ensure the health and safety of workers they engage, or whose work activities they influence or direct. The responsibilities are legislated in *Work Health and Safety Act 2011* and the *Work Health and Safety (Mines) Act 2013* and associated Regulations (collectively referred to as the 'WHS laws').

The Work Health and Safety (Mines) Regulation 2014 commenced on 1 February 2015 and contains specific regulations in relation to mine subsidence.

As outlined in the Guide by the NSW Department of Trade & Investment Mine Safety:

"a PCBU must manage risks to health and safety associated with mining operations at the mine by:

a) *complying with any specific requirements under the WHS laws*

b) *identifying reasonably foreseeable hazards that could give rise to health and safety risks*

c) *ensuring that a competent person assesses the risk*

d) *eliminating risks to health and safety so far as is reasonably practicable*

e) *minimising risks so far as is reasonably practicable by applying the hierarchy of control measures*

f) *any risks that it is are not reasonably practical to eliminate*

g) *maintaining control measures*

h) *reviewing control measures*

The mine operator's responsibilities include developing and implementing a safety management system that is used as the primary means of ensuring, so far as is reasonably practicable:

a) the health and safety of workers at the mine, and

b) that the health and safety of other people is not put at risk from the mine or work carried out as part of mining operations."

The *Tahmoor Colliery Longwall 31 Management Plan for Potential Impacts to the Koorana Homestead Complex* documents the risk control measures that are planned to manage risks to health and safety associated with the mining of Longwall 31 adjacent to the Koorana Homestead Complex in accordance with the WHS laws. Refer to the above mentioned Management Plan for Risk Management relating to the Koorana Homestead Complex.

Prior to active subsidence a *Management Plan for Potential Impacts to Mill Hill* will be developed to documents the risk control measures that are planned to manage risks to health and safety associated with the mining of Longwall 31 adjacent to the Koorana Homestead Complex in accordance with the WHS laws. The above mentioned Management Plan will be developed in accordance with the above WHS laws and Risk Management Procedures will be referred to in the Management Plan.

4 Potential Subsidence Impacts

4.1 Surface Water

4.1.1 Myrtle Creek

Myrtle Creek will not be undermined by Longwall 31 and is not discussed further in this section.

4.1.2 Redbank Creek

Redbank Creek will be directly mined beneath by Longwall 31.

Redbank Creek flows over predominantly Hawkesbury Sandstone bedrock with natural iron hydroxide containing seepage flowing into the creek, resulting in red colouration of the banks and pools.

The main channel of Redbank Creek within the Longwall 31 active subsidence zone is developed principally for industrial use (on the northern bank), with lesser residential and semi-rural residential development on the fringes of Thirlmere (on the southern bank). Agricultural land on the outskirts of the town is used for orchards, vegetable green houses, as well as limited cattle and horse grazing.

The stream bed and banks are generally well vegetated with predominantly native vegetation intermixed with weeds, and do not show significant erosion or bank instability, although significant cracking of sandstone and dislocated blocks of subsidence fractured sandstone are present in and downstream of previously subsided stream reaches (GeoTerra 2017).

Redbank Creek flows above Longwalls 31 and towards the north-east, where it joins Stonequarry Creek approximately 830 metres (m) east of proposed Longwall 32, it then drains to the Nepean River. The creek falls approximately 30 metres over a total length of approximately 2,300m, with an inferred average gradient of 13mm/m.

A summary of the maximum predicted values of cumulative subsidence, upsidence and closure anywhere along these creeks within the SMP Area, after the extraction of Longwall 31, is provided in MSEC (2014).

Table 4 Maximum predicted cumulative subsidence, upsidence and closure in Redbank Creek resulting from extraction of Longwall 31

Drainage Line	Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Upsidence (mm)	Maximum Predicted Cumulative Closure (mm)
Redbank Creek	After LW31	1250	525	575

The maximum predicted upsidence and closure movements in the above table are the maximum values which occur within the predicted limits of 20 mm additional upsidence and 20 mm additional closure due to the extraction of Longwall 31, as well as Longwalls 22 to 30.

4.1.2.2 Shallow Groundwater Hydrological Investigation

Prior to mining beneath Redbank Creek, Tahmoor Colliery submitted Stage 1 of the *Shallow Groundwater Hydrological Management Plan* which included the scope of work for the installation of 2 boreholes. The installation of the boreholes was required to be able to characterise the pre-mining lithology and shallow groundwater in Redbank Creek.

This information has been recorded and Stage 2 of *Shallow Groundwater Hydrological Management Plan* will obtain the results. The Management Plan is prepared in accordance with condition 13 of the Tahmoor Colliery Longwall 31 SMP Approval and will be submitted to the Director ESU for approval.

Figure 8 Redbank Creek – shallow groundwater investigation; borehole location

4.1.3 Change of Grade Affecting Pool Levels

No reversal of flow, increased levels of ponding or increased levels of scouring have been observed in Redbank Creek during the mining of Longwalls 22 to 30. This is because the mining induced tilts are significantly smaller than the natural creek gradients. A similar outcome is expected to occur along Redbank Creeks due to mining Longwall 31.

The maximum predicted changes in grade along the alignments of Redbank Creek is 6 mm/m (i.e. 0.6 %).

The natural grade along the alignment of Redbank Creek within the general SMP Area varies between 5 mm/m and 40 mm/m, with an average natural grade of 15 mm/m. (MSEC, 2014).

The predicted systematic tilts along the alignments of the creek is small compared to the existing natural grades and are unlikely, therefore, to result in any significant increases in the levels of ponding, flooding or scouring.

The creek has perennial, although highly variable, stream flow over Longwall 31 and partially serves as drainage conduit for runoff from the industrial, urban and rural areas within the creek catchment in Thirlmere.

As a result of the generally moderate flow and low gradient, it is assessed that the small changes in grade imposed by subsidence will have an insignificant effect terrestrial and aquatic habitat of Redbank Creek over Longwall 31.

4.1.4 Raising Flood Levels above Building or House Floor Levels

A Flood Study was prepared by Calibre Consulting (2015) to determine if mine subsidence within the area would have a significant impact on all building floor levels previously identified as at risk of flooding. The flood modelling demonstrated that mine subsidence within the area has had no significant impact on the flood immunity of properties or tangible impact on flood related damages up to and including the 100 year ARI event.

4.1.5 Creek Bed Fracturing

The measured valley closure movements along Redbank Creek are similar to, but slightly less than the predicted valley closure. The comparison between the measured and predicted closure movements for this creek are provided in Section 2.5.

Overall, there have been adverse effects on pool depth and longevity, connected stream flow and water quality in Redbank Creek over the subsided longwalls after extraction of Longwalls 25 to 30.

Regular visual inspections have identified subsidence related cracking of numerous sandstone rockbars and rock shelves in Redbank Creek above Longwalls 26 to 31, which has affected pool water levels and pool longevity upstream of the affected rockbars, as well as generating disconnected stream flow.

In addition, new ferruginous springs have been generated, reduced or relocated downstream, which sequentially change location downstream as the longwalls advance down the gradient of the creek (GeoTerra 2017).

It is anticipated that additional fracturing may occur in the creek bed as a result of mining Longwall 31 with similar associated effects on pools and stream flow over Longwall 31 and for up to 250m downstream of Longwall 31.

Some subsidence related fractures may not be visible, however, due to sediment and vegetation cover within and on the banks of the creek.

4.1.6 Surface Water Flow Diversion beyond Natural Levels

As stream bed fracturing and surface flow diversions have been observed over Longwalls 25 to 30, sandstone stream bed fracturing and surface water flow diversion could occur in Redbank Creeks over and downstream of Longwall 31 during and after extraction of Longwall 31.

Compressive strains due to closure are expected to be sufficient to potentially cause the underlying strata to dilate and buckle and induce cracking in the stream bed at some locations which could lead to additional diversion of water from the creek bed into dilated strata beneath it.

It is unlikely, however, based on previous observations over Longwalls 25 to 30 that there will be any net loss of water from the catchment since re-directed flow has previously emerged further downstream (GeoTerra 2017).

If significant stream bed fracturing occurs, it is possible that partial or complete loss of pool standing water levels and connected stream flow may occur in some stream reaches if the rate of diversion exceeds upstream inflow.

In times of heavy rainfall, the majority of runoff flows on / in the creek bed, in addition to the diverted flow within subsidence related dilated strata below the creek bed. In times of low flow, however, some or all of the stream flow is diverted into the dilated / fractured strata below the creek bed, with no overland flow which affects the quantity and quality of observable water flowing in the creek.

Sediments in some sections of the creek cover the sandstone bedrock and any fractures that occur are unlikely to be visible.

Bedrock is exposed in some sections of the creek and fractures may be visible in these locations, including in pools with controlling rockbars where fracturing and surface water flow diversion may occur through the rockbars.

Remediation of fractured rockbars has been successfully undertaken at other streams in the Southern Coalfield (DoP, 2008). Tahmoor Colliery is seeking to remediate sections of the Myrtle and Redbank Creeks to restore permanent water to selected stream reaches and / or pools, and restore associated groundwater levels. Project execution of the initial Trial Project in Myrtle Creek over Longwall 27 is planned to begin in 2017. On completion of these works the effectiveness will be assessed for the appropriate approach and implementation at future sites within Myrtle and Redbank Creeks.

4.1.7 Creek Bed and Bank Erosion and Bed Load Movement

Cracking of creek beds and banks can create new surface water conduits and therefore subsidence may induce minor bed or bank erosion (GeoTerra, 2017). The potential for creek bed and bank erosion of sediments, however, is considered to be unlikely as the majority of cracking is observed within exposed sandstone in the creek bed and pool sides.

Dislocation of fractured / dilated sandstone sheets from subsided sections of the creek has been observed over Longwalls 26 to 30, and it is possible the same will occur after / over extraction of Longwall 31.

If erosion occurs in the creek, it may cause a minor increase in potential bed load movement (GeoTerra, 2017). If erosion and bed load movement occurs, remediation may be required.

4.1.8 Stream Water Quality

Numerous pre-mining ferruginous seeps have been observed in Redbank Creek over Longwalls 25 to 31 prior to the sites being undermined.

If an adverse change in stream water quality occurs through development of an isolated new, or change to an existing ferruginous spring occurs, it is anticipated based on previous observations in the creek that the effect will be localised around the point of discharge and will not adversely affect the overall water quality discharging out of the subsided stream reach, outside of a minor increase in salinity.

The water quality in the creek is highly variable and depends on the amount of flow in the creek at any one time.

4.1.9 Private Dams

To date, a limited number of dams undermined by Longwalls 22 to 30 have been impacted by subsidence with their water holding capacity being effected. Subsidence Advisory NSW has repaired dams that have been impacted by subsidence.

On the basis that the proposed mine plan and geomorphological characteristics of the proposed longwalls and the overlying dams are similar to previously undermined areas, it is not anticipated that any significant adverse effects on dams due to undermining will be observed. However, if their water holding capacity is affected, Subsidence Advisory NSW will assess the impact and compensate the landholder if the impact is due to mining.

4.2 Groundwater

Registered water supply bores used for domestic garden supply (GeoTerra, 2017) along with vibrating wire and open standpipe piezometers are located within the Longwall 25 to 31 subsidence area as summarised below and shown in Figure 8:

a) Open standpipe piezometers and bores: P1 to P3, 67570 (P4), GW63525 (P5), P6 to P8, as well as GW105254, 105813, 107918, 109010 and GW109224.

b) Vibrating wire piezometer arrays TNC 36, 40 and 43.

The potential for adverse impacts on groundwater and baseflow seeps as a result of mine subsidence is summarised in the Section 3.2.2 Levels and Section 3.2.3 Quality.

Near surface ground water levels may be affected by mine subsidence. Any property owner that has a registered borehole impacted by subsidence is connected to town water by Tahmoor Colliery until Subsidence Advisory NSW repair the bore.

4.2.1 Levels

This section refers to groundwater levels and bore yields greater than 20 m below ground level. In relation to aquifer / aquitard interconnection, from past experience in the Tahmoor / Thirlmere area and the greater Southern Coalfield, it has been assessed that hydraulic connection of surface water or alluvial groundwater systems is not likely at mining depths of cover greater than 150m (GeoTerra, 2017).

A temporary lowering of the regional piezometric surface over the subsidence area due to horizontal dilation of strata may occur due to the increase in secondary porosity and permeability.

This effect will be more notable directly over the area of greatest subsidence and dilation, and will dissipate laterally out to the edge of the subsidence zone.

Based on previous observations in the Mine Lease area and the greater Southern Coalfields, groundwater levels may reduce by up to 15 metres and may stay at that reduced level until maximum subsidence develops at a specific location.

The duration of the reduced level depends on the time required to develop maximum subsidence, the time for subsidence effects to migrate away from a location as mining advances to subsequent panels, and the length of time required to recharge the secondary voids.

A gradual recovery over a period of years is currently occurring in previously subsided bores in the Tahmoor Colliery Mining Lase area.

4.2.2 Quality

The local groundwater bores are currently used for domestic garden supply, with the water quality being suitable for selected livestock and limited irrigation use, but not potable water.

No adverse changes to groundwater quality of subsided bores or piezometers have been observed during the mining of Longwalls 25 to 30, apart from minor increases in dissolved iron.

Reduction in groundwater quality is, however, possible.

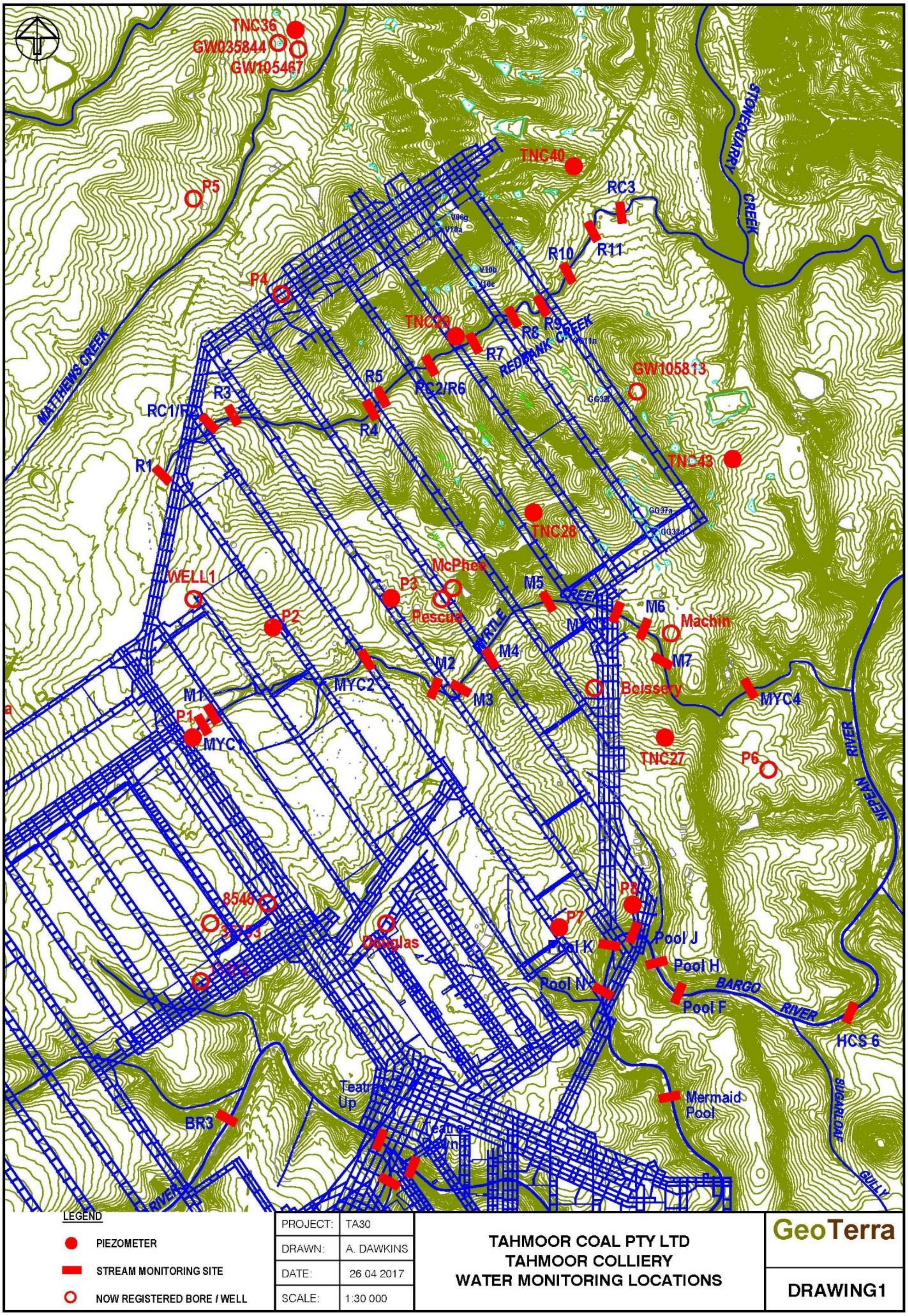

Figure 9 Location of groundwater and exploration bores

4.2.3 Upland Spring Induction

Subsidence in upland areas can cause increased separation between bedding planes in the Hawkesbury Sandstone as well as the interface between Wianamatta Shale and Hawkesbury Sandstone lithologies. This can increase fracture and / or interface drainage of shallow groundwater which in turn can alter baseflow drainage to creeks. As a result, outflow from subsidence affected areas can appear as either more saline and / or more ferruginous seeps, whilst existing seepage outflows may be relocated down gradient in the stream channel.

Bacterial action in the interstitial spaces can cause enhanced iron / manganese concentrations in water that exits in these induced springs.

Numerous pre-mining ferruginous springs have been observed in Redbank Creek over Longwalls 25 to 31 prior to the sites being undermined.

If an adverse change in stream water quality occurs through development of an isolated new, or a change to an existing ferruginous spring occurs, it is anticipated, based on prior observations in the creek that the effect will be localised around the point of discharge and will not adversely affect the overall water quality discharging out of the subsidence affected area.

4.2.4 Mine Water

No observed inflows to workings have been noted in the Southern Coalfields into mines which range from approximately 400 to 550m below surface.

Interpretation of field test data for the Reynolds enquiry (Reynolds, 1977) indicated that vertical flow through the stratigraphy could occur, however it would be too small to measure, with flow in the strata over the workings dominantly in the horizontal direction.

A minimum thickness of unfractured overburden is required to maintain hydraulic separation between a mine and the overlying aquifers, with the critical value depending on lithology, structure and topography. The minimum separation has been established through observation and research in NSW mines as ranging from less than 90m up to 150m. The separation distance over the Tahmoor North Longwalls is well in excess of 150m under both stream valleys and the plateau, where the depth of cover ranges from 430 - 540m.

4.3 Flora and Fauna

4.3.1 Aquatic

Niche undertook an assessment of aquatic environments of habitat there were likely to be susceptible to subsidence, with Redbank Creek being the main natural waterway located above Longwall 31.

In general the aquatic habitat consists predominately of pools with little to no riffles present, with most sites having moderate to high quality riparian and channel health. The streams were controlled by the sandstone geology with bedrock a common component of the streams morphology. There was very little cobble / boulder habitat and stream benthos was dominated by finer sand / silt sized sediment where bedrock did not occur. Macrophyte occurrence varied between sites. Table 6 shows the RCE inventory scores of each site. An RCE score below 20 indicates that the stream is in very poor condition. RCE Scores of 20-40 indicate a stream is in moderate condition and greater than 40 indicates a stream is considered to be in good condition with potential for higher biodiversity values.

Table 5 Redbank Creek – RCE inventory scores

Stream	Redbank Creek		
Site	**1**	**2**	**3**
RCE Score	**35**	38	39

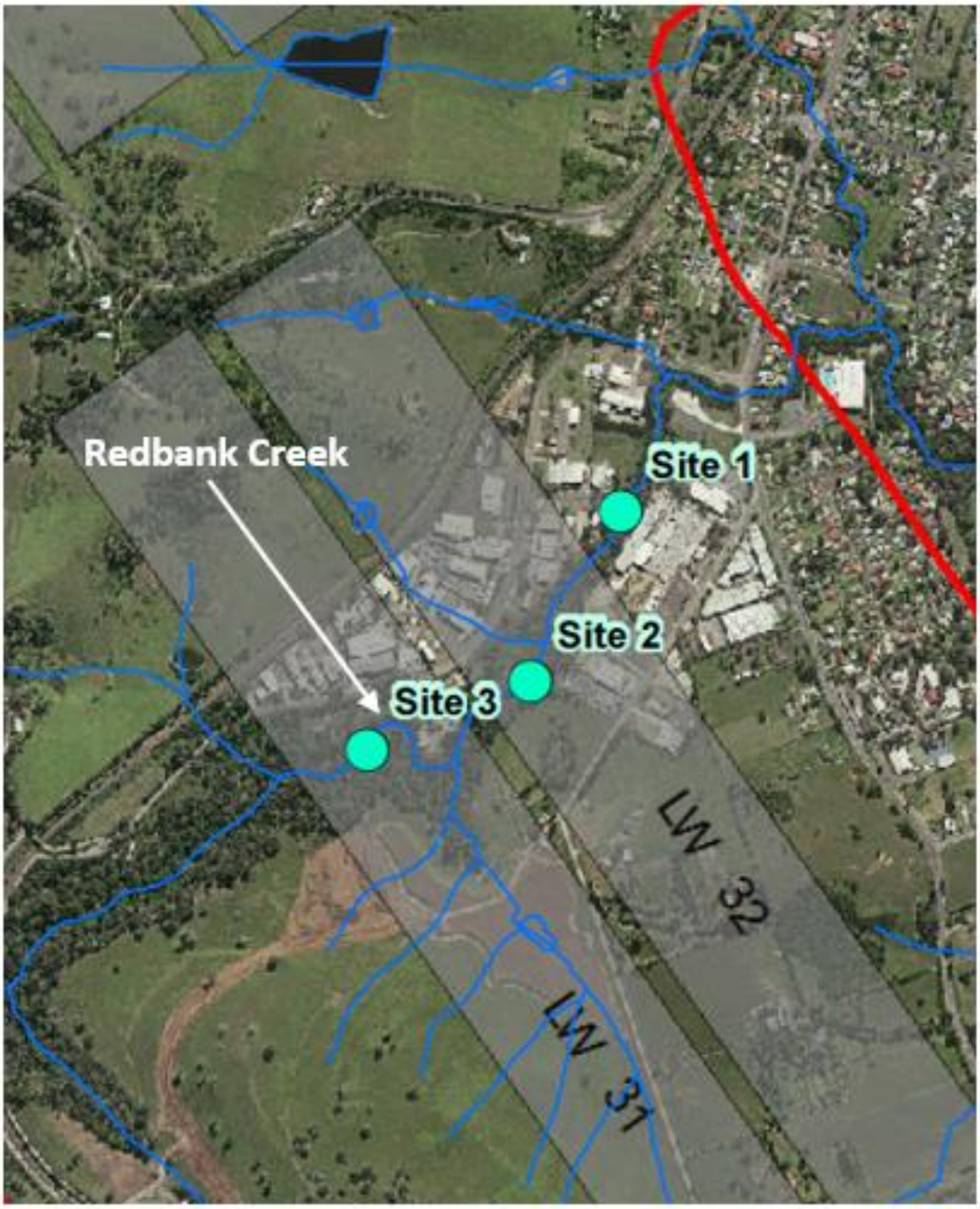

Figure 10 Redbank Creek – location of aquatic environment assessment sites

Site 1 Redbank Creek - Down Stream

The site is located in an urban area of Tahmoor (Figure 2, Plate 1) immediately downstream of Longwall 32. The stream was in moderate condition (RCE score 35) however there were high levels of disturbance including bank erosion, sedimentation and weeds. Canopy vegetation was dominated by weeds including Large Leaf Privet, Small Leaf Privet; however *Eucalyptus tereticornis* was also present. The dominant midstorey species was Turkey Rhubarb and ground cover dominated by Tradescantia spp., *Commelina cyanea*, and *Microleana stipoides*. The vegetation provided moderate shading of the stream.

This stream at the location was mostly shallow (<1m depth) with 2m modal width. The benthic substrate of the stream contained some gravel but was dominated by finer sized sediment including sand and silt. There were few macrophytes present at this site (approximately<3% of the reach contained macrophytes) with the distribution of the macrophytes being confined to the stream edge. There were pools present, however there was little flow at the time of sampling.

Figure 11 Redbank Creek Site 1 – aquatic environment assessment

Site 2 Redbank Creek - Off Bridge Street near Rural Fire Station

The site is located in the urban area of Picton and overlies the proposed Longwall 32 (Figure 2, Plate 2). The stream was in moderate condition (RCE 38) however showed high levels of disturbance including sedimentation, and dominance of weeds in the riparian vegetation. Canopy vegetation was dominated by weeds Large Leaf Privet and Small Leaf Privet; however *Eucalyptus moluccana* and *Angophora floribunda* also occurred. Weedy shrubs dominated the mid-storey including Large and Small Leaf Privet and Lantana (*Lantana camara*). Ground cover was dominated by weeds Wandering Jew (*Tradescantia spp*.), Panic Veldt Grass (*Erharta erecta*), as well as native species *Microleana stipoides*. The vegetation provided moderate shading of the stream.

Figure 12 Redbank Creek Site 2 – aquatic environment assessment

Site 3 Redbank Creek – Upstream near Railway Culvert

The site is located in the urban area of Picton with commercial buildings on the left bank; it overlies

Longwall 31 (Figure 2, Plate 3). The stream was in moderate condition (RCE 39) however showed high levels of disturbance including rubbish, and dominance of weeds. Canopy vegetation was dominated *Backhousia myrhfolia*, and weeds including Large and Small Leaf Privet. The mid-storey was dominated by Bursaria spinulosa and the ground cover by *Lomandra longifolia, Microleana stipodes, Commelina cyanea* as well as the weed Wandering Jew (Tradescantia spp.). The vegetation provided moderate shading of the stream.

This stream was shallow (<1m depth) with 2.5m modal width. The stream substrate consisted of bedrock, sand and silt. There were no macrophytes observed at this site. There were pools present, however there was little flow at the time of sampling. There was a red ferrous precipitate in the water.

Figure 13 Redbank Creek Site 3 – aquatic environment assessment

4.3.1.2 Water Quality

Water quality sampling by Niche (2014) showed that temperature varies seasonally whilst conductivity ranged between 212-2003 µ/cm. Sites in Redbank Creek particularly had raised electrical conductivity. Turbidity was low however default ANZECC trigger values were exceeded at Site 2 (150 NTU).

Considering the sampling was conducted after a moderate rainfall event this result is not considered environmentally significant. Dissolved oxygen ranged between 61 – 90.1% saturation, with most sites falling outside of ANZECC trigger values. Lower dissolved oxygen however is a characteristic of the non-flowing semi-permanent/ephemeral groundwater baseflow dependent ecosystems in the region so these values are not considered environmentally significant. The pH range was generally low (3.88—7.02) and was exceeded at all three sites.

Table 6 Redbank Creek – water quality results

Stream	Redbank Creek		
Site	**1**	**2**	**3**
Temperature ºC	13	13.05	12.34
Electrical conductivity (µS/cm) ANZECC	**1521**	**1478**	**2003**
Turbidity (NTU)	10	**150**	12
Dissolved (oxygen saturation)	**71**	**77.6**	**84.7**
pH	**6.4**	**6.14**	**3.88**
Alkalinity (mg CaCa3/L)	15	15	0
Oxygen reduction potential (mV)	270	146	370

ANZECC guidelines for upland streams: Electrical conductivity (30-350µS/cm), Turbidity (2-25 NTU), pH (6.5-7.5). Dissolved Oxygen (90-110%). Text in bold indicate those variables that exceed the default trigger values.

4.3.1.3 Macroinvertebrates

Results are presented in Table 6 and raw data is provided in Annex 1. Overall, 39 different taxa were collected from the spring sampling. The number of taxa ranged 9-17 among sites.

Table 7 Redbank Creek – AUSRIVAS results

Stream	Redbank Creek		
Site	**1**	**2**	**3**
No of taxa	9	16	10
OE 50)	0.68	0.78	0.53
Signal	3.44	3.44	4
Band	B	B	B

AUSRIVAS results showed that, with the exception of Site 4, 8 and 9, sites scored in Band B. This indicates that sites are significantly impaired. Sites 4, 8 and 9 scored in Band C indicating a severely impaired site. Southern sites in Redbank Creek scored low SIGNAL values indicating that sites are severely polluted as they contain pollution tolerant macroinvertebrate families. Northern sites, Cedar Creek and Matthews Creek, returned a SIGNAL score >4. This indicates that there are more pollution sensitive invertebrates at these sites and the presence of these fauna infer that these streams are unlikely to be severely affected by pollution. One family in particular, Leptophlebiidae (SIGNAL 8) was notably absent from all Redbank Creek sites which was relatively abundant (Annex 1) in Cedar Creek and Matthews Creek. The family is common among the ephemeral / semi-permanent streams in the area and its absence may show that Redbank Creek is under natural or anthropogenic stress.

4.3.1.4 Threatened species, populations and communities

There are no historical records of threatened species, populations or communities identified or current registers with threatened species, populations or communities identified with the active subsidence zone of Longwall 31.

No threatened species are likely to be impacted by subsidence due to the extraction of Longwall 31.

4.3.1.5 Key fish habitat

All creeks are mapped as ‘key fish habitat’ and are classed as having TYPE 1 highly sensitive and TYPE 2 moderately sensitive aquatic habitat. The waterways are classed as TYPE 2 fish passage and as such have moderate key fish habitat (DPI 2013).

It is likely that there will be a net reduction in key fish habitat as a result of localised flow diversion and draining of pools. However stream connectivity, hence fish passage will be accessible in periods of higher flow.

4.3.1.6 Upland Spring Induction

This section refers to upland spring induction that affects habitat in the immediate vicinity of a spring during low water flow (<3ML/day). Previous observations across the Southern Coalfield indicate that the potential for damage to habitat in close proximity to the spring under low flow conditions may be reasonably large. However, the impacts are limited to the immediate spring area and don't proceed down creek to any great distance.

4.3.2 Terrestrial

Niche Environment and Heritage (Niche) undertook a terrestrial flora and fauna assessment on areas of habitat there were likely to be susceptible to subsidence due to Longwall 31, such as watercourses, ridgelines and riparian areas, in particular Redbank Creek.

Vegetation along the banks of Redbank Creek has previously been mapped as Cumberland Shale Sandstone Transition Forest. Based on the result of the field survey, the vegetation mapping appears correct with plots conducted along the upper banks of the creek containing diagnostic overstorey species: *Eucalyptus crebra*, *Eucalyptus punctata* and *Angophora floribunda*, and understorey species consisting of *Acacia parramattensis*, *Sigesbeckia orientalis*, and *Indigofera australis*.

No Critical Habitat to date has been declared for any ecological values within the active subsidence zone of Longwall 31 and no Critical Habitat under either the TSC or EPBC Acts will be impacted.

The majority of vegetation within the active subsidence zone of Longwall 31 would not be impacted by subsidence due to underground mining but impacts may potentially occur for riparian vegetation. Riparian vegetation potentially impacted by subsidence is generally not mapped as discrete vegetation communities, rather these areas display structural and floristic variation within their composite community in response to more frequent contact with the local water table. As such, it would be hard to distinguish impacts to truly riparian vegetation and the intergrade between riparian and woodland communities.

Vegetation which occurs on undulating lands or on ridgelines is unlikely to be impacted by subsidence. It is possible that cracking may occur within these communities, however cracking is unlikely to result in vegetation change as these communities occur in drier soils and are not ultimately reliant upon groundwater for their floristic make up or distribution.

The Cumberland Plain Land Snail has been previously recorded by Niche (2012) just to the immediate west of the study area during an assessment at Innes Street, Thirlmere. The species is likely to occupy areas of Cumberland Plain Woodland within the study area and locality.

Flora of relevance to this assessment include; *Epacris purpurascens var. purpurascens*.

Fauna of relevance that was identified in the study area include; Giant Burrowing Frog (*Heleioporus australiacus),* Black Bittern (*Ixobrychus flavicollis*), Large-footed Myotis (*Myotis adversus*), Red-crowned Toadlet (*Pseudophryne australis*), and Grey-headed Flying Fox (*Pteropus poliocephalus*).

Impacts to vegetation communities are unlikely to result in a significant impact based on the following:

a) Previous impacts to vegetation as a result of gas emissions in the Southern Coalfield are isolated and minor.

b) Surface cracking as a result of subsidence movements is expected to be isolated and minor.

c) In alluvial environments mine subsidence has some potential to affect threatened plant species through changes in hydrology impacting on individual plants or groups of plants. However, impacts to hydrology and surface flow are likely to be minor and localised. Further, the availability of water to the vegetation of the study area is not likely to be altered as the majority of this vegetation is not reliant on standing or flowing surface waters for their distribution and existence. Riparian vegetation associated with streams overlying the study area is relatively robust and unlikely to be sensitive to minor change in the moisture level fluctuations associated with the effects of subsidence.

d) Strata gas release has the potential to result in vegetation die back near the points of emission. Such events are rare and affect relatively small areas (e.g. 0.12 hectares in one documented case on the Cataract River near Appin, (Eco Logical Australia, 2004 in TEC 1997). The vegetation in the affected area subsequently recovered through assisted and natural regeneration.

e) Ridgetop, woodland and paddock vegetation is unlikely to be impacted by subsidence. Some cracking may be observed in the soil, however it is unlikely to result in a significant impact to vegetation composition.

4.4 Archaeological Sites

Niche undertook Aboriginal and European Heritage assessments of the potential subsidence impacts associated with Longwall 31.

During the assessment of Aboriginal Cultural Heritage items, Niche consulted with Representatives of the Cubbitch Barta Native Title Claimants (CBNTC) and the Tharawal Local Aboriginal Land Council (TLALC) as previously identified as Aboriginal community stakeholders during the SMP process for longwalls 27 to 30.

4.4.1 Aboriginal Cultural Heritage

Niche undertook an Aboriginal Cultural Heritage assessment of the potential subsidence impacts associated with Longwall 31. The Aboriginal archaeological assessment focused on the drainage lines present within the subject area as these are the most archaeologically sensitive landforms, and are the landforms most likely to be affected by subsidence movements.

There were five Aboriginal Cultural Heritage sites identified within the active subsidence zone of Longwall 31 as outlined in Table 7. Three of the sites identified are open camp sites, with previous studies showing that stone artefact sites in an open context are not affected by subsidence movements. So there will be no impact to the three open sites from Longwall 31 subsidence, and no further action necessary.

The remaining two sites are:

a) Shelter with art and deposit – located directly above Longwall 29 (AHIP Approved until 19 December 2020)

b) Grinding groove site – located directly above proposed Longwall 32 (AHIP currently being developed before Longwall 32 undermining)

Sandstone shelter sites with art or deposit, have been demonstrated to be susceptible to damage from subsidence movements. If a shelter is situated directly over a longwall or pillar, then there is a greater risk of impact, as these areas are subject to the greatest subsidence movements. The predicted curvatures and strains at the rock shelters which have been previously mined beneath within the Southern Coalfield. It has been reported that, where longwall mining has previously been carried out in the Southern Coalfield, beneath 52 shelters, that approximately 10% of the shelters have been affected by fracturing of the strata or shear movements along bedding planes and that none of the shelters have collapsed (Sefton, 2000).

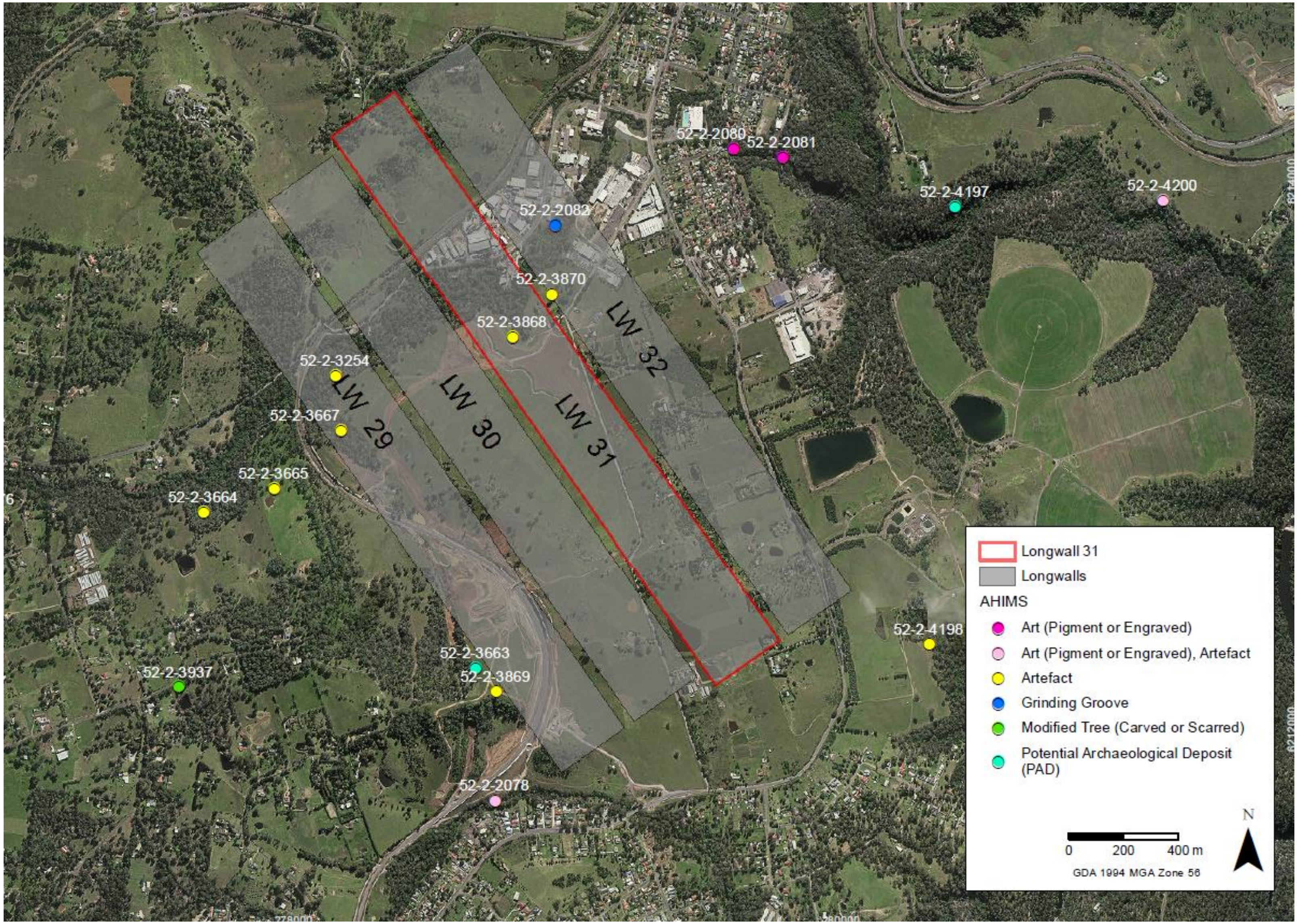

Figure 14 Aboriginal archaeological sites – Longwall 31

Table 8 Aboriginal cultural heritage - recommendations

Site Number and Name	Site Type	Archaeological Significance	Potential For Impact	Recommendations
52-2-3667 Redbank Creek IA 1	Open Camp Site	Low	Negligible	No further action necessary
52-2-3254 Redbank Creek 1	Shelter with Art and Deposit	Low	Moderate	S90 Consent to Disturb from OEH Develop a ACHMP which details monitoring by an archaeologist and Aboriginal Stakeholders ***AHIP Approval CC0000774 received 19/12/2014***
52-2-3868 Redbank Tunnel 3/A	Open Camp Site	Low	Negligible	No further action necessary
52-2-3870 Redbank Tunnel 35/A	Open Camp Site	Low	Negligible	No further action necessary
52-2-2082 Redbank Creek 4	Grinding Groove Site	Low	Moderate	S90 Consent to Disturb from OEH Develop a ACHMP which details monitoring by an archaeologist and Aboriginal Stakeholders prior to undermining of LW32

There is one sandstone shelter site located directly over longwall 29, however it is still in the active subsidence zone of Longwall 31. The Office of Environment and Heritage (OEH) issued an *Aboriginal Heritage Impact Permit* (AHIP) for 52-2-3254 Redbank Creek 1 on the 19 December 2014 (see Appendix A.1) for the duration of six years. No impacts to 52-2-3254 Redbank Creek 1 have been reported to date.

Based on the subsidence predictions provided by MSEC (2014), it is unlikely that the open camp sites will experience adverse subsidence impacts resulting from Longwall 31. However, it is possible that fracturing could occur in the vicinity of the grinding groove site 52-2-2082 Redbank Creek 4 and it is recommended that relevant approvals are obtained prior to subsidence impacts of Longwall 32.

4.4.2 European Historic Heritage

Niche (2014) identified three European heritage sites that could be impacted by subsidence from Longwall 31. Based on the predictions by MSEC (2014), Koorana Homestead is located directly above Longwall 32 and could experience minor impacts, Mill Hill is located at the end of Longwall 31 and could experience minor impacts and the rural landscape located on Thirlmere Way is unlikely to experience impacts from subsidence.

Koorana Homestead is listed as an item of local heritage significance on the *Wollondilly Local Environmental Plan (LEP) 2011* ('Koorana Homestead, outbuildings and trees' – item ID:1207). Niche heritage consultants (2017) have prepared a *Statement of Heritage Impact* (SoHI) with the input from MSEC (subsidence engineers) and John Matheson & Associates (structural engineer). The SoHI for Koorana Homestead was prepared in consultation with the property owner and has been approved by Wollondilly Shire Council.

Niche heritage consultants have been engaged by Tahmoor Colliery to prepare a SoHI for Mill Hill with input from MSEC (subsidence engineers) and John Matheson & Associates (structural engineer). The

SoHI for Koorana Homestead will be prepared in consultation with the property owner was approved Wollondilly Shire Council on 4 October 2017.

The Rural Landscape adjacent to Thirlmere Way is partly located above Longwall 31. The vertical subsidence transitions from the maximum values directly above the proposed longwalls to slightly reduced values above the chain pillars. These variations in the vertical subsidence of around 200 mm to 300 mm occur over distances of 320 metres and, therefore, are not visually perceptible. It is unlikely, therefore, that the vertical subsidence would reduce the visual aesthetics or the heritage value of the land (MSEC 2014).

Table 9 European historical heritage - recommendations

Site Name	Structure Type	Heritage Significance	Potential Impact	Recommendations
Koorana Homestead Complex 2240 Remembrance Drive, Tahmoor	- Main federation style house - Stables - Cottage - 3 brick wells	Local	Low	Statement of Heritage Impact (SoHI) developed in consultation with property owner and Wollondilly Shire Council. ***Approved by Wollondilly Shire Council on 4 October 2017.***
Mill Hill Millers House and Archaeological Relics 675 Thirlmere Way, Picton	- Federation style weatherboard house - small cottage - brick well - possible archaeological remains of windmill	Local	Low	Develop specific SoHI in consultation with property owner and submit to Wollondilly Shire Council prior to subsidence. The SoHI should be developed with input from structural engineers, subsidence engineers and heritage consultants.
Rural Landscape, Thirlmere Way	- No structures	Local	Low	***No further heritage assessment required.***

4.5 Cliffs

There are no cliffs within the active subsidence zone of Longwall 31.

This is based on the cliff definition:

> “Continuous rock face, including overhangs, having a minimum length of 20 metres, a minimum height of 10 metres and a minimum slope of 2 to 1 (>63.4º)”, as per the definition of cliffs provided in the NSW Department of Planning and Environment Standard and Model Conditions for Underground mines.

Cliffs will not be discussed further in this Report.

4.6 Other Natural Features

No other significant environmental features that may be effected by subsidence resulting from the extraction of Longwall 31 have been identified.

5 Management of Potential Impacts

5.1 Environmental Response Group

The Environmental Response Group (ERG) is responsible for providing advice on all environmental and technical issues relating to mine subsidence related impacts of natural features. Any member may call an emergency ERG meeting, with one day's notice, to discuss proposed actions and to keep other parties informed of developments in the monitoring and management of a particular natural feature item.

Members may specialise in the management of one or more natural feature items mentioned in this Management Plan. If the natural feature item does not relate to their field of expertise, they may choose to not participate in the discussions.

The ERG will review survey data as required and analyse monitoring results, determine potential impacts, mitigation works if required and provide advice regarding appropriate actions.

Members of the ERG are highlighted in Section 10.

5.2 Avoidance and Mitigation Measures

5.2.1 Aboriginal Cultural Heritage

Based on the subsidence impacts predicted by MSEC there are not likely to be any impacts at the open camp sites and therefore no mitigation measures are required.

Niche (2014) has recommended that as a result of the predicted impacts it is recommended that further assessment of the grinding groove site Redbank Creek 4 (52-2-2082) with an appropriately qualified archaeologist and in consultation with Aboriginal stakeholders. This assessment would then inform an application to OEH for an Aboriginal Heritage Impact Permit prior to active subsidence.

The shelter with art and deposit and Redbank Creek 1 (52-2-32-54) is located over Longwall 29, no impacts have been reported and no mitigation measures have been recommended.

5.2.2 European Historic Heritage

Based on the site inspection and assessment of Koorana Homestead Complex by structural engineer John Matheson, the structures are considered to be sufficiently ductile to remain safe and serviceable during the extraction of Longwall 31.

No mitigation measures are recommended to be undertaken prior to the period of active subsidence. Subsidence Advisory NSW will engage contractors in readiness for structural repairs in the unlikely event that emergency repairs are required.

Figure 15 Koorana Homestead Complex

Based on the site inspection and assessment of Mill Hill by structural engineer John Matheson (2014), the structures are considered to be sufficiently ductile to remain safe and serviceable during the extraction of Longwall 31. John Matheson will inspect the property prior to active subsidence of Longwall 31 to confirm that building modification has not taken place since 2014.

If confirmed that the property is structurally the same as inspected in 2014 no mitigation measures are recommended to be undertaken prior to the period of active subsidence. Subsidence Advisory NSW will engage contractors in readiness for structural repairs in the unlikely event that emergency repairs are required.

Figure 16 Mill Hill

5.3 Monitoring Measures

A number of monitoring measures will be undertaken during the extraction of Longwall 31 as outlined in Table 12. The below Figure 17 outlines the monitoring sites for:

a) Registered boreholes / wells

b) Stream monitoring sites

c) Piezometers

d) Floristic monitoring sites

e) Macroinvertebrate monitoring sites

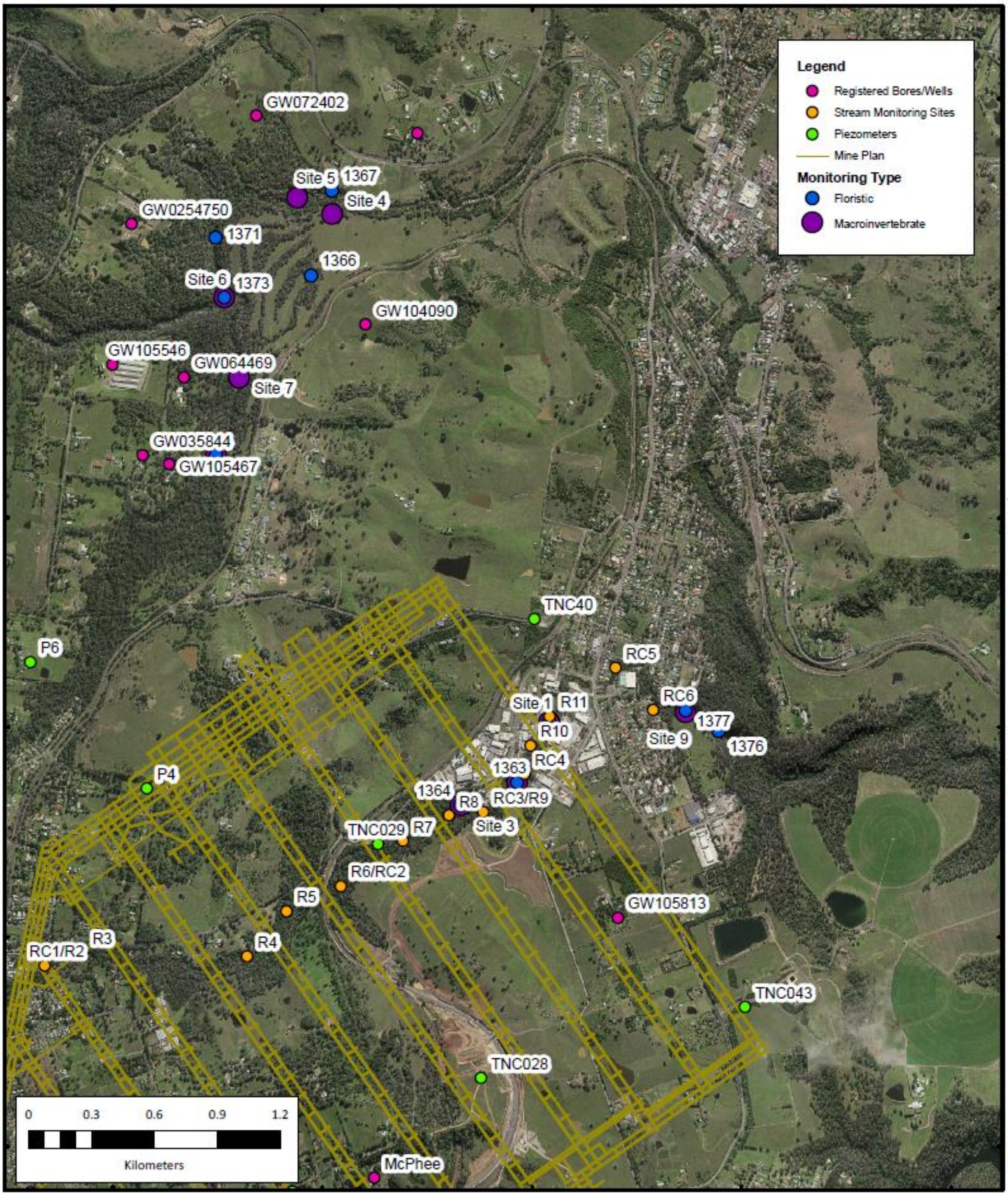

Figure 17 Tahmoor Colliery subsidence monitoring sites

5.3.1 Surface Water

5.3.1.1 Shallow Groundwater Hydrological Investigation

Two shallow groundwater bores were installed in the chain pillar between Longwalls 31 and 32 in September 2017, the first borehole with an open standpipe and the second borehole with three vibrating wire piezometers. During the installation of the boreholes an assessment was completed to characterise the pre-mining lithology and fracture networks in the shallow aquifers down to 50m below creek level of Redbank Creek.

The assessment of the shallow groundwater hydrological investigation will be presented in a *Shallow Groundwater Management Plan* (SGMP). The SGMP will be approved prior to undermining Redbank Creek.

The monitoring that will be conducted as part of the shallow groundwater hydrological investigation is outlined in the Trigger Action Response Plan for Tahmoor Colliery Longwall 31 EMP in Table 12.

5.3.1.2 Survey

The valley closure movements along Redbank Creek have been measured during the extraction of Longwalls 26 to 30 using two monitoring lines located either side of Redbank Creek. The comparisons between the measured and predicted movements for these longwalls are provided in Section 2.5. The measured closure is similar to, but slightly less than the predicted closure obtained using the 2002 ACARP method.

The two ground monitoring lines located either side of Redbank Creek have been extended for Longwall 31. The valley closure along Redbank Creek is determined from the changes in horizontal distance between the corresponding survey marks along the two monitoring lines either side of the creek.

Surveys will be conducted weekly during the active subsidence period. A final survey will be carried out at the completion of Longwall 31.

5.3.1.3 Visual Inspections

During active subsidence of Longwall 31, weekly visual inspections will be undertaken upstream, directly above Longwall 31 and downstream in Redbank Creek. A photograph is taken at the same location each time.

Factors to be monitored in Redbank Creek include:

a) Stream flow and connectivity.

b) Pool longevity and levels.

c) Rock bar and exposed sandstone creek bed integrity / cracking.

d) Field pH EC, DO, ^{o}C and Eh.

e) Laboratory water quality analysis (as required).

f) Spring / seep generation, relocation or modification.

g) Presence / alteration of ferruginous precipitation.

h) Bed and bank stability.

5.3.1.4 Stream Water Level Monitoring

Water level monitoring is undertaken bi-monthly at identified pools in Redbank Creek at 11 stream depth monitoring sites with pressure transducers and loggers that were installed during March 2010.

Baseline water level monitoring data for Redbank Creek has been collected in excess of 2 years prior to Longwall 31 active subsidence. The data collected monthly is reported in the End of Panel Report.

A reference site for stream water level monitoring has been identified in Dog Trap Creek. Data was collected between February 2012 and November 2015 for the Tahmoor South Project. The loggers will be reinstalled in November 2017 and the data will continue to be collected as a reference site for Redbank Creek.

5.3.1.5 Stream Water Quality Monitoring

Water quality monitoring is undertaken in Redbank Creek at sites shown in Figure 18 which started in April 2005. No surface water extraction licences are registered with DPI-W over Longwall 31.

Water quality data is collected bi-monthly in Redbank Creek and is reported in the End of Panel Report.

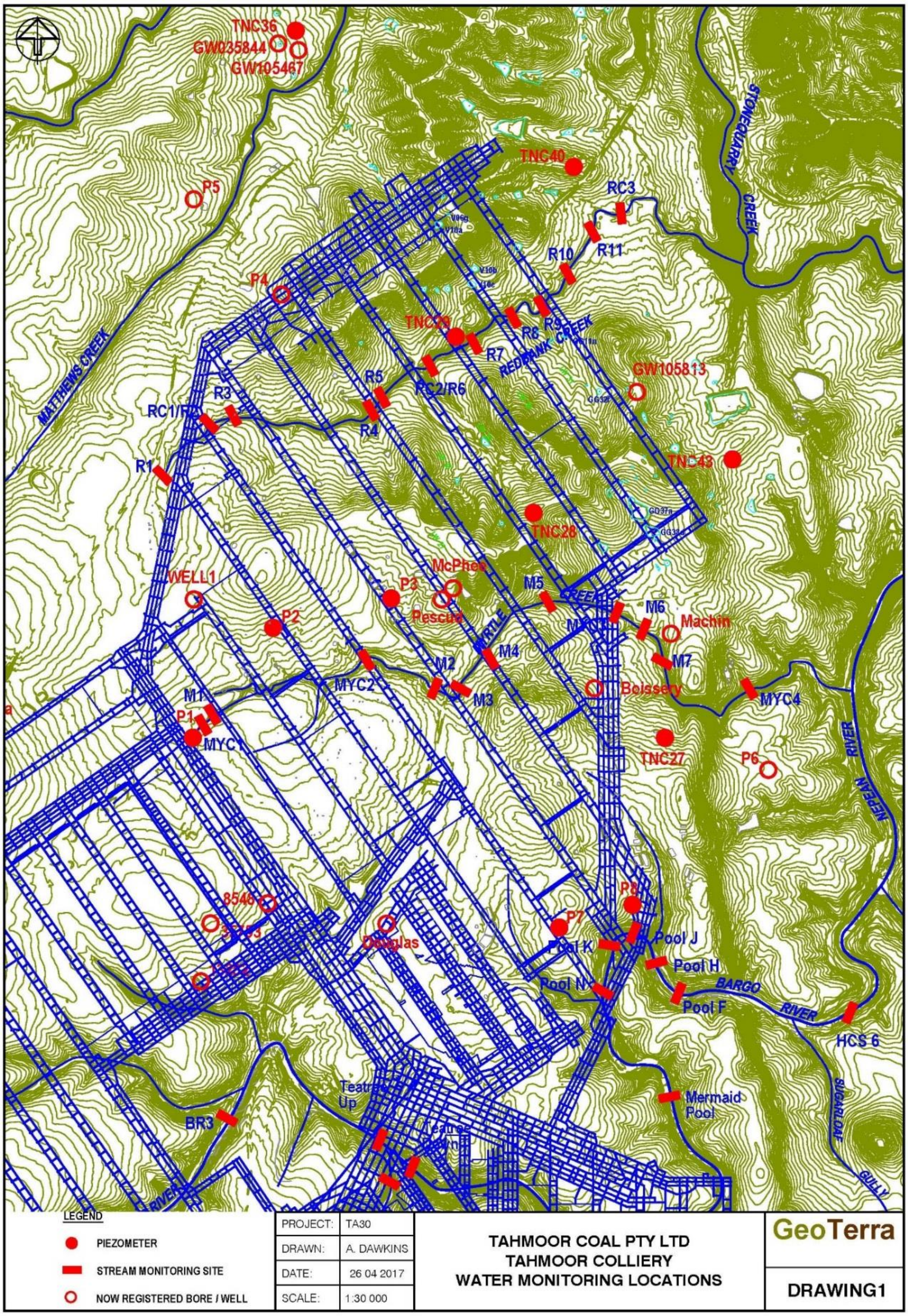

Figure 18 Tahmoor Colliery Longwall 31 water monitoring locations

5.3.1.6 Cliffs

There are no cliffs located in the active subsidence zone of Longwall 31.

5.3.2 Groundwater

Prior to undermining Redbank Creek by Longwall 31 *shall groundwater hydrological investigation and monitoring plan* will be approved by the Director ESU and executed to the satisfaction of the Department and outlined in Condition 13 of the *Subsidence Management Plan Approval for Tahmoor Colliery Longwall 31.*

5.3.2.1 Groundwater Level and Quality

All groundwater monitoring will be consistent with the Murray Darling Basin Authority's "*Groundwater Quality Guidelines*" and the "*Groundwater Sampling and Analysis Field Guidelines*".

Piezometric water levels and water quality will be tested in the private groundwater bores and Tahmoor Colliery piezometers and shown in Figure 17.

Tahmoor Colliery have a rigorous monitoring regime designed to identify when / if and how much subsidence impact occurs within the local and regional groundwater system. Monitoring data is acquired from:

a) Open standpipe water levels and groundwater chemistry.

b) Vibrating wire piezometer pressure heads at various depths through the overburden.

c) Monitoring or local private bore water level, yield or water quality impacts.

A BACI groundwater monitoring program will begin in November 2017 and will consist of control and impact sites.

Data during the extraction of Longwall 31 will be reported in the Longwall 31 End of Panel Report which will summarise all monitoring over that period. The report will outline any changes in the surface water or groundwater system in the mined areas. All results will be reviewed at the end of Longwall 31.

Figure 19 Shallow groundwater monitoring in Redbank Creek

5.3.2.2 Mine Water

Water from the mine overburden seeps into the mine at a rate of approximately 2,500 kL/day. This water is pumped to the surface and directed to the mine's pit top treatment dams. Water quality is monitored under the conditions of the site's EPL as described in the *Tahmoor Annual Review*.

Tahmoor Colliery has continuous water monitoring and data recording for all potable and recycled water delivered into, and for all process, waste and ground water pumped from, the underground mine workings.

Monitoring of this water flow allows Tahmoor Colliery to maintain an overall mine water balance, and to monitor and analyse any short term changes and long term trends in water flow as mining progresses.

5.3.3 Flora and Fauna

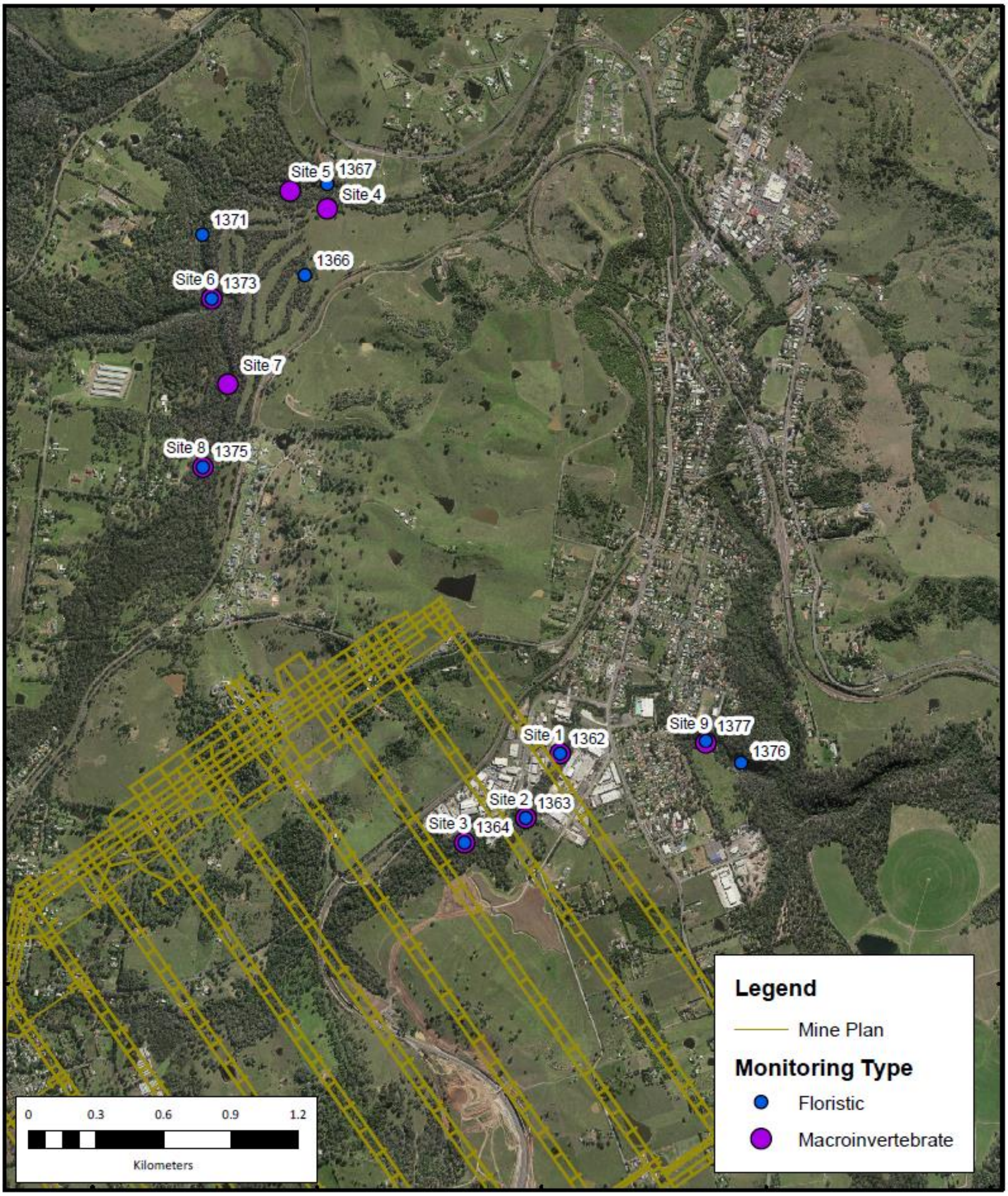

Figure 20 Tahmoor Colliery floristic and macroinvertebrate monitoring

5.3.3.2 Flora Monitoring

Terrestrial ecological assessments by Niche (2014) have determined that the majority of vegetation will not be impacted by subsidence due to the extraction of Longwall 31 and no monitoring of terrestrial flora and fauna is recommended during the extraction of Longwall 31.

No threatened flora species were recorded in the study area during the Niche survey, or survey conducted by Biosis Research (2009). However, within the vicinity of Longwall 31, potential habitat was determined for four threatened flora species that may potentially be impacted by subsidence: *Epacris* *purpurascens* var. *purpurascens*, *Persicaria elatior*, *Pomaderris brunnea* and *Pterostylis saxicola*. Biosis Research (2009) concluded mining of Longwalls 27-30 would be unlikely to have a significant impact on any of threatened flora.

To date, a collection of BioBanking plot data has been completed within the riparian zones along Redbank Creek, Stonequarry Creek, Matthews Creek and Cedar Creek within the Tahmoor North mining lease.

Further BioBanking reference plots have been completed during both spring and autumn within numerous creeks outside of the Tahmoor north mining domain. Creeks include: Dogtrap Creek, Carters Creek, Dry Creek, Eliza Creek, Hornes Creek, Cow Creek, Waterhouse Gully Creek and tributaries of the Bargo River.

The BACI design for the proposed Tahmoor north mining area for future longwalls will incorporate floristic plot / transect collect consistent with the Biodiversity Assessment Methodology (OEH 2016), and establish control sites upstream of the impact areas.

The following section outlines the recommended monitoring program for Aquatic habitats in Redbank Creek before and after active subsidence in Redbank Creek.

5.3.3.1 Fauna Monitoring

Two years of quantitative macroinvertebrate data was collected as part of the Tahmoor South Project (autumn 2012- spring 2013) using a benthic suction sampler (Brooks 1994). All of the data collected is pre-mining data and provides thorough analysis of the macroinvertebrate communities in the Bargo / Tahmoor area. While this data does not include ‘impact sites’ which are relevant to the Tahmoor North monitoring program, it does provide rigorous pre-mining controls that can be used in multivariate statistical analysis of macroinvertebrate communities. The data also includes collection of fish using concertina bait traps at these locations.

This data collected will be directly comparable to baseline quantitative data that will collected as part of the Tahmoor North monitoring program which will use similar techniques, sample replication and program design. Sites from the Tahmoor South program including Cedar Creek and Stonequarry Creek will be utilised as controls in the Tahmoor North monitoring program which will provide some continuity between the programs.

A stream health monitoring program will be conducted in Redbank Creek prior active subsidence. This will provide further information regarding possible changes to the habitats and ecology due to mining related subsidence.

During the Monitoring program:

a) Ensure sampling is conducted at appropriate frequencies.

b) Include additional pre-mining baseline data.

c) Investigate the use of Leptophlebiidae (*Atelophlebia* sp.) as an indicator species to monitor changes to populations and stream recovery as:

   i. They are abundant and common to these ephemeral / semi-permanent streams.

   ii. Are sensitive to changes in water quality including salinity and ferruginous precipitation.

   iii. Previous studies have suggested that these species have been impacted in the Southern Coalfields.

No further assessment such as Referral or Species Impact Statements are recommended for any threatened species populations and communities.

The impacts of longwall mining on aquatic ecology should be assessed at the completion of each longwall panel to ensure any remediation (if required) is undertaken in a timely manner. This will also assist in increasing the accuracy of predictions of impacts from future longwall mining in the area.

At the completion of Longwall 31 a terrestrial ecological assessment will be conducted and reported in the End of Panel Report.

5.3.4 Archaeological Sites

5.3.4.1 Aboriginal Cultural Heritage

There are three open camp sites (Table 8) in the action subsidence zone of Longwall 31 and Niche (2014) have recommended that no further action is necessary.

There is one grinding groove site located in the active subsidence zone of Longwall 31. A section 90 application AHIP is currently being developed by Niche in consultation with Aboriginal stakeholders and key Government agencies for 52-2-2082 Redbank Creek 4. This process include the development of an Aboriginal Cultural Heritage Management Plan (ACHMP) which will outline the management of Redbank Creek 4 (52-2-2082).

A program of archaeological monitoring will be developed in consultation with Aboriginal stakeholders and implemented for the site. The program will aim to replicate and where possible develop the recording methods and action triggers already established by Sefton (2000). A program of archaeological monitoring will be designed and implemented for the other sites potentially affected by subsidence movements, where appropriate.

Tahmoor Colliery received an approved AHIP from OEH on the 19 December 2014 (duration: 6 years) for Redbank Creek 1 (52-2-3254) shelter with art and deposit. It is located directly above Longwall 29 and after the extraction of Longwall 30, no impacts to Redbank Creek 1 (52-2-3254) have been reported.

Each item will be addressed as required and outlined in the Table 10.

Table 10 Aboriginal cultural heritage sites

Site Number and Name	Site Type	Archaeological Significance	Potential For Impact	Recommendations
52-2-3667 Redbank Creek IA 1	Open Camp Site	Low	Negligible	No further action necessary
52-2-3254 Redbank Creek 1	Shelter with Art and Deposit	Low	Moderate	S90 Consent to Disturb from OEH Develop a ACHMP which details monitoring by an archaeologist and Aboriginal Stakeholders ***AHIP Approval CC0000774 received 19/12/2014***
52-2-3868 Redbank Tunnel 3/A	Open Camp Site	Low	Negligible	No further action necessary
52-2-3870 Redbank Tunnel 35/A	Open Camp Site	Low	Negligible	No further action necessary
52-2-2082 Redbank Creek 4	Grinding Groove Site	Low	Moderate	S90 Consent to Disturb from OEH Develop a ACHMP which details monitoring by an archaeologist and Aboriginal Stakeholders prior to undermining of LW32

5.3.5 European Historic Heritage

Three European Heritage sites have been identified as outlined in Table 9.

In consultation with the property owner of Koorana House, a Statement of Heritage Impact (SoHI) has been developed and submitted to Wollondilly Shire Council and the property owner. The SoHI was developed by Niche (Heritage Consultants) in consultation with John Matheson of John Matheson and Associates (Structural Engineer) and Daryl Kay of MSEC (subsidence engineer). A Management Plan for Potential Impacts to the Koorana Homestead Complex was also developed by MSEC in consultation with Niche and John Matheson & Associates to provide detailed information about how the risks associated with mining near the Koorana Homestead Complex will be managed by Tahmoor Colliery.

Visual inspections of the structures will also be carried out on a monthly basis, commencing when the structures are within the active subsidence zone. A baseline photographic survey will be undertaken prior to the influence of Longwall 31. Structural inspections will be undertaken by John Matheson, if required.

In consultation with the property owner of Mill Hill, a SoHI will be developed by Niche and a Management Plan for Potential Impacts to Mill Hill will be developed by MSEC in consultation with Niche and John Matheson & Associates to provide detailed information about how the risks associated with mining near the Koorana Homestead Complex will be managed by Tahmoor Colliery, including the monitoring measures.

Each item will be addressed as required and outlined in the Table 11.

Table 11 European historical heritage items

Site Name	Structure Type	Heritage Significance	Potential Impact	Recommendations
Koorana Homestead Complex 2240 Remembrance Drive, Tahmoor	- Main federation style house - Stables - Cottage - 3 brick wells	Local	Low	Statement of Heritage Impact (SoHI) developed in consultation with property owner and Wollondilly Shire Council. ***Approved by Wollondilly Shire Council on 4 October 2017.***
Mill Hill Millers House and Archaeological Relics 675 Thirlmere Way, Picton	- Federation style weatherboard house - small cottage - brick well - possible archaeological remains of windmill	Local	Low	Develop specific SoHI in consultation with property owner and submit to Wollondilly Shire Council prior to subsidence. The SoHI should be developed with input from structural engineers, subsidence engineers and heritage consultants.
Rural Landscape, Thirlmere Way	- No structures	Local	Low	***No further heritage assessment required.***

5.4 Trigger Action Response Plan (TARP)

Risk control procedures have been developed by Tahmoor Colliery based on consultation with the landowners, key stakeholders, subsidence engineers, structural engineers, archaeologists, ecologists, hydrogeologists and geochemists. Trigger levels for each monitoring parameter are described in the risk control procedures in Table 12.

Tahmoor Colliery will also coordinate with Subsidence Advisory NSW and ensure that building contractors are on standby for immediate call out and service in the event other impacts occur to European Historical Heritage items.

All results from monitoring outlined in below Table 12 will be reported in End of Panel Reports and the Annual Review.

Table 12 Trigger Action Response Plan for Tahmoor Colliery Longwall 31 EMP

*see Table 16 for abbreviations

Natural Feature	Impact	Trigger	Monitoring	Timing & Frequency	By Whom
Groundwater	**Impacts to groundwater quality**	**None**	2 years baseline data of field water quality (EC, pH) for OSPs / private bores	Complete	GeoTerra / Fulton
			Continue monitoring field water quality (EC, pH) in piezometers / bores	Bi-monthly in OSPs, as required in private bores	GeoTerra / Fulton
			2 years baseline monitoring TDS, Na, K, Ca, Mg, F, Cl, SO4, HCO3, NO3, Total N, Total P, Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd, (filtered) in OSP / private bores	Complete	GeoTerra
			Continue monitoring TDS, Na, K, Ca, Mg, F, Cl, SO4, HCO3, NO3, Total N, Total P, Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd, (filtered) in OSP / private bores	Laboratory analysis annually prior to and after active subsidence	GeoTerra
			Review monitoring data and advise Tahmoor Colliery if any exceedances	Within 48 of receiving results	GeoTerra
Groundwater	**Impacts to groundwater quality**	**Short term increase in salinity or reduction in pH outside of baseline variability, with the effect not persisting after a significant rainfall recharge event**	Continue monitoring field water quality (EC, pH) in OSP / private bores	Bi-monthly in OSPs, as required in private bores	GeoTerra / Fulton
			Continue monitoring TDS, Na, K, Ca, Mg, F, Cl, SO4, HCO3, NO3, Total N, Total P, Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd, (filtered) in OSP / private bores	Laboratory analysis annually in OSPs, as required in private bores	GeoTerra
			Review monitoring data and advise Tahmoor Colliery if any exceedances	Within 48 hours of receiving results	Tahmoor Colliery
			Notify key stakeholders including key Government agencies and landowners	Include in Subsidence Monitoring Report, End of Panel Report and Annual Review	Tahmoor Colliery
			Connect landowner to town water if negligible impact to bore water quality from subsidence and pay water account until Subsidence Advisory NSW repair bore.	As required	Tahmoor Colliery
			Continue monitoring field water quality (EC, pH)	Bi-monthly	GeoTerra

Natural Feature	Impact	Trigger	Monitoring	Timing & Frequency	By Whom
Groundwater	**Impacts to groundwater quality**	**Increase in salinity or reduction in pH outside of baseline variability, with the effect persisting after a significant rainfall recharge event**	Continue monitoring TDS, Na, K, Ca, Mg, F, Cl, SO4, HCO3, NO3, Total N, Total P, Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd, (filtered) in OSP / private bores	Laboratory analysis annually in OSPs, as required in private bores	GeoTerra
			Notify key Stakeholders including DRG, Principle Subsidence Engineer and key Government agencies	Within 24 hours	Tahmoor Colliery
			Notify ERG of trigger exceedance and any management decision undertaken (including landowner and Subsidence Advisory NSW	Within 24 hours	Tahmoor Colliery
			Continue reviewing results in consultation with DRG to determine if water quality has remediated.	Annually or as requested by DRG	Tahmoor Colliery
			Connect landowner to town water if negligible impact to bore water quality from subsidence and pay water account until Subsidence Advisory NSW repair bore.	As required	Tahmoor Colliery
Groundwater	**Impacts to Groundwater levels**	**None**	2 years baseline logger download in OSPs and VWPs and dip meter OSPs	Complete	GeoTerra / Fulton
			Measure pressure head of water in borehole and convert to water level in OSPs and VWPs	Minimum continuous 12 hourly readings. Bimonthly download.	GeoTerra / Fulton
			Logger download in OSPs and VWPs and dip meter OSPs and private bores where available	Minimum continuous 12 hourly readings. Bimonthly download.	GeoTerra / Fulton
			Notify key stakeholders including key Government agencies and landowners	Include in Subsidence Monitoring Report, End of Panel Report and Annual Review	Tahmoor Colliery
Groundwater	**Impacts to Groundwater levels**	**Up to 10m water level reduction for < 2 months**	Measure pressure head of water in VWPs and OSPs	Minimum continuous 12 hourly readings. Bimonthly download.	GeoTerra / Fulton
			Logger download in OSPs and VWPs and dip meter OSPs and private bores where available	Minimum continuous 12 hourly readings. Bimonthly download.	GeoTerra / Fulton
			Notify key stakeholders including key Government agencies and landowners	Include in Subsidence Monitoring Report, End of Panel Report and Annual Review	Tahmoor Colliery
			ERG to consider any additional management and monitoring actions	Within 1 week	ERG
			Measure pressure head of water in VWPs and OSPs	Minimum continuous 12 hourly readings. Bimonthly download.	GeoTerra / Fulton

Natural Feature	Impact	Trigger	Monitoring	Timing & Frequency	By Whom
Groundwater	**Impacts to Groundwater levels**	**>10m water level reduction for > 2 months**	Logger download in OSPs and VWPs and dip meter OSPs and private bores where available	Minimum continuous 12 hourly readings. Bimonthly download.	GeoTerra / Fulton
			Notify key stakeholders including DRG, Principle Subsidence Engineer and key Government agencies	Within 24 hours	Tahmoor Colliery
			Notify ERG of trigger exceedance and any management decision undertaken (including landowner and Subsidence Advisory NSW	Within 24 hours	Tahmoor Colliery
			Continue reviewing results to determine if water level has remediated.	End of Panel Report and Annual Review	Tahmoor Colliery
			Connect landowner to town water if bore water quality is impacted by subsidence and pay water account until Subsidence Advisory NSW repair bore.	As required	Tahmoor Colliery
Groundwater	**Impacts to underground workings**	**None**	Volumetric flow monitoring of mine inflow and discharge	Daily	Tahmoor Colliery
Groundwater	**Impacts to underground workings**	**Mine pump out volume within historic monitored range**	Water quality analysis of any anomalous inflow event with the method and parameters to be defined depending on what is being investigated, (i.e. major / minor elements, isotopes, algae etc)	As required	Tahmoor Colliery
Groundwater	**Impacts to underground workings**	**Increase in water discharge of >1ML/day for 7 successive days from active mining areas which are suspected to be as a result of mine subsidence**	Water quality analysis of any anomalous inflow event with the method and parameters to be defined depending on what is being investigated, (i.e. major / minor elements, isotopes, algae etc)	As required	Tahmoor Colliery
			Notify key stakeholders of water quality analysis including DRG, Principle Subsidence Engineer and key Government agencies	Within 24 hours	Tahmoor Colliery
			ERG to consider any additional management and monitoring actions	Within 1 week	ERG
			Review results in consultation with DRG to determine remediation is required	Within 1 month	Tahmoor Colliery
Surface Water		**None**	2 years baseline data of manual field analysis (EC, pH, DO, ORP, temp)	Complete	GeoTerra

Natural Feature	Impact	Trigger	Monitoring	Timing & Frequency	By Whom
	Impacts to stream water quality		Manual field analysis (EC, pH, DO, ORP, temp)	Bimonthly prior to active subsidence	GeoTerra
				Weekly during active mining	GeoTerra
				Bi-monthly after active subsidence for at least 12 months	GeoTerra
			2 years baseline of laboratory analysis of TDS, Na, K, Ca, Mg, F, Cl, SO4, HCO3, NO3, Total N, Total P, Cu, Pb, Zn, Ni, Fe, Mn, As, Li, Ba, (filtered) DOC, Tot. Alkalinity	Complete	GeoTerra
			Laboratory analysis of TDS, Na, K, Ca, Mg, F, Cl, SO4, HCO3, NO3, Total N, Total P, Cu, Pb, Zn, Ni, Fe, Mn, As, Li, Ba, (filtered) DOC, Tot. Alkalinity	Bimonthly prior to active subsidence	GeoTerra
				Weekly during active mining	GeoTerra
				Bi-monthly after active subsidence for at least 12 months	GeoTerra
			Prior to undermining Redbank Creek, install 2 bores in Redbank Creek – Open standpipe piezometer (OSP) and vibrating wire piezometer (VWP)	Complete	Tahmoor Colliery
			Prepare a *Shallow groundwater hydrological investigation and monitoring program*	Prior to undermining Redbank Creek	Tahmoor Colliery
			Logger download in OSP (P9) and VWP (P10) and dip meter OSP (P9)	Bi-monthly	GeoTerra / Fulton
Surface Water	**Impacts to stream water quality**	**<2 month change within baseline variability or water quality reduction over minimum 2 month period.** **Increase in stream Fe hydroxide precipitates**	Manual field analysis (EC, pH, DO, ORP, temp)	Bimonthly prior to active subsidence	GeoTerra
				Weekly during active mining	GeoTerra
				Bi-monthly after active subsidence for at least 12 months	GeoTerra
			Laboratory Analysis of TDS, Na, K, Ca, Mg, F, Cl, SO4, HCO3, NO3, Total N, Total P, Cu, Pb, Zn, Ni, Fe, Mn, As, Li, Ba, (filtered) DOC, Tot. Alkalinity	Bimonthly prior to active subsidence	GeoTerra
				Weekly during active mining	GeoTerra
				Bi-monthly after active subsidence for at least 12 months	GeoTerra

Natural Feature	Impact	Trigger	Monitoring	Timing & Frequency	By Whom
		compared to baseline	Logger download in OSP and VWP and dip meter OSP (P9)	Bi-monthly	GeoTerra / Fulton
			Notify key stakeholders including key Government agencies and landowners	Include in Subsidence Monitoring Report, End of Panel Report and Annual Review	Tahmoor Colliery
Surface Water	**Impacts to stream water quality**	**Significant reduction compared to baseline and predicted impacts last over >2 months and > 2 STD deviation reduction in water quality at downstream monitoring site compared to baseline and / or significant observable increase in Fe hydroxide precipitate compared to baseline observations**	Manual field analysis (EC, pH, DO, ORP, temp)	Annual prior to active subsidence	GeoTerra
				Weekly during active mining	GeoTerra
				Bi-monthly after active subsidence	GeoTerra
			Laboratory Analysis of TDS, Na, K, Ca, Mg, F, Cl, SO4, HCO3, NO3, Total N, Total P, Cu, Pb, Zn, Ni, Fe, Mn, As, Li, Ba, (filtered) DOC, Tot. Alkalinity	Annual prior to active subsidence	GeoTerra
				Weekly during active mining	GeoTerra
				Bi-monthly after active subsidence	GeoTerra
			Notify key stakeholders including DRG, Principle Subsidence Engineer and key Government agencies	Within 1 week	Tahmoor Colliery
			ERG to consider any additional management and monitoring actions	Within 24 hours	ERG
Surface Water	**Impacts to stream water quality**	**Impacts to bedrock** ***Pool level / flow decline <20% during mining compared to baseline for > 2 months***	Continue reviewing results in consultation with DRG to determine if water level has remediated.	Annually or as requested by DRG	Tahmoor Colliery
			Notify key stakeholders including DRG, Principle Subsidence Engineer and key Government agencies	Within 24 hours	Tahmoor Colliery
			Notify ERG of trigger exceedance and any management decision undertaken	Within 24 hours	ERG
Surface Water	**Impacts to stream water level**	**None**	2 years baseline data of water level logger and photographic monitoring from same point each site visit	Complete	Tahmoor Colliery
			Install 2 shallow groundwater boreholes in Redbank Creek LW31 impact zone: - 1 open standpipe borehole - 1 borehole with 3 vibrating wire piezometers	Complete	Tahmoor Colliery
			Characterise pre-mining lithology and fracture networks in shallow aquifers down to 50m below creek level.	Approval of Stage 2 shallow groundwater hydrological investigation prior to undermining Redbank Creek	Tahmoor Colliery

Natural Feature	Impact	Trigger	Monitoring	Timing & Frequency	By Whom
			Logger download in OSPs and VWPs and dip meter in OSPs	Quarterly	GeoTerra / Fulton
			Continue photographic monitoring from same point each site visit	Monthly for at least 2 months prior to active subsidence	Tahmoor Colliery
				Weekly during active subsidence	Tahmoor Colliery
				Bimonthly after active subsidence	Tahmoor Colliery
Surface Water	**Impacts to stream water level**	**Impacts to bedrock** ***<2 months with pool level / flow decline <20% during mining compared to baseline for > 2 months***	Logger download in OSPs and VWPs and dip meter in OSPs	Quarterly	GeoTerra / Fulton
			Continue photographic monitoring from same point each site visit	Monthly for at least 2 months prior to active subsidence	Tahmoor Colliery
				Weekly during active subsidence	GeoTerra
				Bimonthly after active subsidence	Tahmoor Colliery
			Notify key stakeholders including key Government agencies and landowners	Include in Subsidence Monitoring Report, End of Panel Report and Annual Review	Tahmoor Colliery
Surface Water	**Impacts to stream water level**	**Impacts to bedrock** ***>2 months with pool level / flow decline <20% during mining compared to baseline for > 2 months***	Logger download in OSPs and VWPs and dip meter in OSPs	Quarterly	GeoTerra / Fulton
			Continue photographic monitoring from same point each site visit	Monthly for at least 2 months prior to active subsidence	GeoTerra
			Notify key stakeholders including key Government agencies and landowners	Include in Subsidence Monitoring Report, End of Panel Report and Annual Review	Tahmoor Colliery
Surface Water	**Impacts to stream water level**	**Impacts to bedrock** ***Re-direction of surface water flows and / or pool level / flow decline >20% compared to baseline for >2 months***	Continue logger download in OSPs and VWPs and dip meter in OSPs	Quarterly	GeoTerra / Fulton
				Monthly for at least 2 months prior to active subsidence	GeoTerra / Fulton
			Continue photographic monitoring from same point each site visit	Weekly during active subsidence	GeoTerra
				Bimonthly after active subsidence	GeoTerra

Natural Feature	Impact	Trigger	Monitoring	Timing & Frequency	By Whom
			Notify key stakeholders including DRG, Principle Subsidence Engineer and key Government agencies	Within 24 hours	Tahmoor Colliery
			ERG to consider any additional management and monitoring actions	Within 1 week	ERG
			Prepare a Corrective Management Action Plan in consultation with key Government agencies	Timing to be determined by DRG	Tahmoor Colliery
			Notify key stakeholders including key Government agencies and landowners	Include in Subsidence Monitoring Report, End of Panel Report and Annual Review	Tahmoor Colliery
Aboriginal Cultural Heritage	**Impact to SHELTER WITH ART AND DEPOSIT 52-2-3254 Redbank Creek 1**	**None**	Baseline recording of shelter with art and deposit	Complete	Niche
			Prepare an Aboriginal Cultural Heritage Management Plan in consultation with Aboriginal Stakeholders	Complete	Niche
			Apply for an Aboriginal Heritage Impact Permit	Complete	Tahmoor Colliery
Aboriginal Cultural Heritage	**Impact to SHELTER WITH ART AND DEPOSIT 52-2-3254 Redbank Creek 1**	**Minor impacts to the shelter with art deposit**	Record and monitor shelter with art and deposit	Prior to and after LW31 active subsidence	Niche
			ERG to consider any additional management and monitoring actions	Within 1 week	Tahmoor Colliery
			Notify OEH in writing	As soon as practicable after becoming aware of impact	Tahmoor Colliery
Aboriginal Cultural Heritage	**Impact to SHELTER WITH ART AND DEPOSIT 52-2-3254 Redbank Creek 1**	**Major impacts to the shelter with art deposit**	Record and monitor shelter with art and deposit	Prior to and after LW31 active subsidence	Niche
			ERG to consider any additional management and monitoring actions	Within 1 week	ERG
			Notify OEH in writing	As soon as practicable after becoming aware of impact	Tahmoor Colliery
			Prepare remediation plan in consultation with OEH and Aboriginal Stakeholders	After active subsidence	Tahmoor Colliery
Aboriginal Cultural Heritage	**Impact to GRINDING GROOVE SITE 52-**	**None**	Baseline recording of grinding groove site	Prior to active subsidence	Tahmoor Colliery
			Prepare an Aboriginal Cultural Heritage Management Plan in consultation with Aboriginal Stakeholders prior to LW32 active subsidence	Prior to LW32 active subsidence	Niche

Natural Feature	Impact	Trigger	Monitoring	Timing & Frequency	By Whom
	2-2082 Redbank Creek 4		Apply for an Aboriginal Heritage Impact Permit	Prior to LW32 active subsidence	Tahmoor Colliery
Aboriginal Cultural Heritage	**Impact to GRINDING GROOVE SITE 52-2-2082 Redbank Creek 4**	**Minor impacts to grinding groove site**	Record and monitor grinding groove site	Prior to and after LW31 active subsidence	Niche
			ERG to consider any additional management and monitoring actions	Within 1 week	ERG
			Notify OEH in writing	As soon as practicable after becoming aware of impact	Tahmoor Colliery
Aboriginal Cultural Heritage	**Impact to GRINDING GROOVE SITE 52-2-2082 Redbank Creek 4**	**Major impacts to grinding groove site**	Record and monitor grinding groove site	Before active subsidence	Niche
				After active subsidence	Niche
			ERG to consider any additional management and monitoring actions	Within 1 week	ERG
			Notify OEH in writing	As soon as practicable after becoming aware of impact	Tahmoor Colliery
			Prepare remediation plan in consultation with OEH and Aboriginal Stakeholders	After active subsidence is complete	Tahmoor Colliery
European Historical Heritage	**Koorana Homestead Complex**	**None**	Baseline heritage and structural assessments	Complete	Niche / JMA
			Surveys and visual inspections as outlined in Property Subsidence Management Plan (PSMP)	Refer to PSMP for detailed monitoring programme	Tahmoor Colliery
			Review monitoring data	Include in Subsidence Monitoring Report, End of Panel Report and Annual Review	Tahmoor Colliery
European Historical Heritage	**Koorana Homestead Complex**	**Impacts occurring to the structures or to the heritage significance of the property**	Surveys and visual inspections as outlined in Property Subsidence Management Plan (PSMP)	Refer to PSMP for detailed monitoring programme	Tahmoor Colliery
			Review monitoring data	Include in Subsidence Monitoring Report, End of Panel Report and Annual Review	Tahmoor Colliery
			ERG to consider any additional management and monitoring actions	Within 1 week	ERG
European Historical Heritage	**Mill Hill**	**None**	Baseline heritage and structural assessments	Complete	Niche / JMA
			Surveys and visual inspections as outlined in Property Subsidence Management Plan (PSMP)	Refer to PSMP for detailed monitoring programme	Tahmoor Colliery

Natural Feature	Impact	Trigger	Monitoring	Timing & Frequency	By Whom
			Review monitoring data	Include in Subsidence Monitoring Report, End of Panel Report and Annual Review	Tahmoor Colliery
European Historical Heritage	**Mill Hill**	**Impacts occurring to the structures or to the heritage significance of the property**	Surveys and visual inspections as outlined in Property Subsidence Management Plan (PSMP)	Refer to PSMP for detailed monitoring programme	Tahmoor Colliery
			Review monitoring data	Include in Subsidence Monitoring Report, End of Panel Report and Annual Review	Tahmoor Colliery
			ERG to consider any additional management and monitoring actions	Within 1 week	ERG
Flora and Fauna	**Macroinvertebrate**	**None**	Stream Health Assessment	Prior to undermining Redbank Creek	Niche
				End of Panel Reporting	Niche
	Macroinvertebrate	**Impacts occurring to the significance of stream health**	ERG to consider any additional management and monitoring actions	Within 1 week	ERG
			Prepare remediation plan in consultation with OEH and Fisheries	After active subsidence is complete	Tahmoor Colliery
Flora and Fauna	**Amphibian**	**None**	Record and monitor prior to undermining Redbank Creek	Prior to undermining Redbank Creek	Niche
				End of Panel Reporting	
	Amphibian	**Impacts occurring to the significance of amphibian population**	ERG to consider any additional management and monitoring actions	Within 1 week	Niche
			Prepare remediation plan in consultation with OEH	After active subsidence is complete	Tahmoor Colliery
Flora and Fauna	**Riparian**	**None**	Record and monitor prior to undermining Redbank Creek	Prior to undermining Redbank Creek	Niche
				End of Panel Reporting	
	Riparian	**Impacts occurring to the significance of ecology in riparian zone**	ERG to consider any additional management and monitoring actions	Within 1 week	Niche
			Prepare remediation plan in consultation with OEH	After active subsidence is complete	Tahmoor Colliery

5.5 Contingency Plan

In the event that the impacts due to the extraction of Longwall 31 are greater than predicted the following contingent measures would be implemented.

5.5.1 Surface Water

A *Corrective Management Action Plan* (CMAP) has been developed for Stage 1 remediation of Myrtle Creek and submitted to DRG for approval of a Trial Project Site. When extraction of Longwall 32 beneath Redbank Creek is complete, a further CMAP for Redbank Creek will be prepared in consultation with key Government agencies to commence remediation of Redbank Creek. For further details refer to *Tahmoor Colliery Corrective Management Action Plan Revision B dated 16 June 2017.*

Longwall 32 is the final longwall to extract beneath Redbank Creek.

Surface water remediation will involve a staged approach, with outcomes from each stage being assessed to provide the best approach for the next stage. The purpose of this approach is to provide a strategy of continuous improvement from the staged outcomes.

5.5.2 Groundwater

Near surface ground water levels may be affected by mine subsidence. Any property owner that has a registered borehole impacted by subsidence is connected to town water by Tahmoor Colliery until Subsidence Advisory NSW repair the bore.

5.5.3 Flora and Fauna

5.5.3.1 Aquatic

An assessment of aquatic ecology is required at the end of Longwall 31 to determine what remediation is required.

5.5.3.2 Terrestrial

Niche (2014) assessment concluded that the extraction of Longwall 31 is unlikely to have significant impact on any threatened fauna species. Impacts to vegetation associated with subsidence are unlikely, and if occurred, are likely to be localised minor floristic changes.

If impacts do occur, a qualified ecologist will be engaged to assess the impact and prepare a contingency plan.

5.5.4 Aboriginal Cultural Heritage

The following Aboriginal Cultural Heritage items are located within the active subsidence zone of Longwall 31.

5.5.4.1 52-2-3254 Redbank Creek 1

Shelter with art deposit located directly above Longwall 29 and no impacts reported. AHIP Approval CC0000774 received 19/12/2014.

Impacts to date have not been reported, however if impacts do occur a remediation plan will be prepared in consultation with key Government agencies and Aboriginal stakeholders.

5.5.4.2 52-2-3667 Redbank Creek IA 1

Open camp site located directly above Longwall 29 and no impacts reported. Not likely to be impacted.

5.5.4.3 52-2-3868 Redbank Tunnel 3/A

Open camp site located directly above Longwall 29 and no impacts reported. Not likely to be impacted.

5.5.4.4 52-2-3870 Redbank Tunnel 35/A

Open camp site located directly above Longwall 29 and no impacts reported. Not likely to be impacted.

5.5.4.5 52-2-2082 Redbank Creek 4

Grinding groove site located directly above Longwall 32. Develop an ACHMP in consultation with Aboriginal stakeholders that outlines contingency plan.

5.5.5 European Historical Heritage

The following European Historical Heritage items are located within the active subsidence zone of Longwall 31.

5.5.5.1 Koorana Homestead Complex

Based on the site inspection and assessment of Koorana Homestead Complex by structural engineer John Matheson, the structures are considered to be sufficiently ductile to remain safe and serviceable during the extraction of Longwall 31.

No mitigation measures are recommended to be undertaken prior to the period of active subsidence. During active subsidence monitoring results will be reported to landholder, Wollondilly Shire Council and Subsidence Advisory NSW. If an impact is reported, Subsidence Advisory NSW will be notified immediately and the Structures Management Group (SMG) will be responsible for taking the necessary actions required to (refer to *MSEC862-13-01 Property Subsidence Management Plan for Koorana Homestead. Revision D).* Subsidence Advisory NSW will engage contractors in readiness for structural repairs in the unlikely event that emergency repairs are required.

5.5.5.2 Mill Hill

Based on the site inspection and assessment of Mill Hill by structural engineer John Matheson (2014), the structures are considered to be sufficiently ductile to remain safe and serviceable during the extraction of Longwall 31. John Matheson will inspect the property prior to active subsidence of Longwall 31 to confirm that building modification has not taken place since 2014.

If confirmed that the property is structurally the same as inspected in 2014 no mitigation measures are recommended to be undertaken prior to the period of active subsidence. Subsidence Advisory NSW will engage contractors in readiness for structural repairs in the unlikely event that emergency repairs are required.

5.5.5.3 Rural Landscape

No contingency plan is required for the rural landscape on Thirlmere way.

6 Surface Water Remediation

6.1 Myrtle Creek

Mining has moved away from Myrtle Creek and subsidence movements in the creek have effectively ceased. A CMAP has been prepared and submitted to Division of Resources and Geoscience on 16 June 2017 for the commencement of creek remediation.

The CMAP presents a plan with a particular focus on the first stage (Myrtle Creek CMAP Trial Project), which involves initial characterisation of the hydraulic controls and fracture characterisation along Myrtle Creek as a whole, as well as trial remediation of a rock bar constrained pool at Site 23 in Myrtle Creek.

On approval of this document, a detailed Project Plan will be developed in consultation with key Government agencies. On completion of the Myrtle Creek CMAP Trial Project, outcomes will be assessed to determine the best approach for a future Stage 2 remediation works in Myrtle and Redbank Creek.

This will involve a staged approach, with outcomes from each stage being assessed to provide the best approach for the next stage. The purpose of this approach is to provide a strategy of continuous improvement from the staged outcomes.

6.1.2 Rehabilitation Aims and Objectives

At present the aims and objectives for corrective management are based on relatively conceptual understanding of the geomechanical and hydrogeological conditions of the ground conditions at Myrtle Creek.

In accordance with the Longwall 27-30 EMP, the objectives of the corrective action are to conduct rehabilitation works when required, including:

a) Conducting remediation works that protect to the greatest practicable extent the ecological values of the area.

b) Repairing aesthetic values where necessary.

c) Reducing the interaction of surface and groundwater flow where enhanced through mining.

d) Having creeks and pools function in a similar manner to the pre-impact state.

e) Having surface flows and pool water quality continue to provide suitable aquatic habitat.

f) Re-establishing the ecological values to a similar state to before mining;

g) Creeks and catchments yielding similar water quantity and quality following mining.

h) Monitoring and reporting effectiveness of the program.

The corrective action rationale and rehabilitation approach; and subsequent performance measures will be determined and agreed between key stakeholders and Government agencies. Before an agreed rationale and approach can be established, a robust understanding of the ground and environmental conditions is required.

6.1.3 Ecological Values

The Longwall 29 End of Panel Report includes an assessment of the surface water, dams and groundwater (GeoTerra, 2016). The summary of observed impacts following extraction of Longwall 29. In relation to Myrtle Creek, determined that:

> *'No adverse effect on plateau stream ecology has been reported.'*

GeoTerra (2016) also provided a description of the Myrtle Creek ecology as follows:

> *'Myrtle Creek flows directly into the Nepean River approximately 1.8km southeast of Longwall 29. Its headwaters are located upstream of Panel 22 and generally consist of small grass covered channels that become larger and more incised downstream of Panels 23 to 29. Myrtle Creek has been undermined by Longwalls 4, 22, 23B, 24B and 25 to 28, whilst Longwall 29 has not undermined the main channel of the creek The riparian flanks have been significantly altered by residential development in Tahmoor, whilst the channel has not been significantly affected except where general rubbish or solid waste has been dumped in the creek or it is overgrown by invasive weeds. Some isolated weeding and stream bank regeneration works have been conducted, however many of the areas are re-infested with weeds. The stream bed and banks are generally well vegetated, and do not show significant erosion or bank instability.'*

At this stage no ecological values have been affected by mining impacts and therefore do not require specific attention in this CMAP document. Tahmoor Colliery will continue to monitor the ecological values in accordance with the Longwall 27-30 EMP.

6.1.4 Water Level Ascension

One of the primary objectives of the rehabilitation is to restore the pool holding capacity of ponds. This would be expected to reduce the interaction between surface and groundwater flow.

The automated pond level monitors already installed at key locations along Myrtle Creek (for example at Site 23) will be used to quantitatively assess the effectiveness of the rehabilitation.

6.1.5 Surface Flow and Water Quality

Myrtle Creek is ephemeral, and requires review of baseline and proxy data to establish requisite flow conditions. The review will consider the following:

Surface Flow

a) Basin hydrology and run-off.

b) Trends in the data (e.g. precipitation).

c) Consideration of the prevailing and preceding meteorological conditions.

Water Quality

a) Consideration of activities being undertaken in the vicinity – land development, illegal waste tipping, contaminated run-off / leachates.

b) Consideration of any other significant events that may have an influence on water quality (e.g. bushfires).

c) Parameters under consideration will include: pH, EC, turbidity, Oxidation Reduction Potential (Eh), TOC, dissolved organic carbon (DOC), major ions (calcium [Ca], magnesium [Mg], sodium [Na], potassium [K], chloride [Cl], sulphate [SO4] and bicarbonate [HCO3]) and trace metals (aluminium [Al], iron [Fe] and manganese [Mn]).

d) Daily water quality monitoring can be put in place before during and after all rehabilitation works.

6.1.6 Creek Catchment Yield

Since catchment yield has not been impacted by the mining impacts over Myrtle Creek (see **Figure 11**), this is not considered to be suitable rehabilitation completion criteria. Tahmoor Colliery will continue to monitor the flow at site M7 in accordance with the Longwall 27-30 EMP to assess any loss of catchment yield.

6.1.7 Aesthetic Values

The presence rehabilitation (construction works) may impact on ground and environmental conditions, caused by access (tracked equipment), site preparation (trimming of braches and minor clearing) drill-holes (i.e. cavities in the rock) and minor impact on the rock surface by plant and equipment (e.g. drill rig).

To repair any damage, the use of coloured grouts will be considered to restore the aesthetic values to the creek beds following corrective works. Coloured grouts have been used previously at the Waratah Rivulet and at Mahoney's Hole.

The use of aesthetic grouting will be considered following the grout injection program if drill-hole collars compromise the aesthetic appearance of the site.

Revegetation of cleared and impacted areas using appropriate native species may also be implemented at completion of works.

6.2 Ground Characterisation

Ground characterisation will occur at all impacted sites identified in through the SMP / EMP / TARP process subject to access constraints and approval conditions. These include:

a) 8 sites below Longwall 27 (Sites 12 to 19 inclusive); and

b) 4 sites below Longwall 28 (Sites 20, 21, 23 and 26).

Prior to any physical works, a robust understanding of the ground conditions is required. As such, Tahmoor Colliery propose the following ground characterisation approach:

Desktop Study

Based on existing data, a desktop study will be undertaken to provide a hypothetical ground model, including geological / geomechanical, geomorphological, hydrological and hydrogeological characteristics for each site.

This model will consider:

a) Geometrical configuration, i.e. provisional basin plans, long-sections and cross-sections.

b) The mode, volume and location of water loss.

Investigation

Undertake physical investigations to confirm desktop assumptions, supplement data gaps and acquire new information, including:

a) The depth and width to which the fracture network extends.

b) Characteristics of the fracture network, including fracture aperture and hydraulic conductivity.

c) The susceptibility of the rock mass to treatment e.g. grouting.

In turn, understanding of these conditions provides a basis for establishing the feasibility and method for rehabilitation. In addition, the information obtained during the Ground Characterisation Works will provide a baseline from which the efficacy of future rehabilitation can be compared. The works will also assist in estimating expected grout volumes, which has implications on environmental impact (e.g. duration of works).

6.2.1 Methods for Ground Characterisation

In-situ physical characteristics will be determined by intrusive investigation, including:

Borehole drilling

A number of drilling techniques can be employed for borehole drilling:

a) Mini track-mounted NMLC or open hole.

b) Pneumatic hand drill - open hole.

c) Percussion tube hand corer (soil).

d) Geotechnical logging - rock mass characteristics.

Figure 21 Pneumatic hand drill

Figure 22 Pneumatic hand drill

Geophysical Testing

Including:

a) Caliper Tool.

b) ATV (Acoustic Televiewer).

c) OTV (Optical Televiewer).

d) Seismic Tomography and ERI (Electrical Resistivity Imaging).

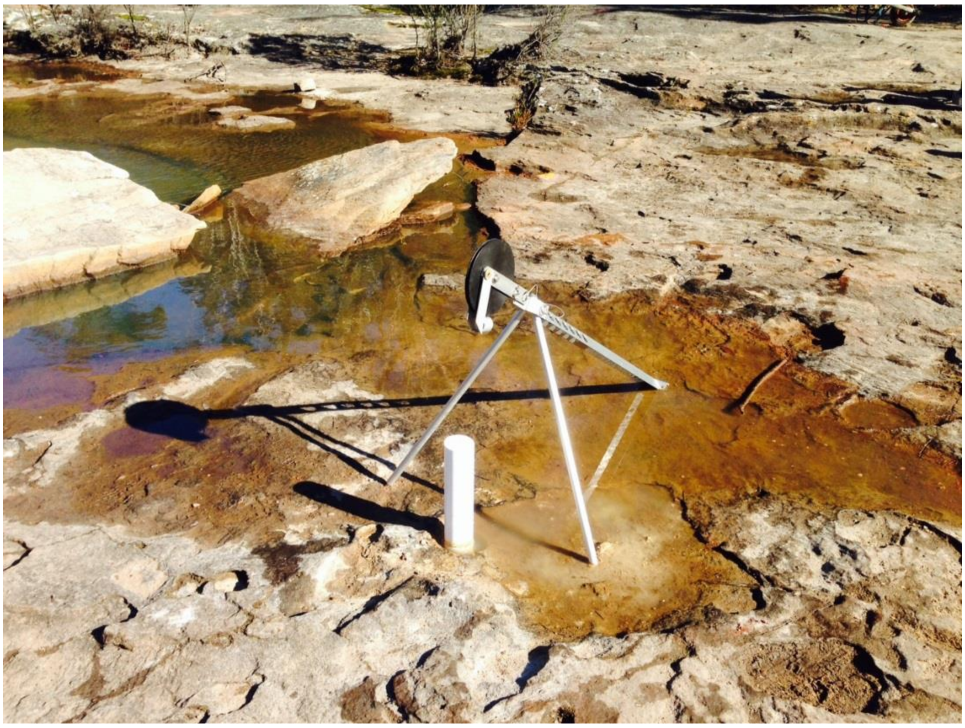

Figure 23 Three arm Caliper tool downhole

Figure 24 Three arm Caliper tool

Hydraulic Conductivity Testing

Including:

a) Falling Head.

b) Packer Testing.

c) Flow Metre.

Additional remote technologies will be considered for environmentally sensitive sites to supplement physical information, including:

a) LiDAR - for hi-resolution topographic survey.

b) UAV - for photogrammetric topographic survey.

c) DifSAR - for 3-dimentional detection of surface topography change, i.e. deformation.

d) LANDSAT - for detection of vegetation change and identifying areas of water loss.

The above methods are addressed in more detail below.

6.2.2 Drilling Method

Accessing the fracture network typically requires a drill rig capable of drilling holes to 10m or so below the level of the base of the creek.

With 5m - 10m high bank sloping back from the creek, a drill rig with capacity to drill 30m deep holes should be used on the banks.

The drill rig will likely be a rotary machine using water to flush the cuttings rather than an air hammer. In holes drilled with compressed air, the compressed air tends to over-pressure existing fractures causing them to be extended and new fractures to be created.

Hand operated drilling machines have been used to drill short holes suitable to grout up near-surface fracture networks. They are not suitable for accessing fractures deeper than about 2m.

Drilling of grout holes will be carried out by diamond coring at a nominal NQ ~60 mm hole diameter, using a diesel-operated rubber tracked mini-drill rig such as Dando or Fraste Multidrill.

During drilling, flush water returned to the borehole collar will be captured in a surface sump and re-circulated via a holding tank to minimise creek contamination and maximize water re-cycling. Baffles and / or filters will be used in the tank and they will be removed daily for filter cake cleaning and removal. Water and cutting loss within fractures during drilling will be minimised by adopting a downstage drilling and grouting technique.

6.2.2.1 Fracture Assessment

Borehole geophysical logging for geotechnical investigations typically involves identification of defects and fractures, and *in-situ* assessment of rock properties, including assessing fluid properties and identifying features associated with fluid or contaminant flow, such as fracture zones and permeable geological units.

The following geophysical tool will be considered for Fracture Assessment:

Caliper Tool

Caliper tools records a single continuous borehole diameter log by means of three mechanically coupled arms in contact with the borehole wall. An indication of fracture aperture and spacing can be achieved.

ATV and OTV

ATV and OTV logging will be considered to acquire oriented defect information, aperture / thickness of features such as joints and bedding. Televiewer logging produces oriented, 360° images of the borehole wall. An acoustic televiewer achieves this by measuring the amplitude and travel time of a reflected acoustic beam, to infer rock hardness and borehole diameter.

An optical televiewer uses a conical mirror lens to capture a high-resolution 360° colour digital photograph of the borehole wall. Televiewers use magnetometer / accelerometer-based deviation modules to accurately orient data acquired downhole and log deviation of the borehole from vertical.

Further Methods for Consideration

Further methods Tahmoor Colliery will consider include cross-hole seismic tomography and ERI (surface or cross-hole). The resolution of these methods are much coarser than ATV or OTV, i.e. they will unlikely identify individual defects; however, larger zones of higher or lower fracture density maybe identifiable, based on rock strength (seismic) and porosity (ERI).

ERI images the distribution of electrical resistivity, and is highly dependent on water content – air filled fractures will have a high resistivity, while water filled fractures will have a low resistivity. ERI survey requires small (15 mm diameter x 100 mm deep) pilot holes for electrodes, drilled every 0.5 to 1.0 m. Electrical safety will be a key determining factor of method suitability/feasibility when working near water.

6.2.2.2 Hydrological Assessment

Catchment Assessment

Considerable hydrological data has been collated before, during and after longwall mining below Myrtle Creek, including development of stream gradient data. This data will be more closely analysed to identify and confirm key hydrological controls (e.g. pools) within the context of rehabilitation.

The hydrological assessment is the logical first phase to better inform the most appropriate locations for drilling fracture characterisation holes and to provide the hydrological background to inform the injection locations.

Stream flow and precipitation data will likely be used as input data for catchment hydrologic modelling.

Model inputs can include daily precipitation and daily measured catchment outflow. Outflow includes direct runoff, interflow via soils and base flow from shallow perched groundwater. By means of nonlinear optimization curve fitting, modelling can indicate a mass balance of water inputs and outputs by estimating daily evapotranspiration and the change in catchment soil and shallow groundwater storage in the modelled period.

To assess any potential mining impacts, a set of parameters will be obtained by using pre-mining precipitation and flow data. These parameters can provide the basis of a hydrologic model for each catchment (or sub-catchment) established over one or more years of pre-mining (baseline) rainfall and flow data, which can be subsequently applied to model periods of rainfall and flow data obtained during the mining period.

Modelling can be calibrated using gauged baseline data.

In-Situ Packer Testing

Typical hydraulic testing methodologies employed at creek sites (e.g. Waratah Rivulet) utilise a modified packer assembly allowing testing without the support of a drilling rig. Packer testing will be considered to assess the permeability of specific fracture zones and the background permeability of the surrounding rock mass. Rising Head Tests (RHTs) can be carried out to supplement packer data.

Data Collection and Analysis

Data analysis will be carried out in accordance to ISO22282-3:2012. A review of the hydraulic borehole test setup and procedure for ground characterization pre-grouting and for quality control will be undertaken during the grouting process and post grouting program.

Alternative Technologies

Alternative technologies to water pressure testing in packer isolated test intervals for characterisation of defect permeability and connectivity include flow metre testing.

Flow meter testing of ground characterisation holes and across holes estimate transmissivity of single fractures (instead of multiple fractures within a test interval as typical for water pressure testing) intersected by the holes and connectivity of the fractures between a set of holes. This technology is most suitable for testing of the achieved level of ground improvement when conducted pre and post grouting across holes located at either site of a treat section. A schematic illustration of the setup is shown in the figure below.

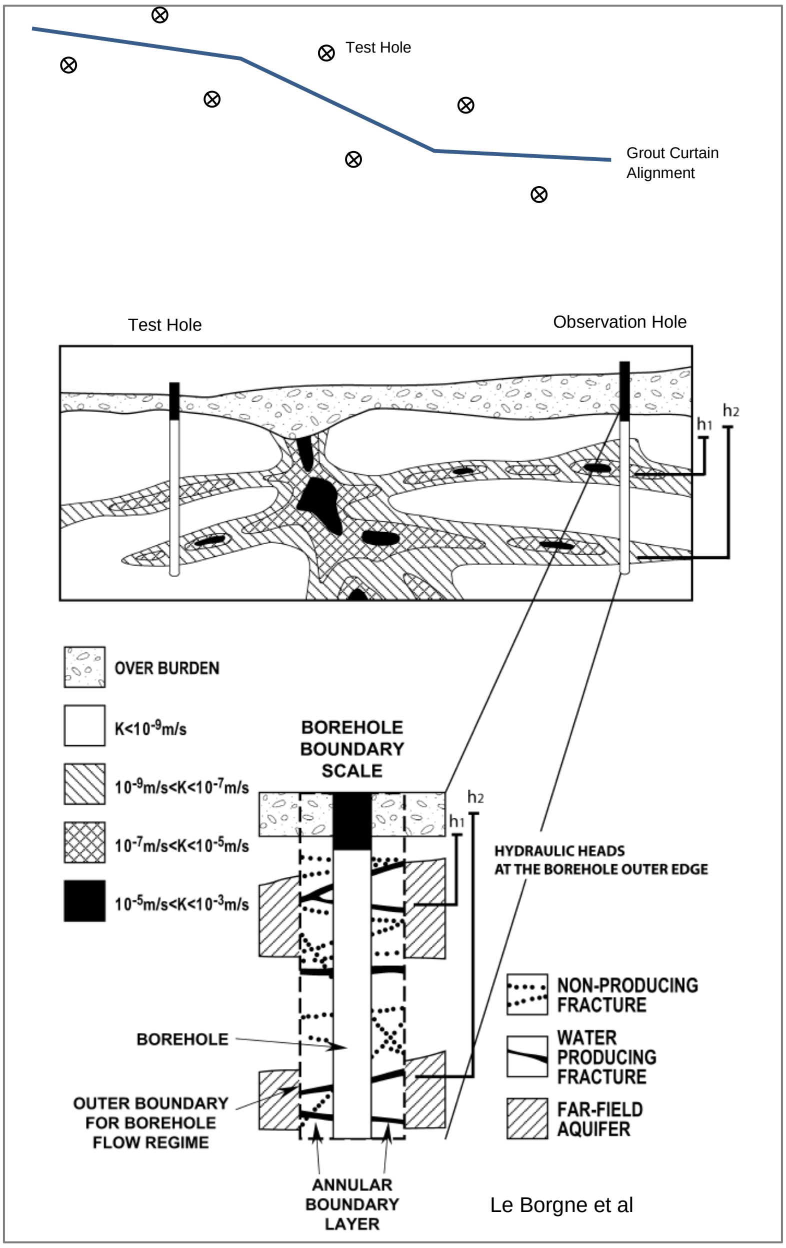

Figure 25 Schematic illustration of the site setup

Impeller flowmeter logging

Impeller flowmeter logging uses an impeller which revolves as fluid flows over it. The number of revolutions per second is logged and used to calculate the velocity of flow within the borehole at certain depths. The tool uses a geophysical logging winch and data logger to record the flow data, and control the depths and logging rate. The impeller flow meter can be used while trolling at a constant rate, to create a profile over a length of the borehole, or else stationary at regular intervals, to measure the flow at particular points. Using these flow values, a hydraulic conductivity can be determined.

6.2.2.3 Correlation of Geophysical and Hydrological Data

The hydraulic conductivity of the rock at the site is directly affected by the secondary porosity of the fracture network in the ground. As a result the findings of the geophysical survey will be reviewed in relation to the hydraulic testing, using software such as WellCAD.

6.2.3 Review

On completion of ground characterisation, the project team will analysis and review the data to calibrate the desktop study ground model, including geological / geomechanical, geomorphological, hydrological and hydrogeological characteristics for each site.

6.3 Rehabilitation Design

Following the data review, rehabilitation design will be undertaken against agreed rehabilitation criteria, aimed at improving:

a) Ecosystem function, including maintaining or establishing self-sustaining native ecosystems comprised of local native plant species; with a landform consistent with the surrounding environment.

b) Decrease water level recession rates for pools, such that they demonstrate a similar pool behaviour to that which existed prior to subsidence impact.

c) Aesthetic values where necessary.

Rehabilitation design includes:

a) Product selection (e.g. grout type).

b) Product application methodology.

c) Test specifications (for completion reporting).

6.3.1 Product Selection

There are a number of products available to the construction market for the filling of gaps, sealing of surfaces and reducing permeability of materials, some have previously been trialed in creek bed remediation.[1]

The use of sand, and sand with colloidal silica binder was initially trialled to remediate a rock bar in the Waratah Rivulet. The strategy proved to be unsuccessful as a consequence of grout material washing out of the fractures (Greg Tarrant, pers. comm). At times the flow in streams such as the Waratah Rivulet and Myrtle Creek can exceed 200 ML/day.

The injection of polyurethane (PUR) within the Waratah Rivulet was considered to be successful and won the UNSW Minerals Council Environmental Excellence Award. The rock bar is understood to still be overflowing to this day. Clearly the Waratah Rivulet experience should not be blindly applied to Myrtle Creek however it is considered prudent to adopt a strategy that recognises that PUR injection is the only proven rehabilitation method and to exclude PUR only if a viable alternative is developed. It is emphasised that whilst Tahmoor Colliery will make every endeavour to minimise costs, the most effective rehabilitation available will be implemented.

The outcomes of the site characterisation work, particularly the extent and width of open fractures, together with maximum potential flow rates will be key drivers in the selection of grout product at any given site.

1

Commonwealth of Australia 2014, Temperate Highland Peat Swamps on Sandstone: evaluation of mitigation and remediation techniques, Knowledge report, prepared by the Water Research Laboratory, University of New South Wales, for the Department of the Environment, Commonwealth of Australia.

Table 13 High level considerations for selection of a product for creek bed remediation

Material	Flowability / Viscosity	Durability	Toxicology	Expandability	Control
Cement	Poor	Moderate	Moderate	Poor	Poor
Sand	Poor	Poor	Good	Poor	Poor
Bentonite	Moderate	Moderate	Good	Moderate	Poor
Polyurethane Resin (PUR)	Good	Good	Good	Good	Good
Bitumen	Good	Good	Poor	Poor	Moderate
Latex	Good	Moderate	Moderate	Poor	Good

Given the environmental sensitivity of the area, it is unlikely that cementitious, bitumous or latex products will be suitable. PUR are likely the more appropriate grout type product, with potable water compatibility.

6.3.2 Product Approvals

Whichever product is selected, it will likely require approval for application from key stakeholders. As discussed above, there is a precedent for use of PUR in environmentally sensitive areas.

6.3.3 Product Application

Product application will be by an appropriately trained and certified application specialist, approved to use the chosen product by the product supplier. We note that the relationship between product supplier and applicator will likely be kept separate; for example, if the supplier is also the applicator of the product being used, there is neither incentive nor accountability for the works to be undertaken in a manner that uses the appropriate volume of product to seal the rock mass.

The application (or constructability) of different grout products is determined by a number of limiting factors, including:

a) Ground Conditions.

b) Accessibility.

c) Environmental Constraints / Compliance.

d) Timing.

e) Experience of Applicator.

Product application design will consider these factors, as well as the most effective treatment application configuration, including:

a) Shallow pre-treatment grouting.

b) Shallow pattern grouting.

c) Shallow to deep ‘curtain’ approach.

d) Surface aesthetic filling.

With regard to surface aesthetic filling, it is likely that in some stream bed, pool and bar locations, the appearance of water flowing over rather than through the rock mass can be improved by sealing all surface cracking.

6.4 Rehabilitation Plans – Site Specific

Following Rehabilitation Design, Tahmoor Colliery will prepare site specific rehabilitation plans for discrete sites, in consultation with Department of Resources and Geoscience and other stakeholders, The Plans will include specific details relating to:

a) Access.

b) Plant and Equipment Type.

c) Treatment Layout Plan.

d) Site Specific Erosion and Sediment Control Measures.

6.5 Construction Documentation

In addition to administrative controls covered in existing environmental documentation (e.g. Sediment and Erosion Control Plan), Tahmoor Colliery consider appropriate planning, supervision, quality control and assurance are required to carefully apply grouting products to the natural environment.

As such, the rehabilitation campaigns should be treated as formal construction projects, deeming the consideration of:

a) A robust Project Works Schedule, to manage program and budgets.

b) An overarching Project Construction Safety and Environmental Management Plan (CSEMP) for the proposed works, with task specific environment and safety plans.

c) Risk workshops for key tasks and change management.

d) A Project / Site Manager to manage and co-ordinate site works, including:

   i. Preparation of a daily project works diary to document construction works, materials, safety and environmental learnings and conformance with the CSEMP and relevant sections of the EMP.

   ii. Oversight of the implementation of design requirements and performance criteria.

   iii. Preparation of weekly reporting, including cost tracking.

   iv. Quality Control and Assurance protocols, particularly in relation to Verification of Works, which might include Caliper, ATV / OTV and Packer Testing to inform the ongoing rehabilitation design, anticipated material volumes, schedule and efficacy of the works.

6.6 Reporting

Following completion of rehabilitation works at any discrete site, Tahmoor Colliery will provide a completion report to key Government agencies, demonstrating the rehabilitation criteria has been met.

The water level recession rates, ecosystem and aesthetic performance indicators will be considered to have been met if data analysis indicates there is not a statistically significant change in conditions after rehabilitation, compared to conditions prior to the triggering of rehabilitation.

The completion report will likely include:

a) Summary of works executed.

b) Permeability test results.

c) Demonstration of crack infilling.

d) Monitoring results.

e) Overall summary of hydrological performance.

6.6.1 Completion Criteria

In the absence of further mining impacts, some of the potential remediation objectives envisaged in the Longwall 27-30 EMP do not require restoration. These include:

a) Restoration of the ecological value.

b) Restoration of creek or catchment yield.

The project completion criteria are designed to provide a quantitative means to assess the pre-mining and post restoration aspects that relate to the functioning of the creek. The completion criteria are:

a) Reduction in pool water level recession rates.

b) Measurement of the extent of fracture in-filling.

c) Measurement of reduction in rock mass permeability.

6.6.1.1 Restoration of Pool Holding Capacity

Myrtle Creek is recognised as an ephemeral stream based on the hydrological assessment. However whilst flow is not continuous, pools are generally expected to retain water (unless unusual climatic conditions are evident (e.g. drought).

The completion criteria in relation to pool holding capacity at Site 23 is that the recession rate within pool 23 will be rehabilitated to pre-mining conditions as far as practicable.

6.6.1.2 Fracture Filling Criteria

A quantitative measure of the fracture apertures (void spaces) will be obtained by borehole Caliper and recorded by televiewer prior to the commencement of grout injection. The data will include the location and aperture size at least 5 locations across the rock bar at Site 23.

Following grout injection, the same sites will be re-drilled and repeat measurement of the fracture profile will be conducted (or as near as practicable).

The completion criteria in relation to fracture filling is that at least 95% of all fractures across the Site 23 rock bar will be filled.

6.6.1.3 Rock Mass Permeability

A quantitative measure of rock mass permeability will be obtained by packer testing. At least 5 drill holes at a minimum of 3 depths will be measured prior to grout injection. The holes will be located across the Site 23 rock bar.

Following grout injection, the same sites will be re-drilled and packer tests conducted at the same locations and the same depths as prior to grouting (or as near as practicable).

The completion criteria in relation to permeability is that a reduction in permeability of at least 3 orders of magnitude will be obtained. In addition, the permeability of the rock bar retaining the pool at Site 23.

6.7 Limitations

As remediation efforts move upstream, flow decreases and the benefits of intervention are likely to diminish while the effort involved is likely to increase. Part of the strategy will involve determining an acceptable balance between beneficial outcomes and remediation effort, collateral impact and cost.

This component of the strategy is beyond the scope of this Report and is not considered further.

No amount of remediation will be able to maintain connected water flow along the full length of the subsidence affected reach of Myrtle Creek. The upstream extent at which water is maintained permanently at the surface in a natural creek is a function of many factors, but primarily the quantity of flow in the creek. Flow diminishes in an upstream direction toward the catchment headwaters.

Flow is also a function of rainfall runoff and catchment characteristics.

Factors that affect the rate and quantity of rainfall runoff reporting to the creek include relative proportion of natural bushland to urban / rural development and the number of farm dams diverting runoff to storage. This temporal and spatial variation of flow means that the upstream location where water is apparent on the surface is ever-changing as is the length of time that upstream pools remain filled after rainfall.

Flow in natural creek systems involves surface flow and sub-surface flow. In downstream sections of a creek system, sub-surface flow may only be a small proportion of the total flow, but as the flow volume diminishes upstream toward the headwaters, a greater proportion of the flow occurs as sub-surface flow.

Mining-induced subsidence movements have the effect of increasing the lateral connectivity through sub-surface fractures in the stream bed.

A greater quantity of the total stream flow can then occur as sub-surface flow and surface flow may not develop until further downstream when either the flow rate increases sufficiently or mining impacts are no longer present.

7 Other Remediation

7.1 Groundwater

7.1.1 Mine Inflows

To date, no abnormal flow from the surface into the mine has been observed and it is not anticipated to occur in the future, although additional inflow to the workings does occurs through subsidence, bedding separation and fracturing of the goaf within the overburden directly above the workings.

Application of an appropriate technique to manage an abnormal inflow to the mine will be determined by agreement with all stakeholders based on the advice of hydrogeologists and ground consolidation technical experts.

If it did occur, selection of the optimum application and combination of materials and techniques will depend on the nature and magnitude of the inflow, technical advice and on stakeholder input.

Tahmoor Colliery would work closely with specialist ground support and PUR injection companies with appropriate experience in chemical injection techniques for consolidation of unstable and porous ground and in the use of such measures to control ground water flows.

The mine's water inrush plan details methodologies relating to grout and PUR-based solutions to localised inflow situations and defines the capability of each product used for ground consolidation and water control, MSDS documents, technical specifications as well as case studies of applications where each product and sealing technique would be most effective.

Pro-active responses based on projected inflows mean that actions may be considered and planned at the time, with reference to pre-planned scenarios. In addition to underground sealing of inflows it may be practical to undertake sealing works from the surface, depending on specific environmental factors related to the proposed work.

With ongoing projections of inflows over the entire longwall block based on the data available at any point in the progress of each longwall, the ERG will take appropriate early remedial action that is anticipated to negate the need to activate the defined response to an actual trigger.

7.1.2 Mine Sealing

The installation of seals in the underground workings is not anticipated to be required.

However, if, required, isolation of areas could be conducted as specific mining areas are completed, with the seals containing monitoring, drainage and sampling facilities to allow water accumulation behind the seals to be monitored, sampled and managed while current areas are mined.

The final sealing of the mine requires bulkheads to be installed that ensure that any water reporting to the mine will be controlled.

Trigger mechanisms that will initiate the decision to abandon other remedial techniques and commence the installation of bulkheads either to isolate areas or to seal the mine are defined as part of the mine closure plan.

7.2 Flora and Fauna

7.2.1 Terrestrial Flora and Fauna

The following remediation for terrestrial flora and fauna is recommended by Niche. All remediation works that are undertaken near waterways, must take appropriate measures to minimise environmental impacts. This includes avoiding the spread of Chytrid Fungus following the NPWS guidelines and the removal of areas of riparian vegetation to provide access for plant and equipment to the waterways.

Any subsidence impacts from the proposal on terrestrial ecological values should be assessed at the completion of each longwall panel to ensure any remediation (if required) is undertaken in a timely manner. This will also assist in increasing the accuracy of predictions of impacts from future longwall mining in the area. The condition of plant communities and habitats should be assessed at sample sites that were assessed prior to the commencement of longwall mining to gain further information regarding possible changes to the habitats due to mining related subsidence.

In the unlikely event that gas release related die-off is observed, actions should be taken to monitor the extent of and recovery of any such vegetation impacts.

7.2.2 Aquatic Flora and Fauna

The impacts of longwall mining on aquatic ecology will be assessed at the completion of each longwall panel to ensure any remediation (if required) is undertaken in a timely manner. This will also assist in increasing the accuracy of predictions of impacts from future longwall mining in the area. Remediation will be conducted in accordance with the SMP and experience from past remediation techniques. Refer to Section 6 *Surface Water Remediation* for further details.

7.3 Archaeological Sites

7.3.1 Aboriginal Cultural Heritage

All Aboriginal Cultural Heritage items must have an AHIP approved by OEH Heritage prior to impact. During the development of the AHIP a ACHMP is developed in consultation with Aboriginal stakeholders and it will outline the recommended remediation of the site.

7.3.2 European Historical Heritage

If the landowners believe they have experienced a mining impact at Koorana Homestead Complex and / or Mill Hill, Subsidence Advisory NSW will assess the damage to determine the cause. If the damage is determined to be attributable to mine subsidence, a scope will be prepared and compensation will be assessed.

8 Reporting

8.1 Monitoring Report

The *Tahmoor Colliery Longwall 31 Subsidence Monitoring Report* is distributed to key stakeholders during the extraction of Longwall 31 and includes the following information:

a) Monitoring period.

b) Current length of extraction.

c) Distance travelled by longwall since previous report.

d) Distance to completion of longwall.

e) Summary of observed ground movements.

f) Have any triggers been reached.

g) Monitoring results for natural features outlined in this Management Plan.

8.2 Annual Report

Annual reporting for the EMP will be in accordance with Condition 16 and Condition 12 g) of the *Subsidence Management Plan Approval for Tahmoor Colliery Longwall 31.* The Annual Reporting will be prepared and presented in the Longwall 31 End of Panel Report. The Report will include but not be limited to:

a) A summary of the subsidence and environmental monitoring results for the year.

b) An analysis of these monitoring results against the relevant:

   i. Impact assessment criteria.

c) Monitoring results from previous panels.

   i. Predictions in the SMP.

d) Identify any trends in the monitoring results over the life of the activity; and

e) Describe what actions were taken to ensure adequate management of any potential or actual subsidence impacts due to mining.

The End of Panel Report will be submitted with the Tahmoor Colliery Annual Review as an Appendix.

8.3 Incidents

The protocol for the notifications of identified exceedances of the trigger levels will be reported in compliance with Condition 14 of the *Subsidence Management Plan Approval for Tahmoor Colliery Longwall 31* as outlined below:

Incident and Ongoing Management Reporting

14. The Leaseholder must within 24 hours of becoming aware of the occurrence, notify:

a) The Principal Subsidence Engineer.

b) Director ESU.

c) SA.

d) NSWoW.

e) Other relevant stakeholders and any Government Agency with a regulatory role if they request such notification, of the following:

   i. Any significant unpredicted and / or higher-than-predicted subsidence and / or abnormalities in the development of subsidence.

   ii. Any exceedance of predicted impacts on groundwater resources and / or the natural environment that may have been caused (whether partly or wholly) by subsidence.

   iii. Any observed subsidence impacts adverse to the serviceability and / or safety of infrastructure and other built structures that may be affected by longwall mining.

   iv. Any significant subsidence-induced cracking and / or ground deformations observed in any surface areas within the SMP application area.

   v. Any buildings, structure and infrastructure, which have become or likely to become hazardous as a result of subsidence, and

   vi. Development of instability and / or falls of rocks within any areas with cliff formation and / or steep slopes that may have been affected by subsidence.

f) The operators of infrastructure affected by subsidence.

Note: *Under Condition 11, the Leaseholder can be directed to, among other things, prepare a report on an incident reported under this condition. A report on the details of the incident, including likely or known causes, responses action and proposed response measures will* *generally be required for incidents that involve material property or environmental damage or have the potential to cause such damage.*

All incidents are reported in the End of Panel Report and Annual Review.

8.4 Complaints

Complaints will be managed in accordance with the Tahmoor Colliery *Community Complaint and Enquiry Procedure.*

9 Audit and Review

Should an audit of the Management Plan be request during that period the following shall occur:

a) An auditor shall be approved by the Secretary of the Department of Planning and Environment (DPE).

b) The scope of the audit shall be approved by the Secretary of the DPE.

The audit report will include:

c) A compliance table indicating the compliance status of each condition of approval.

d) Not use the term “partial compliance”.

e) Recommend actions in response to non-compliances.

f) Review the adequacy of the EMP.

g) Identify opportunities for improved environmental management and performance.

Within six weeks of completing the audit, or otherwise as agreed ty the Secretary, Tahmoor Colliery will submit a copy of the Report to the Director Environment Sustainability Unit and to the Secretary of DPE together with Tahmoor Colliery’s response to any recommendations contained in the audit report and a timetable to implement the recommendations.

10 Contact List

Table 14 Environmental Response Group contact list

Organisation	Contact	Phone	Email	Focus
Division of Resource & Geoscience – *Inspector Environment*	Will Mitry	04 28770312	will.mitry@industry.nsw.gov.au	Environmental Management
Division of Resource & Geoscience – *Team Leader Environment*	Greg Kininmonth	02 42228304	greg.kininmonth@industry.nsw.gov.au	Environmental Management
Mine Safety Operations – *Principal Subsidence Engineer & Senior Inspector*	Gang Li	02 49316644	gang.li@industry.nsw.gov.au	Subsidence Risk Management
GeoTerra - *Principal Hydrogeologist / Geochemist*	Andrew Dawkins	04 1700302	geoterra@iinet.net.au	Surface and groundwater
Mine Subsidence Engineering Consultants – *Subsidence Engineer*	Daryl Kay	02 94133777	daryl@minesubsidence.com	Subsidence Engineer
John Matheson and Associates – *Structural Engineer*	John Matheson	04 18238777	jma.eng@bigpond.net.au	Structural Engineer
Niche Environment and Heritage – *Team Leader Heritage*	Renee Regal	96 305658	rregal@niche-eh.com	Aboriginal Cultural Heritage
Niche Environment and Heritage – *Senior Ecologist*	Luke Baker	96 305658	lbaker@niche-eh.com	Ecology
Wollondilly Shire Council – *Senior Planner*	Michael Buckley	02 46400100	michael.buckley@wollondilly.nsw.gov.au	European Historical Heritage
Tahmoor Colliery – *Manager Environment & Community*	Andrew Reid	04 11440912	andrew.reid@glencore.com.au	Management of this document
Tahmoor Colliery – *Approvals & Community Coordinator*	Belinda Treverrow	04 58627752	belinda.l.treverrow@glencore.com.au	Management of this document
Tahmoor Colliery – *Environmental Coordinator*	Fiona Robinson	02 46400048	fiona.robinson@glencore.com.au	Management of this document
Subsidence Advisory NSW – *Manager Infrastructure*	Matthew Montgomery	02 93728539	matthew.montgomery@finance.nsw.gov.au	Subsidence impacts to infrastructure

11 Reference

Reference
AS/NZS 4360:2004 (2004) *Risk Management.* Joint publication by Standards Australia and Standards New Zealand, 2004.
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DPE (2012). *Standard and Model Conditions for Underground Mining. NSW Department of Planning and Environment.* http://www.planning.nsw.gov.au/Portals/0/Development/SSD_-_Draft_Model_Conditions_-_Underground_Mine.pdf.
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Niche Environment and Heritage, (2014). *Tahmoor North, Longwalls 31 to 37 Terrestrial Ecology Assessment.* December 2014.
Tahmoor Colliery, *Myrtle Creek Corrective Management Action Plan Revision B* dated 16 June 2017

WRM, (2014). *Flood Impact Assessment: LW31 – 37 Tahmoor Coal Pty Ltd 107-02-B.* Prepared by WRM Water and Environment. December 2014.

12 Definitions

Table 15 Definitions

Term	Meaning
Angle of draw	The angle of inclination from the vertical of the line connecting the goaf edge of the workings and the limit of subsidence (which is usually taken as 20 mm of subsidence).
Chain pillar	A block of coal left unmined between the longwall extraction panels.
Cover depth (H)	The depth from the surface to the top of the seam. Cover depth is normally provided as an average over the area of the panel.
Critical area	The area of extraction at which the maximum possible subsidence of one point on the surface occurs.
Curvature	The change in tilt between two adjacent sections of the tilt profile divided by the average horizontal length of those sections.
Extracted seam	The thickness of coal that is extracted. The extracted seam thickness is thickness normally given as an average over the area of the panel.
Face length	The width of the coalface measured across the longwall panel.
Goaf	The void created by the extraction of the coal into which the immediate roof layers collapse.
Goaf end factor	A factor applied to reduce the predicted incremental subsidence at points lying close to the commencing or finishing ribs of a panel.
Horizontal displacement	The horizontal movement of a point on the surface of the ground as it settles above an extracted panel.
Inflection point	The point on the subsidence profile where the profile changes from a convex curvature to a concave curvature. At this point the strain changes sign and subsidence is approximately one half of S max.
Incremental subsidence	The difference between the subsidence at a point before and after a panel is mined. It is therefore the additional subsidence at a point resulting from the excavation of a panel.
Overlap adjustment factor	A factor that defines the ratio between the maximum incremental subsidence of a panel and the maximum incremental subsidence of that panel if it were the first panel in a series.
Panel	The plan area of coal extraction.
Panel length (L)	The longitudinal distance along a panel measured in the direction of (mining from the commencing rib to the finishing rib.
Panel width (Wv)	The transverse distance across a panel, usually equal to the face length plus the widths of the roadways on each side.
Panel centre line	An imaginary line drawn down the middle of the panel.
Pillar	A block of coal left unmined.
Pillar width (Wpi)	The shortest dimension of a pillar measured from the vertical edges of the coal pillar, i.e. from rib to rib.
Strain	The change in the horizontal distance between two points divided by the original horizontal distance between the points.
Sub-critical area	An area of panel smaller than the critical area.

Term	Meaning
Subsidence	The vertical movement of a point on the surface of the ground as it settles above an extracted panel.
Tilt	The difference in subsidence between two points divided by the horizontal distance between the points.
Uplift	An increase in the level of a point relative to its original position.

Table 16 Abbreviations

Abbreviation	Meaning
CCL	Consolidated Coal Lease
DRG	Department of Resource and Energy
EMP	Environmental Management Plan
ERG	Environmental Response Group
ML	Mining Lease
OEH	Office of Environment & Heritage
OSP	Open standpipe
PSMP	Property Subsidence Management Plan
VWP	Vibrating wire piezometer

13 Appendix

A.2 Aboriginal Heritage Impact Permit C0000774

Issue of Aboriginal Heritage Impact Permit

National Parks and Wildlife Act 1974

Office of Environment & Heritage
NSW GOVERNMENT

Your reference:
Our reference: AHIMS No. 3781 / SF14/37781
Notice number: C0000777
Contact: Fran Scully (02) 9995 6830

Tahmoor Coal Pty Ltd
Remembrance Drive
TAHMOOR
NSW 2573

NOTICE OF THE ISSUE OF

ABORIGINAL HERITAGE IMPACT PERMIT C0000774

Issued pursuant to section 90C(4) of the *National Parks and Wildlife Act 1974*

BACKGROUND

A. Tahmoor Coal Pty Ltd (the applicant) applied to the Office of Environment and Heritage (OEH) under section 90A of the *National Parks and Wildlife Act 1974* (NPW Act) for an Aboriginal Heritage Impact Permit (AHIP). The AHIP application was in relation to harm to AHIMS #52-2-3254 (Redbank Creek 1) as a result of subsidence impacts from longwall mining at Longwall 28, Thirlmere.

B. OEH received the application on 28 November 2014 and further information was received on 12 December 2014 and 15 December 2014.

ISSUE OF ABORIGINAL HERITAGE IMPACT PERMIT

1. OEH has considered the application and supporting information provided, and matters under section 90K of the NPW Act and has decided to issue an AHIP C0000774 subject to conditions.
2. The AHIP is attached.
3. You should read the AHIP carefully and ensure you comply with its conditions

It is an offence under section 90J NPW Act to fail to comply with the conditions of the AHIP. The maximum penalty that a court may impose on a corporation for failing to comply with this AHIP is $1.1m. OEH can also issue penalty notices for this offence.

Notice No. C0000777
Application Ref No. A18385-2014
Printed: 5:06:41 PM 17/12/2014
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Issue of Aboriginal Heritage Impact Permit

National Parks and Wildlife Act 1974

Office of Environment & Heritage

NSW GOVERNMENT

S. Harrison ....

SUSAN HARRISON

Senior Team Leader Planning

Greater Sydney Region

(by Delegation)

Date: 19 December 2014

INFORMATION ABOUT THIS NOTICE

- Details provided in this notice will be available on OEH's Public Register in accordance with section 188F of the NPW Act.

Variation of this AHIP

- This AHIP may only be varied on application by the AHIP holder or by OEH to correct typographical errors or resolve inconsistencies between conditions of the AHIP. A permit can only be varied by subsequent variation notices.

Appeals against this decision

- You can appeal to the Land and Environment Court against this decision. The deadline for lodging the appeal is 21 days after you were given notice of this decision.

Notice No. C0000777
Application Ref No. A18385-2014
Printed: 5:06:41 PM 17/12/2014

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Aboriginal Heritage Impact Permit

Section 90 of the *National Parks and Wildlife Act 1974*

NSW GOVERNMENT | Office of Environment & Heritage

AHIP number: C0000774

(AHIMS Permit ID: 3781)

AHIP Issued To:

Tahmoor Coal Pty Ltd
Remembrance Drive
TAHMOOR
NSW 2573

OEH Office issuing this AHIP
Office of Environment and Heritage
Regional Operations
Greater Sydney Region
PO Box 644
Parramatta
NSW 2124
Telephone number: (02) 9995 6830

Additional details for public register

a) Name of development or project	AHIMS #52-2-3254 (Redbank Creek 1)
b) Location	100m east of Bridge Street, Thirlmere
c) Local Government Area(s)	Wollondilly
d) Description of harm authorised	• Harm to certain Aboriginal objects through the proposed works
e) AHIP commencement date and duration	*Commencement:* 19 December 2014 *Duration:* 6 years

AHIP number: C0000774
Application Ref No. A18385-2014 Page 1 of 13
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Aboriginal Heritage Impact Permit

Section 90 of the *National Parks and Wildlife Act 1974*

NSW GOVERNMENT | Office of Environment & Heritage

AHIP TO HARM ABORIGINAL OBJECTS

A. Background

(i) On 28 November 2014an application was made to the Chief Executive of the Office of Environment and Heritage (OEH) for an Aboriginal Heritage Impact Permit (AHIP) pursuant to s.90 of the *National Parks and Wildlife Act 1974* (the Act).

(ii) The application is to allow harm to AHIMS #52-2-3254 (Redbank Creek 1) as a result of mining subsidence impacts following on from longwall mining at longwall 28 in Thirlmere.

(iii) OEH considered the application and supporting information provided, and matters under section 90K of the Act and decided to issue an AHIP subject to conditions.

B. AHIP issued subject to conditions

An AHIP is issued to harm Aboriginal objects identified in Schedules B and C, in accordance with the conditions of this AHIP.

This AHIP is issued pursuant to section 90 of the Act.

C. Commencement and duration of AHIP

This AHIP commences on the date it is signed unless otherwise provided by this AHIP.

Unless otherwise revoked in writing, this AHIP remains in force for 6 years.

D. Proposed Works

Longwall mining at longwall 28, Thirlmere, resulting in subsidence and subsidence induced movements at the ground surface.

Note: A Dictionary at the end of the AHIP defines terms used in this document. Further information about this AHIP is also set out after the Dictionary.

S. Harrison

SUSAN HARRISON
Senior Team Leader Planning
Greater Sydney Region
(by Delegation)
DATED: 19 December 2014

AHIP number: C0000774 Page 2 of 13
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LAND TO WHICH THIS AHIP APPLIES

Land as illustrated in **Attachment 1: Map of the land to which this AHIP applies.**

CONDITIONS

The conditions of this AHIP specify the actions that are permitted and/or required in relation to areas and Aboriginal objects, which are detailed in the Schedules that follow.

Administrative Conditions

Responsibility for compliance with conditions of AHIP

1. The AHIP holder must ensure that all persons involved in actions or works covered by this AHIP (whether employees, contractors, sub-contractors, agents or invitees) are made aware of and comply with the conditions of this AHIP.

Project manager to oversee the actions relating to this AHIP

2. A suitably qualified and experienced individual must be appointed as a project manager who is responsible for overseeing, for and on behalf of the AHIP holder, all the actions relating to this AHIP.
3. The individual appointed as project manager must be the project manager nominated in the application form.
4. If an alternative to the nominated project manager is appointed, OEH must be notified of their contact details within **14 days** of this appointment.

Actions must be in accordance with AHIP application

5. All actions on the land must be carried out in accordance with the application except as otherwise expressly provided by a condition of this AHIP.

Operational Conditions

Certain Aboriginal objects must not be harmed

6. All human remains in, on or under the land must not be harmed, other than any human remains identified in Schedule B4.

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Section 90 of the *National Parks and Wildlife Act 1974*

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Harm of certain Aboriginal objects through the proposed works

7. The Aboriginal objects described in Schedule C may be harmed. Nothing in this condition authorised harm to Aboriginal objects described in Schedule A (whether human remains, Aboriginal objects or 'no-harm areas').

Notification and Reporting Conditions

Notification of commencement and completion of actions

8. Written notice must be provided to the OEH office at least **7 days** prior to the commencement of actions authorised by this AHIP.

9. Written notice must be provided to the OEH office within **7 days** of the completion of actions authorised by this AHIP.

Copy of this AHIP and notices to be provided to Registered Aboriginal Parties

10. A copy of this AHIP must be provided to each Registered Aboriginal Party, within **14 days** of receipt of the AHIP from OEH.

11. Where this AHIP is varied or transferred, a copy of the AHIP variation or transfer notice must be provided to each Registered Aboriginal Party, within **14 days** of receipt of the notice.

Human remains

12. If any human remains (other than any human remains described in Schedule B4) are discovered and/or harmed in, on or under the land, the AHIP holder must:
    - (a) not further harm these remains
    - (b) immediately cease all work at the particular location
    - (c) secure the area so as to avoid further harm to the remains
    - (d) notify the local police and OEH's Environment Line on 131 555 as soon as practicable and provide any available details of the remains and their location, and
    - (e) not recommence any work at the particular location unless authorised in writing by OEH.

Incidents which may breach the Act or AHIP

13. The AHIP holder must notify the OEH office in writing as soon as practicable after becoming aware of:
    - (a) any contravention of s.86 of the Act not authorised by an AHIP, and/or
    - (b) any contravention of the conditions of this AHIP.

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Reports about incidents which may breach the Act or AHIP

14. Where OEH suspects that an incident has occurred which may have breached the Act or AHIP, OEH may request a written incident report, which includes the following:
    - (a) the nature of the incident
    - (b) the actual or likely impact of the incident on Aboriginal objects and/or Aboriginal places
    - (c) the nature and location of these Aboriginal objects and/or Aboriginal places, referring to and providing maps and photos where appropriate
    - (d) any conditions of an AHIP which may have been breached, and
    - (e) the measures which have been taken or will be taken to prevent a recurrence of the incident.
15. The incident report must be provided to the OEH office within the timeframe specified in the request.

Provision of Aboriginal Site Impact Recording Form

16. An Aboriginal Site Impact Recording Form must be completed and submitted to the AHIMS Registrar, for each AHIMS site identified in Schedules B and C, within **4 months** of the completion of the actions authorised by this AHIP.

    Note:
    - (i) The Aboriginal Site Impact Recording Form can be found on the OEH website: http://www.environment.nsw.gov.au/licences/DECCAHIMSSiteRecordingForm.htm
    - (ii) Contact details for the AHIMS Registrar can be found on the OEH website: http://www.environment.nsw.gov.au/contact/AHIMSRegistrar.htm

General Conditions

Indemnity

17. The AHIP holder agrees to indemnify and keep indemnified, the Crown in right of NSW, the Minister administering the Act, the Chief Executive of OEH, and their employees, agents and contractors, in the absence of any willful misconduct or negligence on their part, from and against all actions, demands, claims, proceedings, losses, damages, costs (including legal costs), charges or expenses suffered or incurred by them resulting from:
    - (a) any damage or destruction to any real or personal property; and
    - (b) injury suffered or sustained (including death) by any persons arising out of or in connection with any actions undertaken pursuant to this AHIP.

Release

18. The AHIP holder agrees to release to the full extent permitted by law, the Crown in right of NSW, the Minister administering the Act, the Chief Executive of OEH, and their employees, agents and contractors, in the absence of any willful misconduct or negligence on their part, from all suits, actions, demands and claims of every kind resulting from:

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(a) any damage or destruction to any real or personal property; and

(b) injury suffered or sustained (including death) by any persons arising from or in connection with any actions undertaken pursuant to this AHIP.

Written notice

19. Any requirement to provide written notice to the OEH office in this AHIP may be complied with by faxing the notice to the OEH office's fax number or by sending by registered post to the OEH office's address. The OEH office's contact details are specified at the front of this AHIP.

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SCHEDULES

The following schedules identify the areas and Aboriginal objects that are subject to the conditions of this AHIP.

Schedule A: Aboriginal objects which must not be harmed

A1 Human remains

All human remains in, on or under the land must not be harmed, other than any human remains identified in Schedule B4, as specified by the conditions of this AHIP.

A2 Aboriginal objects that are identified on AHIMS

N/A

A3 No-harm areas

N/A

Schedule B: Aboriginal objects that may be harmed through the certain actions

B1 Movement only

N/A

B2 Test/Salvage excavations

N/A

B3 Community collection

N/A

B4 Other

N/A

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Schedule C: Aboriginal objects which may be harmed through the proposed works

The Aboriginal objects described in this schedule may be harmed, but only in accordance with the conditions of this AHIP (excluding any Aboriginal objects described in Schedule A).

C1 Harm of Aboriginal objects identified on AHIMS

Portion of Site (whole or part)	AHIMS Site ID	Site Feature	Site Name	Information access restriction? (Y/N)	Easting	Northing	Datum
Whole	52-2-3254	Shelter with art and deposit	Redbank Creek 1	N	278155	6213290	GDA

C2 Areas where harm of Aboriginal objects is authorised

N/A

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DICTIONARY

In this AHIP, unless the contrary is indicated the terms below have the following meanings:

Aboriginal object	has the same meaning as in the Act.
Act	means the *National Parks and Wildlife Act 1974*.
AHIMS	means the Aboriginal Heritage Information Management System maintained by OEH, as defined in s.90Q of the Act.
AHIP	means Aboriginal Heritage Impact Permit
AHIP holder	means the entity or person listed on the cover page under the heading "AHIP issued to".
Application	means the completed application form and all other documents in written or electronic form which accompanied the application when it was lodged or which were subsequently submitted in support of the application.
Community collection	means the collection of Aboriginal objects by one or all Registered Aboriginal Parties or their representatives.
Community collection area	means an area described as a community collection area in Schedule B3
Harm	has the same meaning as in the Act. In relation to Aboriginal objects, harm means the movement, damage, defacement and/or destruction of Aboriginal objects. In relation to an Aboriginal place, harm means the damage, defacement and/or destruction of the Aboriginal place.
Land	means the land described under the heading "Land to which this AHIP applies".
No-harm areas	means those areas described in Schedule A3.
OEH	Office of Environment and Heritage (NSW).
OEH office	means the office listed on the cover page of this AHIP.
Proposed works	means the works described under the heading "D. Proposed Works" at the front of this AHIP.
Public register	means the public register established under s.188F of the Act, that contains details of AHIPs issued by the Chief Executive of OEH, as described under the heading "Information about this AHIP".
Registered Aboriginal Parties	means the Registered Aboriginal Parties listed in the application.
Salvage excavation	means an archaeological excavation carried out in accordance with the methodology accompanying the application, as modified by the conditions of this AHIP. The purpose of salvage excavation is to recover a sample of Aboriginal objects as an archival record of Aboriginal life from a site that will be destroyed.
Salvage excavation area	means any area described as a salvage excavation area in Schedule B2.
Test excavation	means an archaeological excavation carried out in accordance with

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	methodology accompanying the application, as modified by the conditions of this AHIP. The purpose of test excavation is to collect a sample of Aboriginal objects, in order to establish the nature and extent of sub-surface Aboriginal objects and to assist in the assessment of management options for the site.
Test excavation area	means any area described as a test excavation area in Schedule B2

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INFORMATION ABOUT THIS AHIP

Public Register

Under section 188F of the Act, the Chief Executive of OEH is required to keep a public register containing the details of each AHIP issued. The details of this AHIP that will be published on the public register are outlined on the front page of this AHIP.

The public register is available online at www.environment.nsw.gov.au

Appeals

Under section 90L of the Act, the AHIP holder may appeal to the Land and Environment Court if they are dissatisfied with any condition of this AHIP. The appeal must be locged within 21 days of the date this AHIP was issued.

Penalties for breach of the Act or AHIP condition

Significant penalties can be imposed by the Land and Environment Court for harm to an Aboriginal object or Aboriginal Place other than as authorised by a condition of an AHIP, or for a breach of an AHIP condition. OEH can also issue penalty notices for a breach of the Act or AHIP condition.

Responsibility for obtaining all approvals and compliance with applicable laws

The AHIP holder is responsible for obtaining and complying with all approvals necessary to lawfully carry out the work referred to in this AHIP, including but not limited to development consents.

Other relevant provisions of the *National Parks and Wildlife Act*

Newly identified Aboriginal objects must be notified to the Chief Executive of OEH under s.89A of the Act using the form available online at www.environment.nsw.gov.au

Stop work orders, interim protection orders and remediation directions may be issued in certain circumstances to protect Aboriginal objects or places.

Obligation to report Aboriginal remains under Commonwealth laws

The AHIP holder may have additional obligations to report any discovery of Aboriginal remains under the *Aboriginal and Torres Strait Islander Heritage Protection Act 1984*.

Exercise of investigation and compliance powers

Officers appointed or authorised under the Act may exercise certain powers and functions, including the power to enter land.

Duration of AHIP

This AHIP remains in force for the period specified in the AHIP.

Variation of AHIP

The AHIP holder may apply to the OEH office for a variation of any conditions of an AHIP, using the AHIP variation application form available online at www.environment.nsw.gov.au. Requests for significant variations must be accompanied by evidence of further consultation with Registered Aboriginal Parties and may include payment of fees.

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The conditions of an AHIP may be varied at any time by the Chief Executive of OEH in order to correct a typographical error or to resolve an inconsistency between conditions. The AHIP holder may appeal a decision of the Chief Executive of OEH to vary the conditions of the AHIP.

Transfer of AHIP

The AHIP holder may apply to transfer this AHIP to another person by using the AHIP transfer application form available online at www.environment.nsw.gov.au.

Surrender of AHIP

The AHIP holder may apply to surrender this AHIP by using the AHIP surrender application form available online at www.environment.nsw.gov.au. The surrender must be approved by the Chief Executive of OEH and may be subject to conditions.

Suspension and revocation of AHIP

An AHIP may be suspended or revoked at any time at the discretion of the Chief Executive of OEH. Prior to suspending or revoking the AHIP, the AHIP holder will be given notice and an opportunity to make submissions. The AHIP holder will be notified in writing of the final decision. The AHIP holder may appeal a decision to revoke the AHIP.

Entry to land

An AHIP does not automatically entitle its holder to enter land for the purpose of conducting work related to the AHIP. The AHIP holder is responsible for obtaining permission to enter land from the owner and/or occupier of the land.

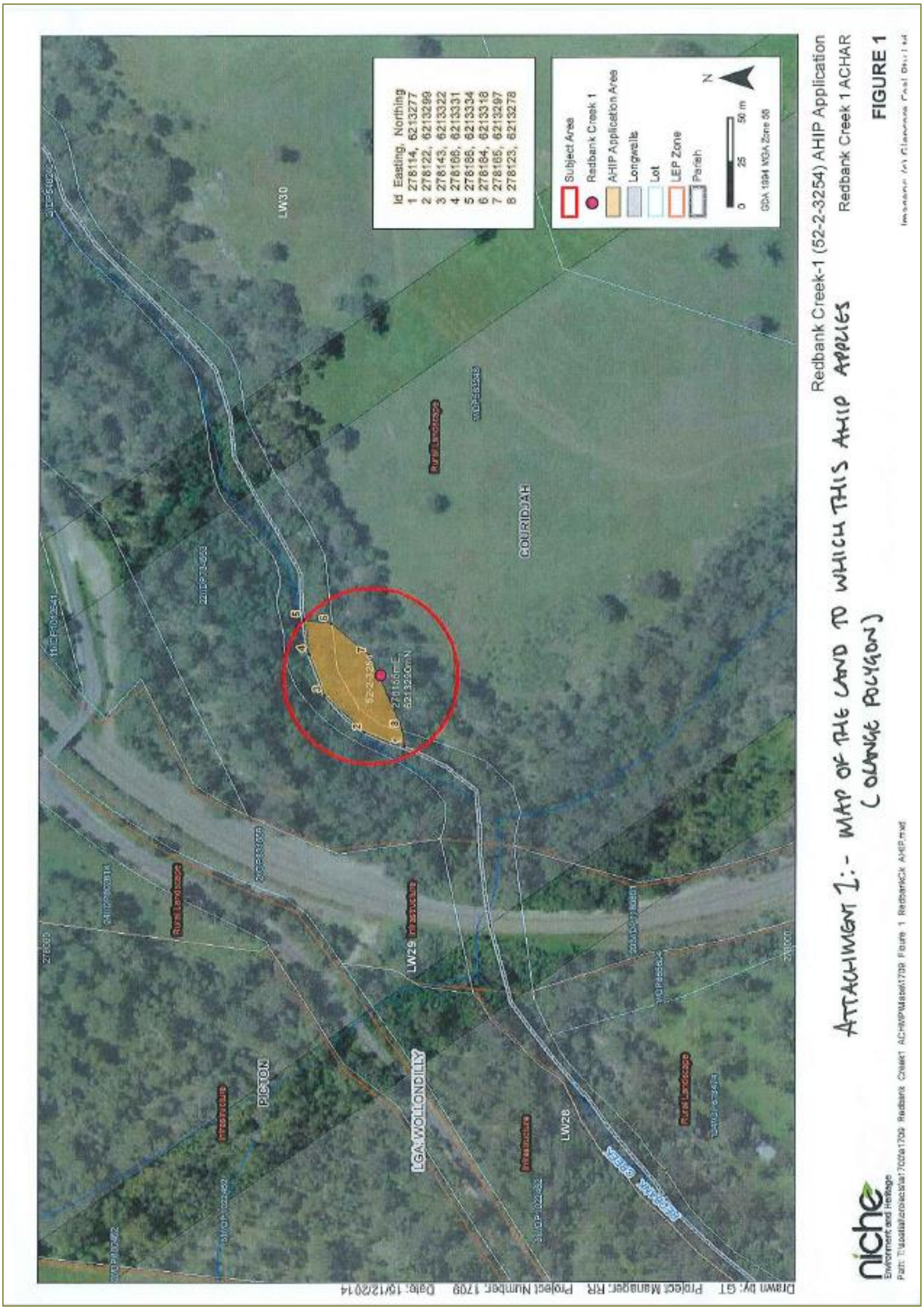
Disclosure of information pursuant to lawful requirement

This AHIP does not prevent the disclosure of any information or document in OEH's possession in accordance with any lawful requirement.

Making copies of reports

By providing a report, the AHIP holder acknowledges that OEH can use the information in that report to inform its regulatory functions, note details of that report in AHIMS and include a copy of the report in its library which may be available to members of the public.

OEH is able to make copies of any reports provided to OEH under this AHIP.


Redbank Creek-1 (52-2-3254) AHIP Application
Redbank Creek 1 ACHAR
FIGURE 1
ATTACHMENT 1:- MAP OF THE LAND TO WHICH THIS AHIP APPLIES
(ORANGE POLYGON)
Subject Area
Redbank Creek 1
AHIP Application Area
Longwalls
Lot
LEP Zone
Parish
LW30
LW29
LW28
COURIDJAH
PICTON
LGA: WOLLONDILLY
niche
Drawn by: GT Project Manager: RR Project Number: 1709 Date: 19/12/2014