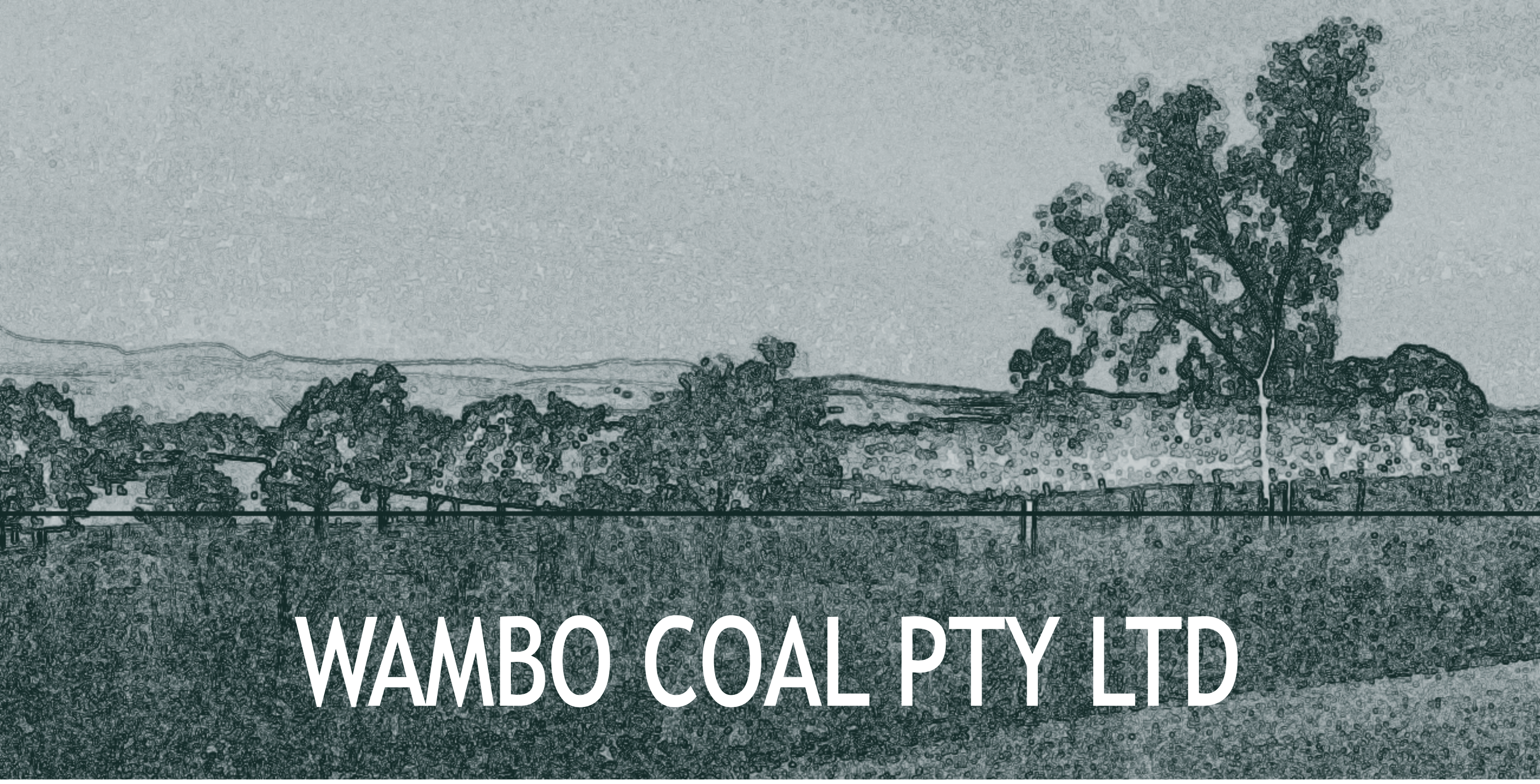

WAMBO COAL PTY LTD

NORTH WAMBO UNDERGROUND MINE
LONGWALL 10A MODIFICATION

ENVIRONMENTAL ASSESSMENT

APPENDIX C

Wambo Creek and Stony Creek Impact Assessment

Peabody ENERGY

Wambo Coal Pty Ltd

North Wambo Underground Mine Longwall 10A Modification

Subsidence Impacts on Wambo Creek and Stony Creek

August 2014

Version Control

Revision	Date	Author	Reviewed by	Comments
0.1	5/8/2014	Lisa Granqvist	Steve Perrens	First draft
0.2	12/8/2014	Lisa Granqvist	Steve Perrens	Second draft
0.3	19/8/2014	Lisa Granqvist	Steve Perrens	Third draft
0.4	27/8/2014	Steve Perrens		Final

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Acronyms and Abbreviations

AEMR	Annual Environmental Management Report
AHD	Australian Height Datum
ARI	Average recurrence interval
EP&A Act	Environmental Planning and Assessment Act 1979
LMP	Land Management Plan
NWUM	North Wambo Underground Mine
WCPL	Wambo Coal Pty Limited

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1 Introduction

1.1 Background

Evans & Peck has been engaged by Wambo Coal Pty Limited (WCPL), a subsidiary of Peabody Energy Australia Pty Limited (Peabody) to prepare an assessment of the impacts on Wambo Creek and Stony Creek due to subsidence associated with proposed Longwall 10A of the North Wambo Underground Mine (NWUM) (**Figure 1**).

The NWUM is located at the Wambo Coal Mine in the Hunter Coalfield of New South Wales (NSW), approximately 15 kilometres (km) west of Singleton NSW. Open cut and underground mining operations have been conducted at the Wambo Coal Mine since mining commenced in 1969 (WCPL, 2012).

The area in the vicinity of the mine contains a number of coal seams in the Wittingham Coal Measures, including the Whybrow, Wambo, Arrowfield and Bowfield Seams, shown on **Figure 2.** The location of the cross section shown in **Figure 2** is provided in **Figure 3**. Historical workings in the vicinity of the NWUM include bord and pillar workings and longwall panels associated with the Homestead and Wollemi Mines in the Whybrow Seam.

WCPL is currently mining from the Wambo Seam in the NWUM using continuous miners and longwall mining methods. The mine was approved under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) in February 2004. The approval included the extraction of eight longwalls in the Wambo Seam (Longwalls 1 to 8) and thirteen longwalls in each of the Arrowfield and Bowfield Seams.

Modification of the approval for the extraction of two additional longwalls in the Wambo Seam (Longwalls 9 and 10) was granted in July 2013 (DA 305-7-2003 MOD13).

WCPL completed mining of Longwall 1 in February 2009. Longwalls 2 to 7 were completed between March 2009 and January 2014. If the Longwall 10A Modification is not approved, Longwalls 8 to 10 are scheduled to be completed by July 2015 (WCPL, 2013).

WCPL is currently seeking approval to modify DA 305-7-2003 to enable extraction of an additional longwall panel (Longwall 10A), located south of Longwall 10 as shown on **Figure 1**.

For the purposes of this report, the “Approved Layout” refers to the approved longwall panels within the Wambo (Longwalls 1 to 10), Arrowfield and Bowfield Seams. The “Modified Layout” refers to the Longwall 10A together with the Approved Layout.

This report draws upon information presented in specific studies undertaken for NWUM, which are listed in **Section 6**.

1.2 Scope

This report has been prepared to assess potential impacts to Wambo Creek (also known as South Wambo Creek) and Stony Creek as a result of subsidence associated with Longwall 10A (i.e. the impacts of the Modified Layout scenario when compared with the impacts of the Approved Layout scenario). Potential impacts considered include:

- possible increased ponding as a result of differential subsidence;
- possible increased erosion as a result of increased creek gradients; and
- possible cracking of creek beds as a result of tensile strains, leading to loss of flow.

Proposed monitoring and mitigation measures to manage potential impacts are provided in **Section 4**.

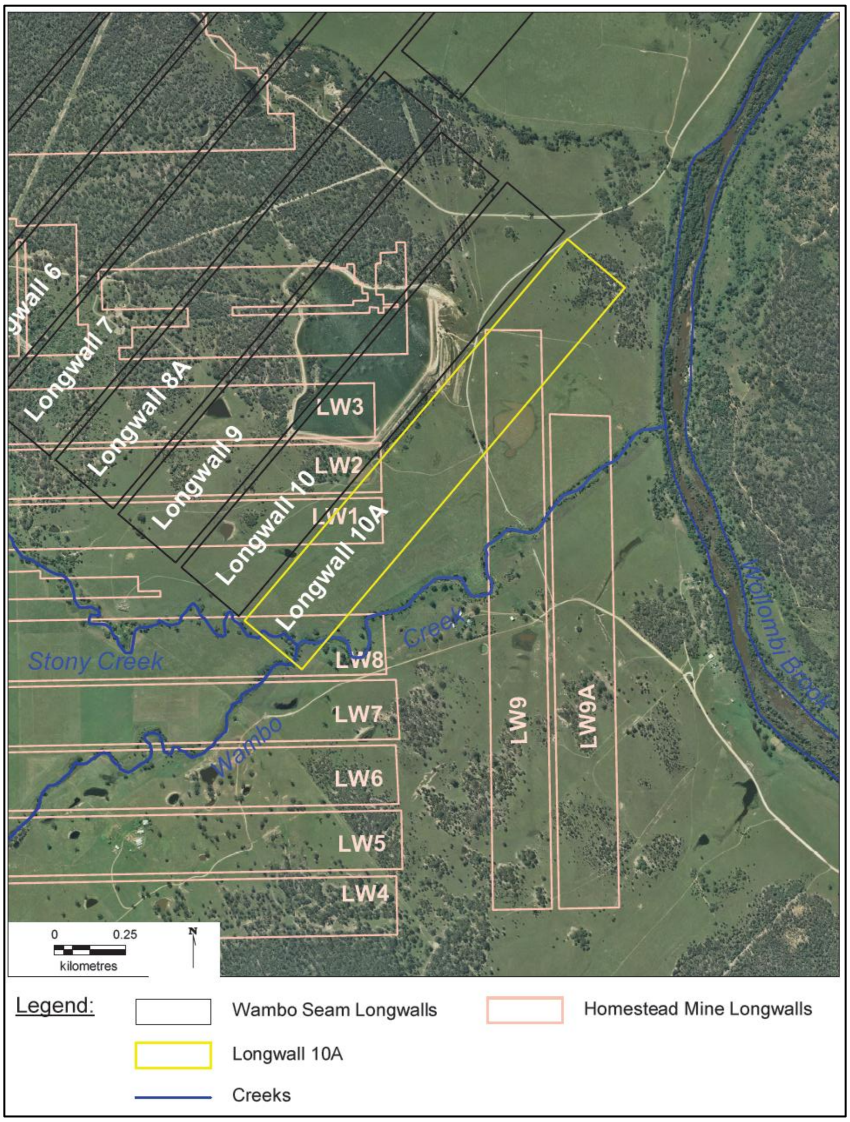

Figure 1: Location of Proposed Longwall 10A

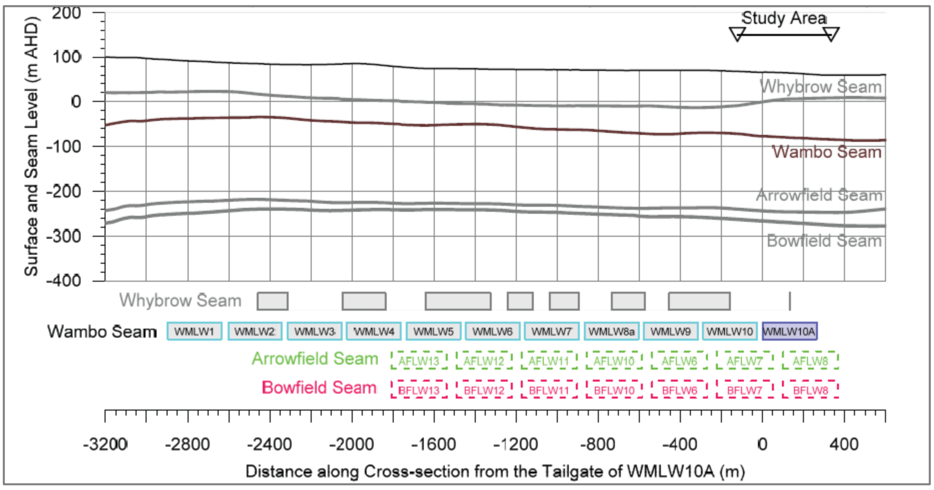

Figure 2: Surface and Seam Levels Along Cross-Section 1 (see Figure 3 for location)

(Source: MSEC, 2014a)

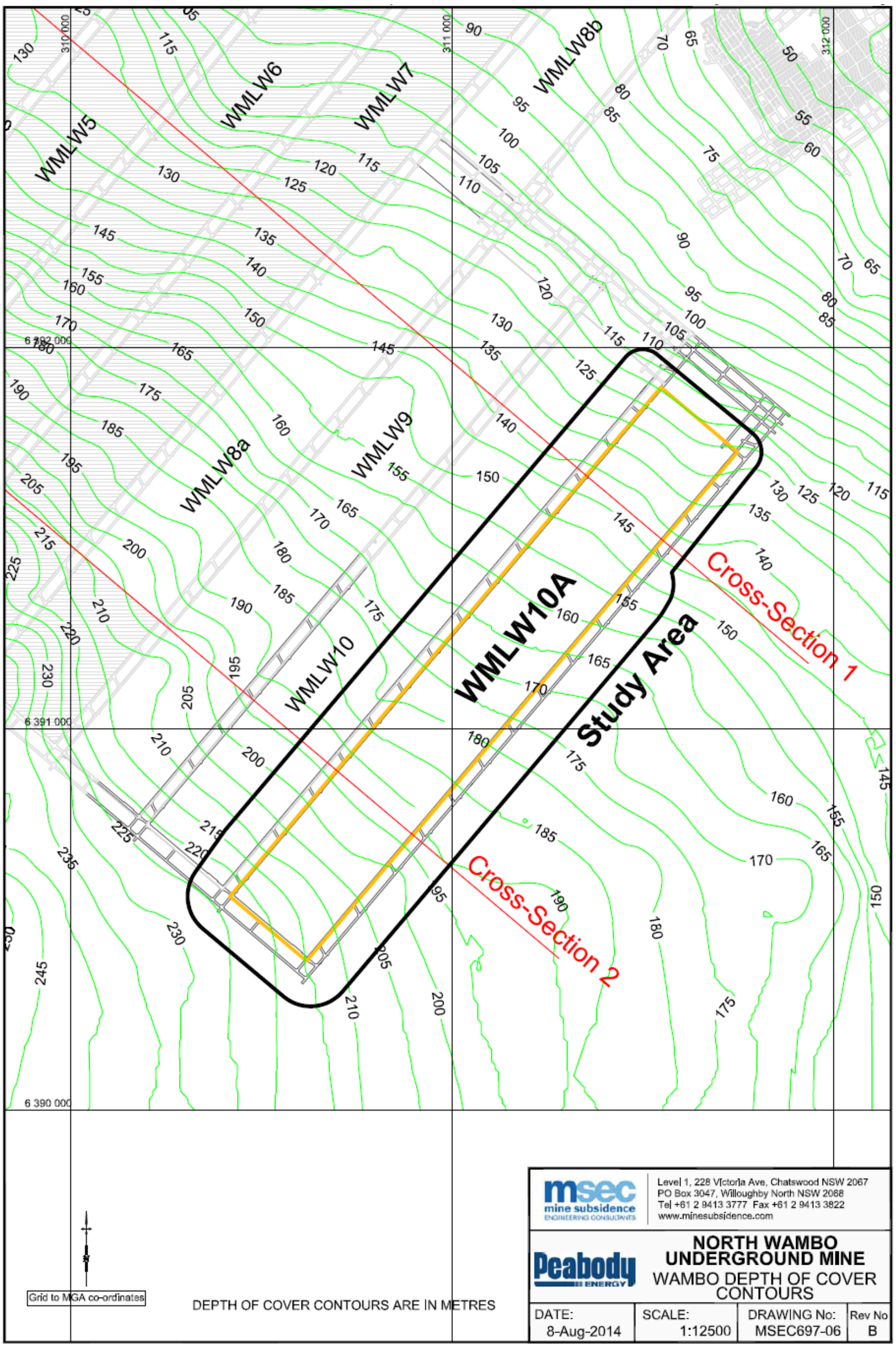

Figure 3: Wambo Depth of Cover Contours and Cross-section Locations

(Source: MSEC, 2014a)

2 Existing Creek Conditions

2.1 Overview

As shown in **Figure 1**, the south-west end of Longwall 10A will be located below the junction of Wambo Creek and Stony Creek. **Figure 4** is an aerial photograph of the confluence of Wambo Creek and Stony Creek that also shows an outline of the south-west corner of Longwall 10A.

Wambo Creek and Stony Creek originate in the Wollemi National Park and flow east, joining at NWUM above proposed Longwall 10A at which point they have catchment areas of 40.7 km² and 11.2 km² respectively. Wambo Creek continues to flow north-east to Wollombi Brook, which subsequently flows north-east to the Hunter River. Both Wambo Creek and Stony Creek are ephemeral and are generally dry for most of the year.

The catchments of these creeks predominantly comprise cleared undulating to rolling hills in the lower valley to uncleared scrub and forest in the hilly, upper reaches of the Wollemi National Park. The lower reaches are generally used for grazing or cropping (Coffey, 1999). Surface elevations range from 65 metres (m) Australian Height Datum (AHD) at the junction of Wambo and Stony Creeks, to 220 m AHD on the ridgelines within the mine area and 650 m AHD in Wollemi National Park.

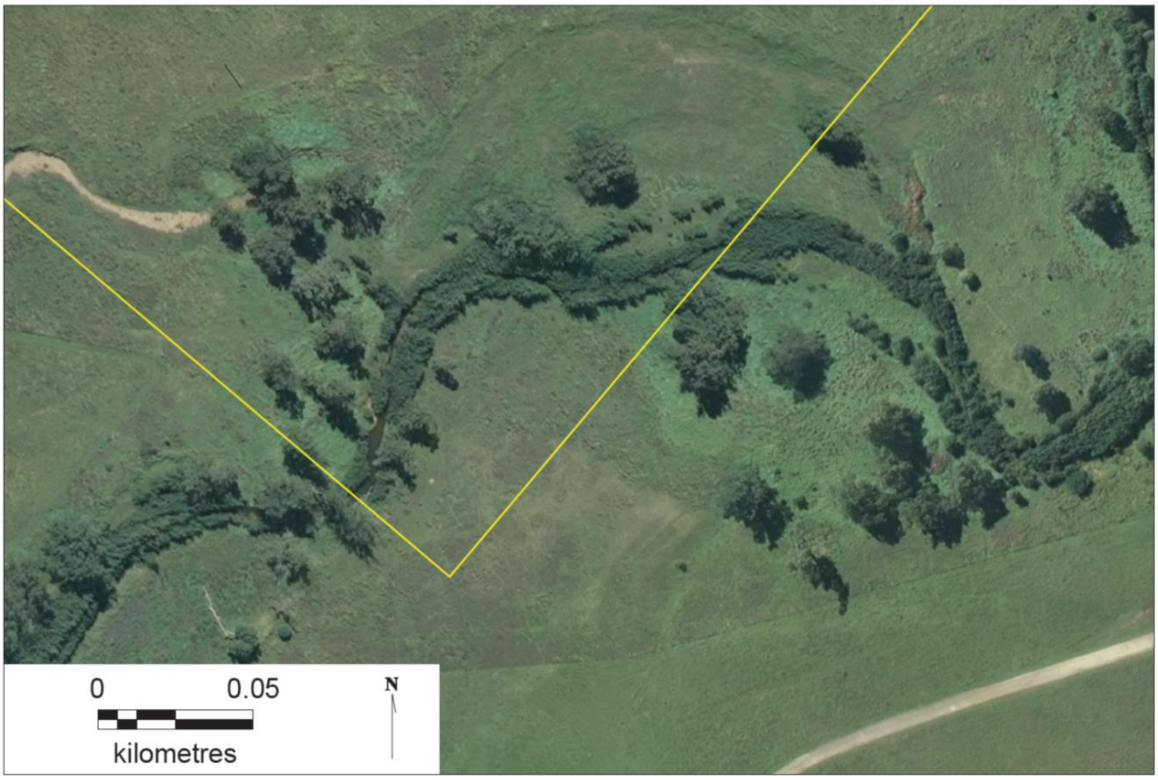

Figure 4: Aerial photograph of Wambo and Stony Creek confluence (WCPL, flown April-October 2013)

Note: extent of Longwall 10A marked in yellow

2.2 Creek Flow

To estimate peak discharges in North Wambo Creek for average recurrence intervals (ARIs) of 2, 20 and 100 years Gilbert and Associates (2009) previously used a runoff routing model (RORB) which had been calibrated to recorded floods on Doyles Creek.

Estimated flows for Wambo Creek and Stony Creek have been derived by scaling the flows for North Wambo Creek using the general relationship for peak flows set out in *Hydrological Recipes* (Grayson et.al, 1996) ($Q \sim A^{0.63}$) and are provided in **Table 1**. Flows for 5, 10 and 50 year ARI events have been estimated by interpolation.

Table 1: Catchment Areas and Estimated Peak Flood Discharges (m^3/s)

Creek	Catchment Area (km^2)	ARI (years)					
		2	5	10	20	50	100
Stony Creek (confluence with Wambo Creek)	11.2	22	27	31	36	45	53
Wambo Creek (confluence with Stony Creek)	40.7	49	60	70	80	101	119
Wambo & Stony Creek (confluence with Wollombi Brook)	54.4	59	72	84	96	121	143

2.3 Stream Order

The Strahler stream ordering system (based on defined watercourses on 1:25,000 topographic maps) is used as the basis in the *Water Management Act 2000* and associated regulations for regulating 'Controlled Activities' in close proximity to watercourses. 'Controlled Activities' include preservation of riparian corridors, carrying out of in-stream works and construction of watercourse crossings. At their confluence, Stony Creek and Wambo Creek are fourth and fifth order streams respectively.

2.4 Creek Characteristics

A site inspection, including a visual assessment of Wambo and Stony Creeks, was undertaken by Evans & Peck on Wednesday 16 July 2014. The site inspection focused on the areas of the creeks which lie above the proposed Longwall 10A and which had previously been undermined by Longwall 8 in the Homestead mine workings in the Whybrow Seam. In addition, Evans and Peck inspected other areas of Stony Creek that have previously been undermined by Longwalls 3, 4 and 5 at the NWUM. Evans & Peck has also reviewed previous studies, aerial photographs and topographic maps of the area.

In the vicinity of Longwall 10A, both Stony Creek and Wambo Creek have predominantly alluvial bed material with very occasional rock outcrops along Wambo Creek downstream of the area that would be impacted by subsidence.

As illustrated in **Figure 5**, the bed material in Stony Creek is predominantly medium to coarse sand (0.2 millimetres [mm] to 2 mm) and gravel (up to 60 mm). The visible bed material in Wambo Creek is predominantly medium to coarse sand. However, it is likely that the in-channel terraces comprise gravel beds that are overgrown with vegetation.

The finer size sand fraction of the bed material is likely to be mobilised at velocities of the order of 0.2 metres per second (m/s) while velocities in excess of 1.2 m/s would be required to mobilise the coarser gravels.

As shown in **Figure 6**, upstream of the junction with Wambo Creek, Stony Creek has a wide (approximately 7 m) shallow channel with well grassed banks and inset terraces varying from 1 - 2 m high. The bed of Stony Creek has sections that are well grassed (e.g. **Figure 6**) and sections with extensive areas of exposed sand and gravel (e.g. **Figure 5**). Wambo Creek is narrower than Stony Creek and has an incised low flow channel with a series of high flow channels separated by alluvial deposits within a wider main channel. As shown in **Figure 7** and **Figure 8**, the channel of Wambo Creek is heavily overgrown with River Oaks (*Casuarina cunninghamiana*), which have grown significantly since 2008 (the Google Earth image dated 16/12/2008 shows a clear creek channel with large areas of sand/gravel bed and bars).

There is evidence that Wambo Creek has undergone channel realignment immediately downstream of the confluence of Wambo and Stony Creeks. This past alignment, which ran in an arc extending about 80 m to the north of the current Wambo Creek alignment can be seen on **Figure 4**, and is marked on the 1:25,000 topographic map (based on aerial photography from 1973). Inspection of the **Figure 4** reveals signs of other flow paths which have been active in the past. This indicates that this reach of Wambo Creek has medium to high sensitivity, with potential for further creek realignment in the future.

The natural grades of the creeks in the vicinity of the proposed longwall are generally less than 1% (MSEC 2014a). There was no flow in the creeks during the site visit, but a number of small pools in areas not affected by longwalls in the Whybrow seam were observed. This is consistent with observations made during previous studies (Coffey 1999, MSEC 2014a).

Wambo Mining Corporation Pty Ltd extracted coal between 1991 and 1999 from the Whybrow Seam in the Homestead mine. Longwall Panels 1 to 3 of the Homestead mine were situated beneath Stony Creek, while Longwalls 5 to 7 and 9 to 9A were beneath Wambo Creek. Panel 8 was situated below both Stony and Wambo Creeks (see **Figure 1**). Coffey (2000) notes that the bed of both Wambo and Stony Creeks were altered by subsidence resulting from the Homestead mine, with troughs forming over the centre of the extracted Panels and some creek banks becoming unstable due to cracking. The overall gradient of the creek bed was maintained. However, some ponding occurred in subsidence troughs.

WCPL is currently mining within the Wambo seam at the NWUM. Gilbert and Associates (2014) observed that Longwalls 1 to 6 have resulted in subsidence of the creek bed and bank levels. However, the surveyed cross sections did not show any significant change in shape as a result of mining. This indicates that there have been no ongoing erosional or depositional changes as a result of Longwalls 1 to 6 in the Wambo seam.

Figure 5: Typical creek bed material – Stony Creek

Figure 6: Stony Creek upstream of confluence

Figure 7: Wambo Creek upstream of confluence, looking downstream

Figure 8: Wambo Creek downstream of confluence, looking upstream

3 Potential Impacts

The potential impacts of subsidence on Wambo and Stony Creeks will be influenced by the extent and magnitude of differential subsidence, gradients and strains due to Longwall 10A, including:

- possible increased erosion as a result of scarp subsidence leading to head-cut erosion in creeks;
- possible increased ponding as a result of differential subsidence; and
- possible cracking of creek beds as a result of tensile strains.

The impacts of subsidence are primarily a function of the depth of cover above the coal seam, the height of the extracted seam and width of the extraction panel. The depth of cover above Longwall 10A increases from about 120 m at the northern end to 220 m at the southern end (**Figure 3**). It should be noted that Longwall 10A is supercritical, that is, the subsidence is dependent only on extraction height.

The potential impacts as a result of two "scenarios", as outlined in **Table 2,** are discussed in the following sections.

Table 2: Modelled Subsidence Scenarios

Layout	Scenario
Approved Layout	Subsidence as a result of mining the approved longwall panels within the Wambo (Longwalls 1 to 10), Arrowfield and Bowfield Seams (**Figure 9**).
Modified Layout	Subsidence as a result of mining Longwall 10A in addition to the Approved Layout (**Figure 10**)

The predicted impacts of the Approved Layout were provided in the following reports:

- *Wambo Development Project Subsidence Assessment* (G.E. Holt and Associates Pty Ltd, 2003);
- *North Wambo Underground Mine Modification Subsidence Assessment* (MSEC, 2013);
- *Wambo Development Project Surface Water Assessment* (Gilbert and Associates, 2003);
- *North Wambo Underground Mine Subsidence Assessment – Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of a Revised Extraction Plan for Longwalls 7 to 10 in the Wambo Seam* (MSEC, 2014b);
- *Assessment of Potential Environmental Consequences for Surface Water Resources Resulting from Extraction of North Wambo Underground Mine Longwalls 9 and 10* (Gilbert and Associates, 2014);
- *Environmental Assessment for the Modification of DA 305-7-2003 (Mod 13) the Addition of North Wambo Underground Mine Longwalls 9 and 10* (WCPL, 2012); and
- *North Wambo Underground Longwall 10A Modification Subsidence Assessment* (MSEC, 2014a).

Detailed assessment of the likely magnitude and impacts of subsidence on Wambo and Stony Creeks was undertaken by MSEC (2014a). **Figure 9** shows the predicted subsided surface levels due to the North Wambo, Arrowfield and Bowfield Underground Mines (Approved Layout) while **Figure 10** shows the predicted surface levels for the Modified layout with the addition of Longwall 10A.

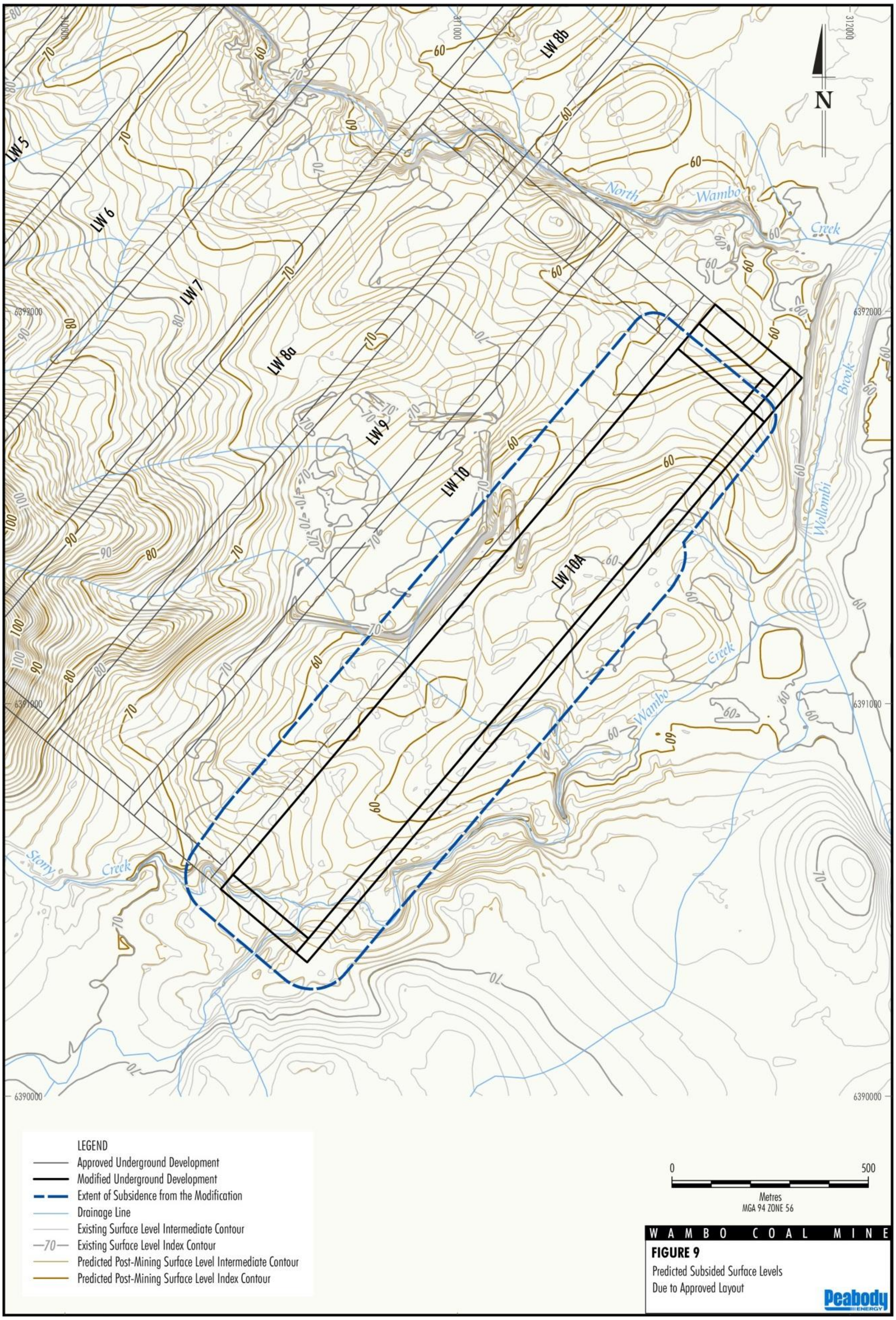

Figure 9: Predicted subsided surface levels due to Approved Layout

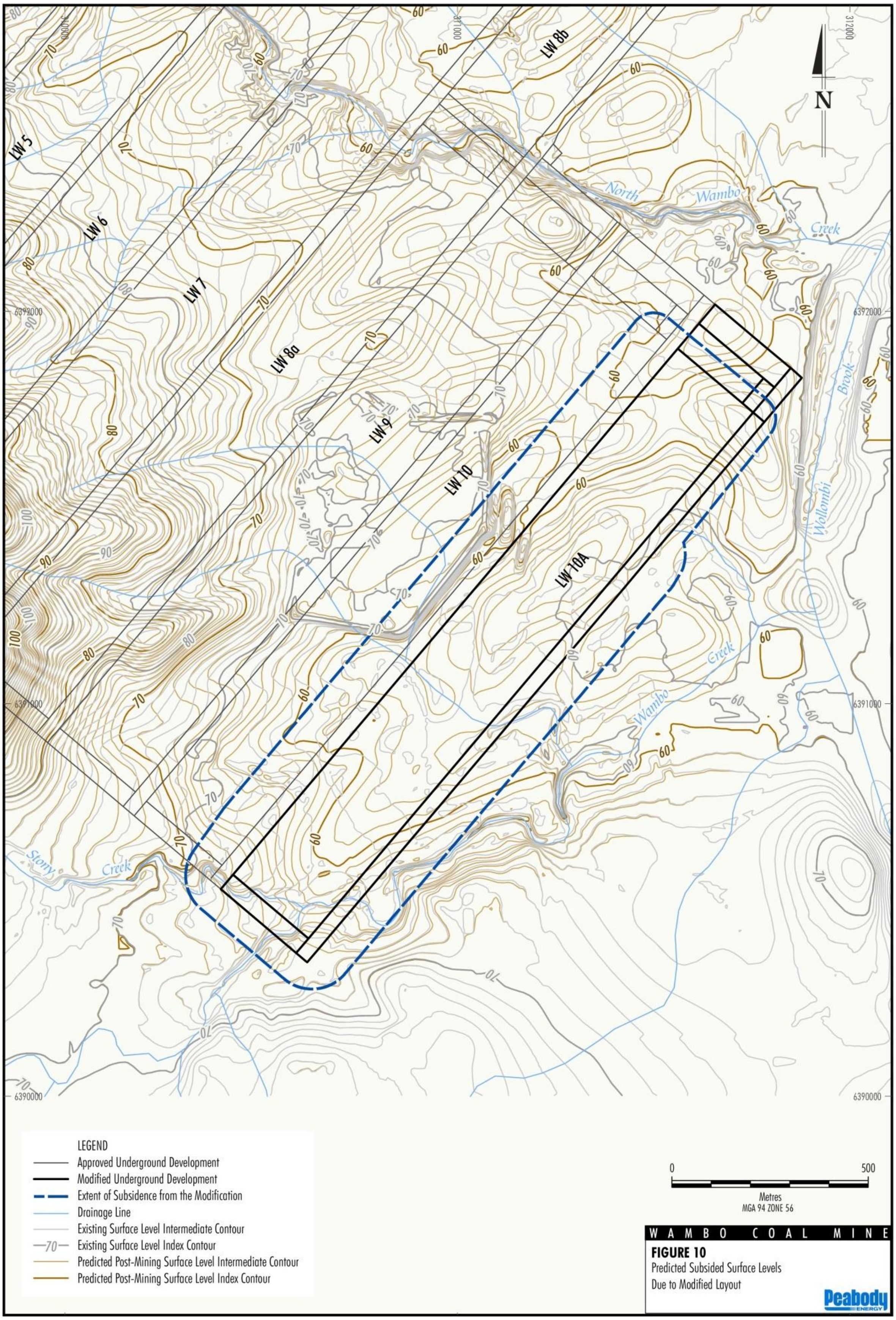

Figure 10: Predicted subsided surface levels due to Modified Layout

Table 3 summarises the maximum predicted subsidence and gradient along the stretches of Wambo Creek and Stony Creek affected by Longwall 10A due to the extraction of Longwall 10A only, the Approved Layout and the Modified Layout.

Table 3: Predicted Maximum Subsidence Impacts

Mining Layout	Subsidence mm	Gradient %
Wambo Creek		
Approved Layout	1,600	2.3
Modified Layout	2,400	3.8
Stony Creek		
Approved Layout	1,000	1.7
Modified Layout	1,500	2.2

Source: data provided by MSEC

The predicted maximum grades and subsidence as a result of the Modified Layout are expected to occur directly above Longwall 10A. However, it should be noted that the maximum predicted grades and subsidence due to the Approved Layout will not necessarily occur at the same location.

Figure 11 and **Figure 12** compare surface levels and gradients for the existing and post-mining mining layouts for Wambo and Stony Creeks respectively. Note that chainage zero is located at the confluence of the creeks.

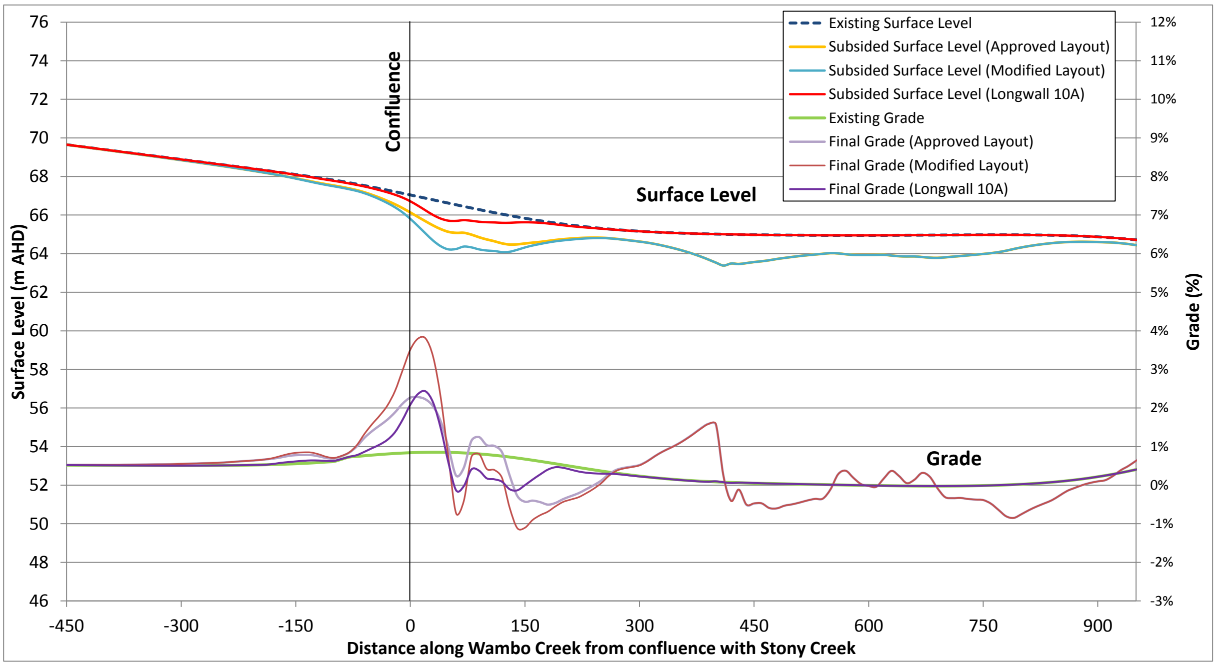

Figure 11: Wambo Creek - Existing and Predicted Post Mining Levels and Grades
(Note exaggerated vertical scale)

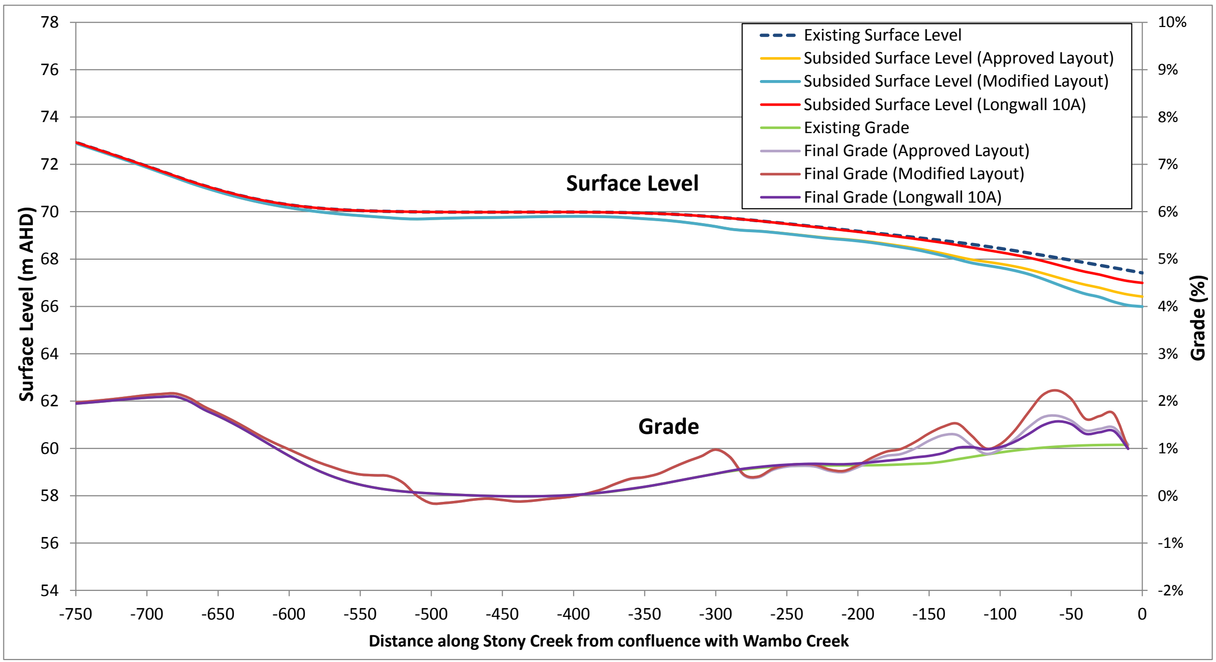

Figure 12: Stony Creek – Existing and Predicted Post Mining Levels and Grades
(Note exaggerated vertical scale)

3.1 Potential Erosion Impacts

MSEC (2014a) notes that mining could potentially result in an increased likelihood of scouring of the beds along Wambo and Stony Creeks in locations where mining induced gradients considerably increase the natural stream gradients.

As shown on **Figure 11**, the grade in Wambo Creek is predicted to increase from 0.9% (existing), to 2.2% (Approved Layout) and 3.8% (Modified Layout) 20 m downstream of the confluence of Wambo and Stony Creeks. Based on a simple hydraulic analysis, an increase in channel slope from around 2.2% to 3.8% has the potential to increase velocity by 20%.

As shown on **Figure 11,** the grade in Stony Creek is predicted to increase from 1.0% (existing), 1.7% (Approved Layout) to 2.2% (Modified Layout) at a location approximately 60 m upstream of the confluence of Wambo and Stony Creeks. Based on a simple hydraulic analysis, an increase in channel slope from around 1.7% to 2.2% has the potential to increase velocity in the channel by around 55%.

As discussed in **Section 2.4,** the finer size sand fraction of the bed material is likely to be mobilised at velocities of the order of 0.2 m/s, while velocities in excess of 1.2 m/s would be required to mobilise the coarse gravels. An increase in velocity due to the increase in creek slope as a result of subsidence is likely to mobilise the finer material and possibly also the coarser gravel. The areas subject to changes in grade, particularly in Wambo Creek are likely to be vulnerable to scour and mitigation measures are likely to be required (refer **Section 4**).

The degree of accrual scouring and erosion that occurs will also depend on ground conditions, including vegetation and bed material. During the site inspection, it was observed that the banks were generally well vegetated, with vegetation types including grass, reeds and River Oak. In addition, the bed material of both creeks ranged from grassed soil to gravel and small boulders. In some locations along Wambo Creek, larger vegetation (River Oak) was growing within the channel (**Figure 7** and **Figure 8**).

While vegetation is a key stabilising influence, it is not the solution to all potential erosion problems and may not be effective if the physical changes to channel slope lead to velocity increases beyond the capacity of the vegetation to stabilise the bed or banks. In some instances, dense stands of vegetation, such as River Oaks, may initiate channel instability when they are uprooted in larger floods.

Mitigation and management measures to reduce the impacts of mining induced erosion are provided in **Section 4.**

3.2 Potential Ponding Impacts

Ponding will occur where mining induced stream gradients oppose and are greater than the natural stream gradients (MSEC, 2014a). As Wambo and Stony Creeks enter the subsidence trough from the west, gradients increase from the natural stream grades existing prior to mining. As the Wambo Creek exits from the longwall subsidence trough to the west, gradients decrease.

As shown on **Figure 11**, under the Modified Layout, ponding to a maximum depth of 0.7 m, extending for about 210 m is predicted in Wambo Creek between CH 30 m and CH 240 m (**Figure 11**). Ponding, extending for about 560 m with a maximum depth of 1.2 m, is also predicted to occur between CH 310 m and CH 870 m in Wambo Creek as a result of the Approved Layout (with no change to the predicted impact as a result of the Modified Layout).

Ponding is not predicted to occur in Stony Creek (**Figure 12**).

As noted in **Section 2.4**, pools are a natural feature of the creeks. Mitigation and management measures to protect against mining induced erosion impacts are provided in **Section 4**.

3.3 Potential Cracking of Creek Beds

MSEC (2014a) notes that fracturing of the uppermost bedrock, where the tensile strains have been greater than 0.5 mm/m or where the compressive strains have been greater than 2 mm/m, as a result of mining has been observed in the past.

Maximum tensile strains are likely to occur in regions of maximum tensile curvature around the edges of longwalls, as inferred by subsidence contours. It is possible, therefore, that fracturing would occur in the uppermost bedrock along the sections of the creeks located directly above the proposed and future longwalls.

MSEC (2014a) notes that Wambo and Stony Creeks have shallow incisions into the surface soils, but have exposed bedrock and isolated outcropping along the lower reaches. As Wambo and Stony Creeks have alluvial beds where they are located above Longwall 10A, it is unlikely that cracking would be visible at the surface directly above the proposed longwall. Any cracking in the beds of the streams would only be visible at the surface where the depths of the surface sediments are shallow, or where the bedrock is exposed, the nearest example being several hundred metres downstream of the junction.

G.E. Holt and Associates (2003) noted that no seam to surface connection occurred as a result of mining in the Homestead Underground Mine where cover thickness to the Whybrow seam was between 100 – 250 m. However, some connective cracking occurred in areas where cover depth was only 70 m. As there is about 100 m between the Wambo and Whybrow seams, it is unlikely that connective cracking would occur between the seams leading to increased connective cracking between the Whybrow seam and the surface.

During the site inspection, some cracking due to past mining was observed on the top of the bank of North Wambo Creek at the north-east edge of Longwall 8A (see **Figure 13**). This location has a shallow depth of cover to the Wambo seam (approximately 110 m) compared to the cover between Wambo and Stony Creek above Longwall 10A (200 – 230 m) (**Figure 3**). In addition, the area above Longwall 8A is located outside the limit of alluvium (**Figure 14**). Therefore, any cracking in the vicinity of Wambo or Stony Creeks as a result of Longwall 10A is expected to be significantly less than has observed adjacent to North Wambo Creek.

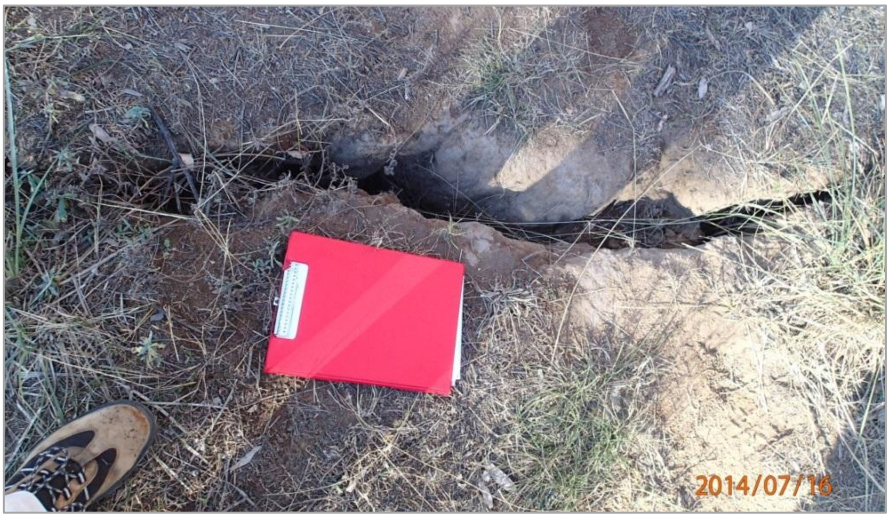

Figure 13: Example of Observed Surface Cracking near Longwall 8A

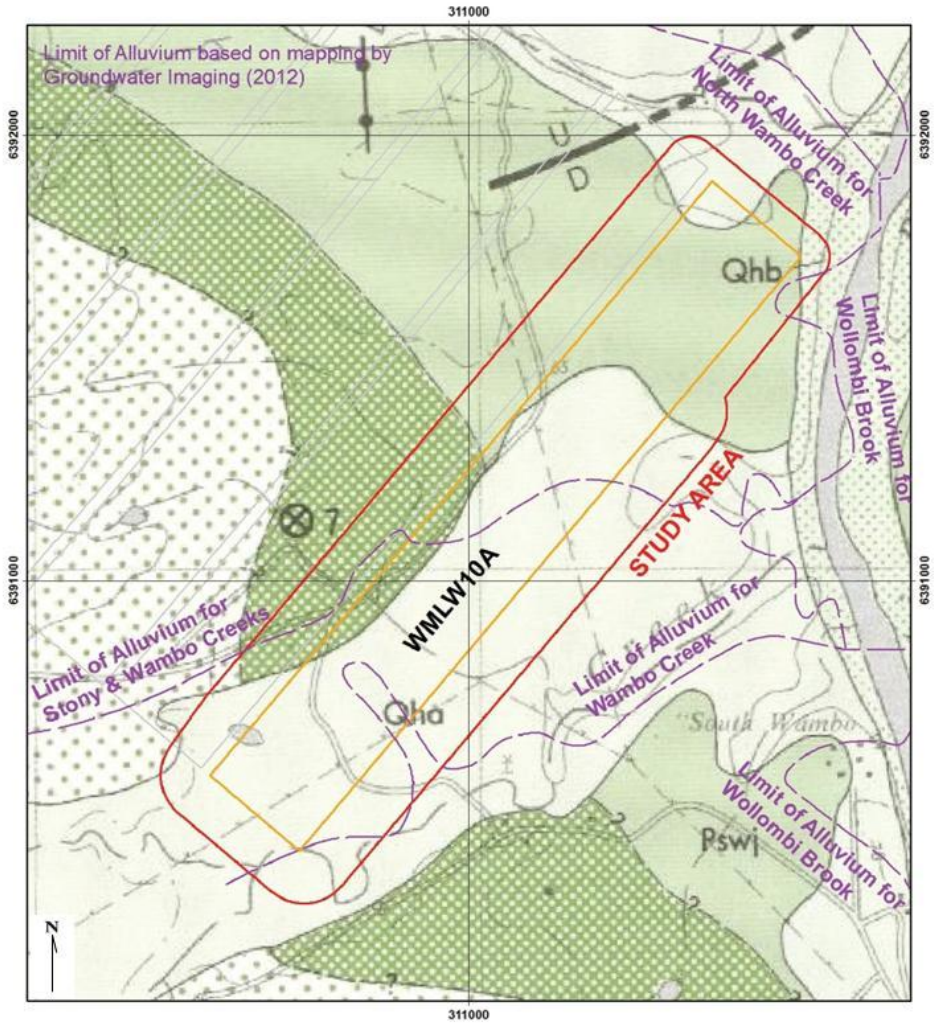

Figure 14: Proposed Longwall 10A Overlaid on Geological Map Doyles Creek 90321

(Source: MSEC, 2014a)

3.4 Potential Water Quality Impacts

The main potential impact of the Modification on downstream water quality relates to bed and bank sediment mobilised as a result of erosion/scour from locations where the gradient of the creek bed is predicted to increase. The proposed monitoring/mitigation measures (**Section 4**) are intended to minimise the mobilisation of sediment and thereby mitigate downstream water quality impacts.

4 Monitoring and Management

The following sections provide recommended impact management and monitoring measures.

4.1 Past Remediation

As discussed in **Section 2.4**, Wambo and Stony Creeks were affected by subsidence resulting from mining in the Whybrow Seam. Geoterra (2003a, 2003b), Coffey (1999, 2000) and Gilbert & Associates (2003) discuss past remedial works undertaken on Wambo and Stony Creeks to address subsidence impacts due to mining in the Whybrow seam. Past remediation works have included:

- ripping of the ground surface to assist in the sealing of subsidence cracking and prevent rilling and piping;
- construction of stone weirs to arrest bed erosion;
- grouting of Wambo Creek bed;
- bank re-profiling and revegetation;
- channel re-alignment and widening (minimal);
- outer bend bank stabilisation through the placement of rock armouring;
- fencing of revegetated areas to stabilise eroding banks;
- removal of logs and trees; and
- installation of creek crossings for vehicles and stock.

4.2 Geomorphological Survey

As recommended by Gilbert and Associates (2003), detailed longitudinal geomorphological surveys should be conducted along creek reaches affected by subsidence. The surveys should include a photographic record with location co-ordinates, with any areas of potential instability noted. Surveys should be undertaken at least three times:

- prior to subsidence (i.e. the commencement of mining);
- immediately following subsidence; and
- following the completion of any restoration or remediation works.

4.3 Bed and Bank Stability

As discussed in **Section 3.1**, the area most vulnerable to scour is confined to a small section of channel at the confluence of Wambo and Stony Creeks, where the predicted change in grade is a maximum. As shown on **Figure 11** and **Figure 12**, the Modified Layout results in an increase of grade (1.5%) and subsidence (about 0.8 m), compared to the Approved Layout.

It is recommended that the area should be monitored and the post-mining profile be regularly observed particularly after any flow. Where there is no evidence of a head-cut developing, instability of the banks could be addressed by battering back the bank and then establishing vegetated ground cover. WCPL has experience in the implementation of these types of works, as they have already been used in other areas of Wambo and Stony Creeks.

Areas of bank stabilisation should have a 10 m buffer zone of vegetation established from the top of the bank, as recommended by the *Wambo and Stony Creek Management Plan* (Coffey, 1999). Temporary use of fast growing hydro seeding should be used to protect the ground whilst longer term species are established. Native vegetation species, such as *Allocasuarina leuhmannii* (Bull Oak), *Casuarina cunninghamiana* (River Oak), *Eucalyptus tereticornis* (River Red Gum) and *Eucalyptus crebra* (Narrow Leaved Iron Bark) should be used for long term protection, once the banks have stabilised, to establish sustainable riparian zone rehabilitation. Eroding areas should be fenced to prevent stock access.

Vegetation should be monitored and managed in accordance with the *Flora and Fauna Management Plan* (WCPL, 2014a). For unconsolidated banks that slump easily, the vertical bank should be graded back to its angle of repose before revegetation.

If, however, changes in grade and bed level near the junction of Stony Creek and Wambo Creek lead to the development of a head-cut, this may eventually result in bed lowering and channel widening affecting both creeks for several hundred metres upstream unless mitigation measures are implemented. Should a head-cut start to develop, WCPL should consider remedial works, such as a constructed rock ramp, in Wambo Creek at the location of the maximum change in grade downstream of the confluence. A conceptual long section of a rock ramp is shown in **Figure 15.**

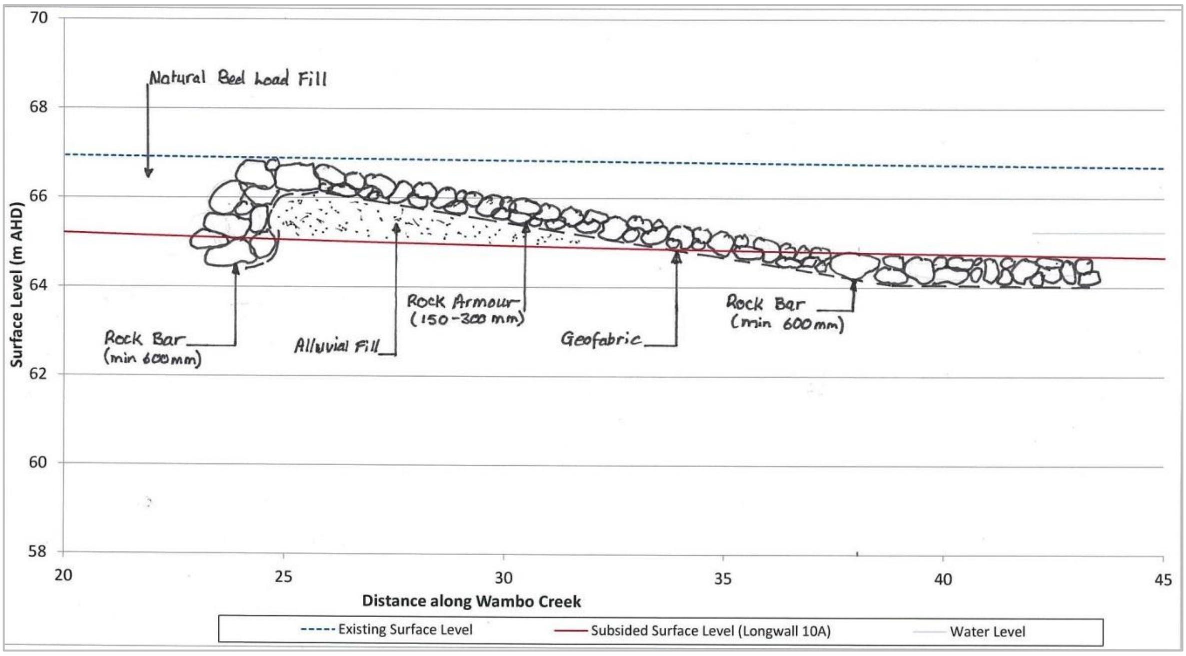

Figure 15: Conceptual Rock Ramp Longitudinal Profile

The aim of the rock ramp would be to minimise the extent of disturbance along Wambo and Stony Creeks while maintaining the existing hydraulic, hydrologic and geomorphic functions of the creeks, as required by the NSW Office of Water's *Guidelines for instream works on water front land* (NSW Office of Water, 2012).

Key features of such a structure would be:

- The toe of the structure would be located downstream of the confluence to permit subsequent construction of a further 'lift' to accommodate subsidence effects attributable to longwall extraction from other seams in the future.
- Rock bars comprising large boulders (>600 mm diameter) would be constructed at each end of the structure to 'anchor' it.
- The ramp itself would be constructed on placed alluvial fill overlain with geofabric and rock protection (nominal 300 mm deep with size range of 150-300 mm).
- The subsidence profile indicates that a pool will form downstream into which flow down the ramp will discharge. Downstream scour protection would be provided for about 5 m.

- By establishing a level at the upstream rock bar that is the same as the existing creek bed level, it is anticipated that bed-load from both the creeks would rapidly fill that part of the subsidence trough and equilibrium bed-load transport would be re-established.

Issues that may require consideration include:

- ancillary works required to minimise the risk of future channel avulsion leading to re-establishment of a flow path along the existing ancestral channel to the north of the existing channel;
- the provision of small pools within the ramp to provide for fish passage (subject to advice from an aquatic ecologist.

Detailed design would be required. In addition, a sediment and erosion control plan would need to be developed for the works, and ongoing management strategies developed as part of an overall creek management plan.

As discussed in **Section 2.3**, Stony Creek and Wambo Creek are fourth and fifth order streams respectively. As such, design and construction of works within these creeks are regulated by the controlled activity provisions of the *Water Management Act 2000*. A controlled activity approval would be required from the NSW Office of Water before commencing any works.

Information required when seeking approval is outlined in the NSW Office of Water's *Guidelines for instream works on water front land* (NSW Office of Water, 2012). Information required for assessment by the NSW Office of Water includes:

- Detailed design drawings of proposed works.
- Detailed report of pre and post construction hydraulic conditions.
- Detailed plans of permanent bed and bank stabilisation works for scour protection.
- Photographs of the site.
- A vegetation management plan.
- Sediment and erosion control plan.
- A site management plan.
- Costing of all works and stages of works.
- Copies of other relevant approvals.

4.4 Ponding

Based on the predicted subsidence effects, it is envisaged that two long pools would develop within the creek channels directly above Longwall 10A. As noted in **Section 2.4**, pools are a natural feature of the creeks and it is unlikely that remedial works would be required. In addition, any increased ponding along the creeks is likely to be 'in-channel'.

However, if subsidence creates a pool that is significantly larger than predicted, remedial actions could include:

- Assessment of the ecological significance of the pool and its impact on the aquatic and riparian habitat by an appropriately qualified ecologist.
- Consultation with regulatory agencies to determine whether action is warranted to reduce or eliminate the pool.

- Drainage works and rehabilitation of subsidence troughs as necessary, as outlined in the *Land Management Plan (LMP) for North Wambo Underground Mine Longwalls 7 to 10* (WCPL, 2014).
- Channel excavation and stabilisation works to re-grade a downstream section of channel in order to eliminate or reduce the length of the pool.
- The construction of designated crossing areas to allow stock access to the creeks to drink from new pools, as recommended by Coffey (1999).

4.5 Stream Bed Cracking

As discussed in **Section 3.1**, any stream bed cracking resulting from Longwall 10A induced subsidence, if it were to occur, would be located at the edges of Longwall 10A. Any such cracking would be identified through creek channel monitoring.

The LMP for NWUM Longwalls 7 to 10 (WCPL, 2014b) recommend that minor surface cracks be in-filled with soil or other suitable materials, such as mulch and the surface area re-graded and re-compacted. Erosion protection measures, such as vegetation planting, could also be used. However, natural healing and regeneration is the favoured management strategy in most instances, due to the likely level of disturbance caused by other strategies, such as backfilling with imported materials from haulage trucks.

Significant bed-rock cracking could warrant grouting of the underlying bedrock. This would be implemented in consultation with regulatory agencies in the unlikely event significant cracking occurred.

5 Conclusions

Compared to the currently approved longwall extraction in the Wambo, Arrowfield and Bowfield seams (the Approved Layout), the proposed extraction of coal from Longwall 10A in the Wambo seam is predicted to lead to a maximum incremental subsidence of 0.9 m in Wambo Creek and 0.5 m in Stony Creek resulting in maximum increase in gradient of 1.5% and 0.5% respectively. These impacts would occur in the vicinity of the junction of Stony Creek and Wambo Creek, which is an area of geomorphic sensitivity.

Any potential for bed or bank scouring as a result of the predicted subsidence and change in gradient are within the range that are capable of being mitigated by a range of mitigation techniques previously applied by WCPL on other sections of Stony and Wambo Creeks or by the construction of a purpose designed rock ramp.

The prompt implementation of any necessary mitigation works would minimise the risk of any change in sediment movement along the creek or upstream migration of head-cuts along both creeks.

Following successful implementation of the relevant management and mitigation measures, the Modified Layout would be expected to have negligible impact on downstream water quality in Wollombi Brook.

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WCPL 2014b, *North Wambo Underground Mine Extraction Plan Longwalls 7 and 8 – Appendix B Land Management Plan*

Topographic maps and aerial photographs:

- 1:25,000 topographic maps (Doyles Creek [9032-1-N], Parnell [9032-1-S]);
- Google Earth aerial photograph (dated 16/12/2008); and
- Aerial photograph provided by WCPL (flown April-October 2013).