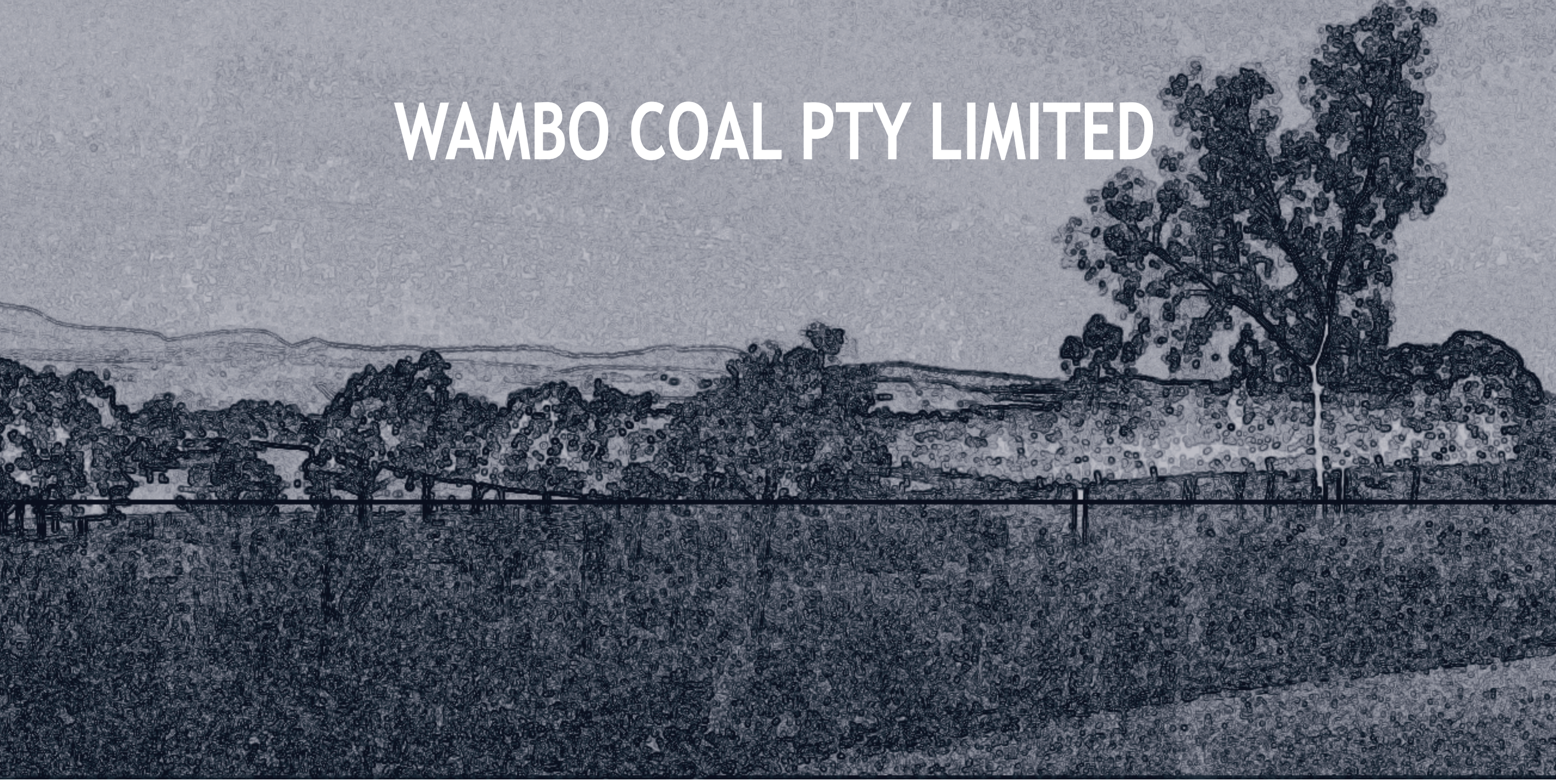
WAMBO COAL PTY LIMITED



SOUTH WAMBO
UNDERGROUND MINE MODIFICATION

ENVIRONMENTAL ASSESSMENT

APPENDIX C

Surface Water Assessment

Peabody ENERGY

Advisian
WorleyParsons Group

Wambo Coal Pty Limited

South Wambo Underground Mine Modification

Surface Water Assessment
March 2016

www.advisian.com

Version Control

Revision	Date	Author	Reviewed by	Comments
0.1	25 Jan 2016	PJD	SP	
0.2	27 Jan 2016	PJD	SP	
0.3	29 Jan 2016	SP/PJD	SP	
1.1	2 Feb 2016	SP/PJD	RS	
1.2	19 Feb 2016	SP/PJD	SP	
2.0	22 Feb 2016	SP/PJD	RS	
3.0	26 Feb 2016	SP/PJD	SP	
3.1	29 Feb 2016	SP/PJD	SP	
3.2	2 Mar 2016	SP/PJD	RS/WCPL	
4.0	11 March 2016	SP/PJD		

List of Abbreviations

AFLW	Arrowfield Seam Longwall
AEP	Annual Exceedance Probability
BOM	Bureau of Meteorology
DPI	Department of Primary Industry
DSNR	Department of Sustainable Natural Resources
EC	Electrical Conductivity
EA	Environmental Assessment
EPA	Environment Protection Authority
km	kilometres
km^2	square kilometres
m	metre
m/s	metres per second
m^3/s	cubic metres per second
m AHD	metres Australian Height Datum

mg/L	milligrams per litre
ML	megalitres
ML/day	megalitres per day
mm	millimetres
MSEC	Mine Subsidence Engineering Consultants
Mtpa	million tonnes per annum
NSW	New South Wales
NWUM	North Wambo Underground Mine
OEH	Office of Environment and Heritage
ROM	run-of-mine
RWEP	Remnant Woodland Enhancement Program
SBUM	South Bates Underground Mine
SEARs	Secretary's Environmental Assessment Requirements
SWUM	South Wambo Underground Mine
UW1	Unnamed Drainage Line 1
UW2	Unnamed Drainage Line 2
UW3	Unnamed Drainage Line 3
WAL	Water Access Licence
WCPL	Wambo Coal Pty Limited
WHLW	Woodlands Hill Seam Longwall
µS/cm	microSiemens per centimetre

Table of Contents

1 Introduction ... 1
1.1 Background ... 1
1.2 Modification Overview ... 1
1.3 Secretary's Environmental Assessment Requirements for the Modification ... 7
1.4 Scope ... 7
2 Description of Existing Conditions ... 9
2.1 Overview ... 9
2.2 Site Location, Landforms, Land Use & Drainage ... 9
2.3 Climate & Rainfall ... 10
2.4 Creek Characteristics ... 11
2.5 Stream Order ... 14
2.6 Creek Flow in North Wambo, Stony, and Wambo Creeks ... 15
2.7 Flow in Wollombi Brook ... 20
2.8 Flooding ... 21
2.9 Water Sharing Plans & Water Users ... 22
2.10 Surface Water Quality ... 24
3 Potential Impacts ... 27
3.1 Subsidence Effects ... 28
3.2 Potential Erosion Impacts ... 34
3.3 Potential Ponding Impacts ... 37
3.4 Potential Cracking of Creek Beds ... 40
3.5 Potential Water Quality Impacts ... 42
3.6 Potential Reduction in Creek Flows due to Groundwater Depressurisation ... 42
3.7 Potential Changes to Flood Behaviour ... 45
3.8 Potential Impacts on Licensed Water Users ... 45
4 Monitoring and Management ... 47
4.1 Geomorphological Survey ... 47
4.2 Bed and Bank Stability ... 47
4.3 Ponding ... 48
4.4 Stream Bed Cracking ... 48
4.5 Erosion and Sediment Control for Surface Development Area ... 50
4.6 Surface Water Quality ... 50
4.7 Extraction Plan ... 51
5 Conclusions ... 52
6 References ... 54

List of Appendices

A. Existing Creek Conditions – Record of Site Inspection

B. Creek Flow Records – North Wambo, Stony and Wambo Creeks

List of Figures

Figure 1.1: Approved Wambo Coal Mine General Arrangement 2
Figure 1.2: Modified Wambo Coal Mine General Arrangement 3
Figure 1.3: Modified Surface Infrastructure Layout 5
Figure 2.1: Flow Monitoring Site Locations 16
Figure 2.2: Flow Duration Graph for North Wambo Creek 18
Figure 2.3: Flow Duration Graph for Wambo Creek 18
Figure 2.4: Flow Duration Graph for Stony Creek 19
Figure 2.5: Flow Duration Curves for Wollombi Brook Upstream and Downstream of Wambo 21
Figure 2.6: Lower Wollombi Brook Water Source Water Access Licences in the Vicinity of Wambo 23
Figure 2.7: Surface Water Quality Monitoring Locations 25
Figure 3.1: Natural and Predicted Subsided Surface Levels and Grades along North Wambo Creek and North Wambo Creek Diversion for the Modified Layout (MSEC, 2016) 31
Figure 3.2: Natural and Predicted Subsided Surface Levels along North Wambo Creek and North Wambo Creek Diversion for the Approved Layout (MSEC, 2016) 31
Figure 3.3: Natural and Predicted Subsided Surface Levels and Grades along Wambo Creek for the Modified Layout (MSEC, 2016) 32
Figure 3.4: Natural and Predicted Subsided Surface Levels along Wambo Creek for the Approved Layout (MSEC, 2016) 32
Figure 3.5: Natural and Predicted Subsided Surface Levels and Grades along Stony Creek for the Modified Layout (MSEC, 2016) 33
Figure 3.6: Natural and Predicted Subsided Surface Levels along Stony Creek for the Approved Layout (MSEC, 2016) 33
Figure 3.7: Natural and Predicted Subsided Surface Levels and Grades along UW3 for the Modified Layout (MSEC, 2016) 34
Figure 3.8: Predicted Approved and Modified Topographic Depressions Post Mining 39
Figure 3.9: Baseflow Variation in Wollombi Brook (HydroSimulations, 2016) 43
Figure 3.10: Baseflow Variation in North Wambo Creek (HydroSimulations, 2016) 43
Figure 3.11: Baseflow Variation in Stony Creek (HydroSimulations, 2016) 44
Figure 3.12: Baseflow Variation in Wambo Creek (HydroSimulations, 2016) 44

List of Tables

Table 2.1: Summary Mean Rainfall Statistics (millimetres) 10
Table 2.2: WCPL Surface Water Flow Monitoring Locations 15
Table 2.3: Locations Adopted for Creek Flow Assessment 17
Table 2.4: Catchment Areas and Estimated Peak Flood Discharges (m^3/s) 20
Table 2.5: Potentially Affected Surface WALs in the Vicinity of Wambo 22
Table 2.6: Wambo Surface Water Quality Summary for Local Watercourses (WCPL, 2015a) 26
Table 3.1: Comparison of Maximum Predicted Subsidence Parameters for the Approved Layout and Modified Layout West of Wollombi Brook (MSEC, 2016) 28
Table 3.2: Comparison of the Maximum Predicted Subsidence Parameters for the Watercourses due to the Approved Layout and the Modified Layout (after MSEC, 2016) 29
Table 3.3: Predicted Maximum Depths and Lengths of the Topographic Depressions along the Creeks (Approved and Modified Layouts) (after MSEC, 2016) 38

1 Introduction

1.1 Background

Wambo Coal Mine (Wambo) is situated approximately 15 kilometres (km) west of Singleton, near the village of Warkworth, New South Wales (NSW). Wambo is owned and operated by Wambo Coal Pty Limited (WCPL), a subsidiary of Peabody Energy Australia Pty Limited.

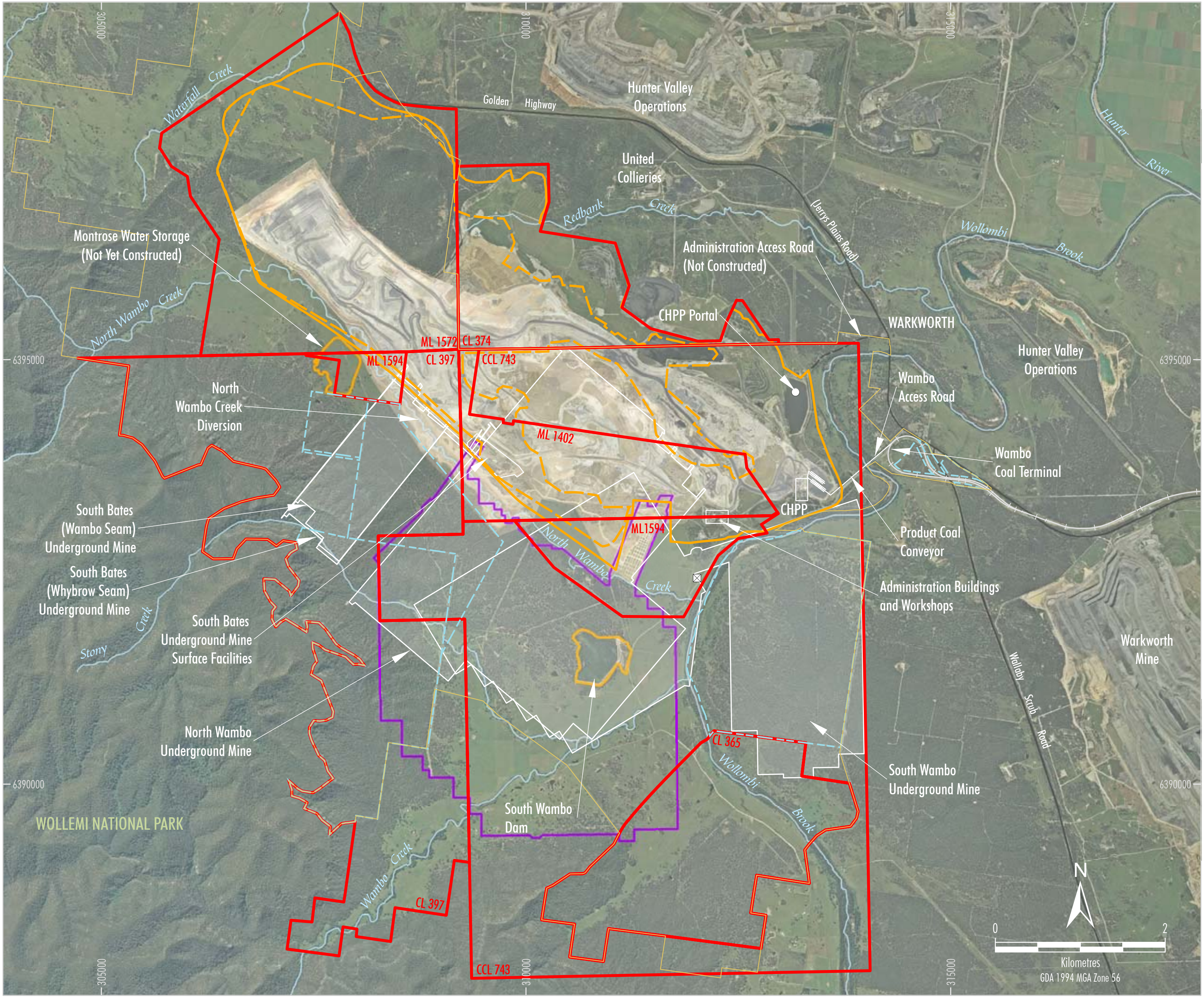
A range of open cut and underground mine operations have been conducted at Wambo since mining operations commenced in 1969. Mining under the Development Consent (DA 305-7-2003) commenced in 2004 and currently both open cut and underground operations are conducted. The approved underground mining operations include the extraction of longwalls in the Whybrow, Wambo, Arrowfield and Bowfield Seams. The approved operations in the Arrowfield and Bowfield Seams form part of the South Wambo Underground Mine (SWUM) (**Figure 1.1**).

WCPL is seeking approval to modify the Development Consent (DA 305-7-2003) for Wambo to allow for the realignment and extension/relocation of the approved South Wambo (Arrowfield Seam) Underground Mine longwall panels and mining of the Woodlands Hill Seam rather than the Bowfield Seam (the South Wambo Underground Mine Modification [the Modification]) (**Figure 1.2**).

1.2 Modification Overview

The Modification would involve a realignment and extension/relocation of the approved SWUM (Arrowfield Seam) longwall panels and mining of the Woodlands Hill Seam rather than the Bowfield Seam. Longwall mining areas associated with the Modification are detailed below (**Figure 1.2**):

- **Area 1 (Woodlands Hill Seam)** – The modified mine layout includes additional longwall panels in the Woodlands Hill Seam beneath the approved Surface Development Area.
- **Area 2 (Arrowfield Seam and Woodlands Hill Seam)** – The modified mine layout includes a reorientation and minor extension of the approved Arrowfield Seam mine layout in Area 2. The Woodlands Hill Seam is proposed to replace the Bowfield Seam in this location with a reorientation and minor extension to the approved mine layout.
- **Area 3 (Arrowfield Seam and Woodlands Hill Seam)** – The modified mine layout includes an extension of mining in the Arrowfield Seam and Woodlands Hill Seam into Area 3, comprising three longwall panels in the Arrowfield Seam and four longwall panels in the Woodlands Hill Seam.
- **Area 4 (Approved Arrowfield Seam)** – The Modification does not propose any changes to the approved Arrowfield Seam mine layout to the east of Wollombi Brook. The approved Bowfield Seam mine layout is no longer proposed to be mined in Area 4 and therefore there would be a reduction in subsidence impacts in Area 4.



LEGEND
- Mining and Coal Lease Boundary
- WCPL Owned Land
- Existing/Approved Surface Development Area
- Approved Open Cut Limit
- Approved Underground Development
- Historic Underground Workings
- Approved Ventilation Shaft
- Remnant Woodland Enhancement Program (RWEP) Area

Source: *Department of Lands (July 2009); WCPL (2015); WCPL Orthophoto (Apr-Oct 2013)*

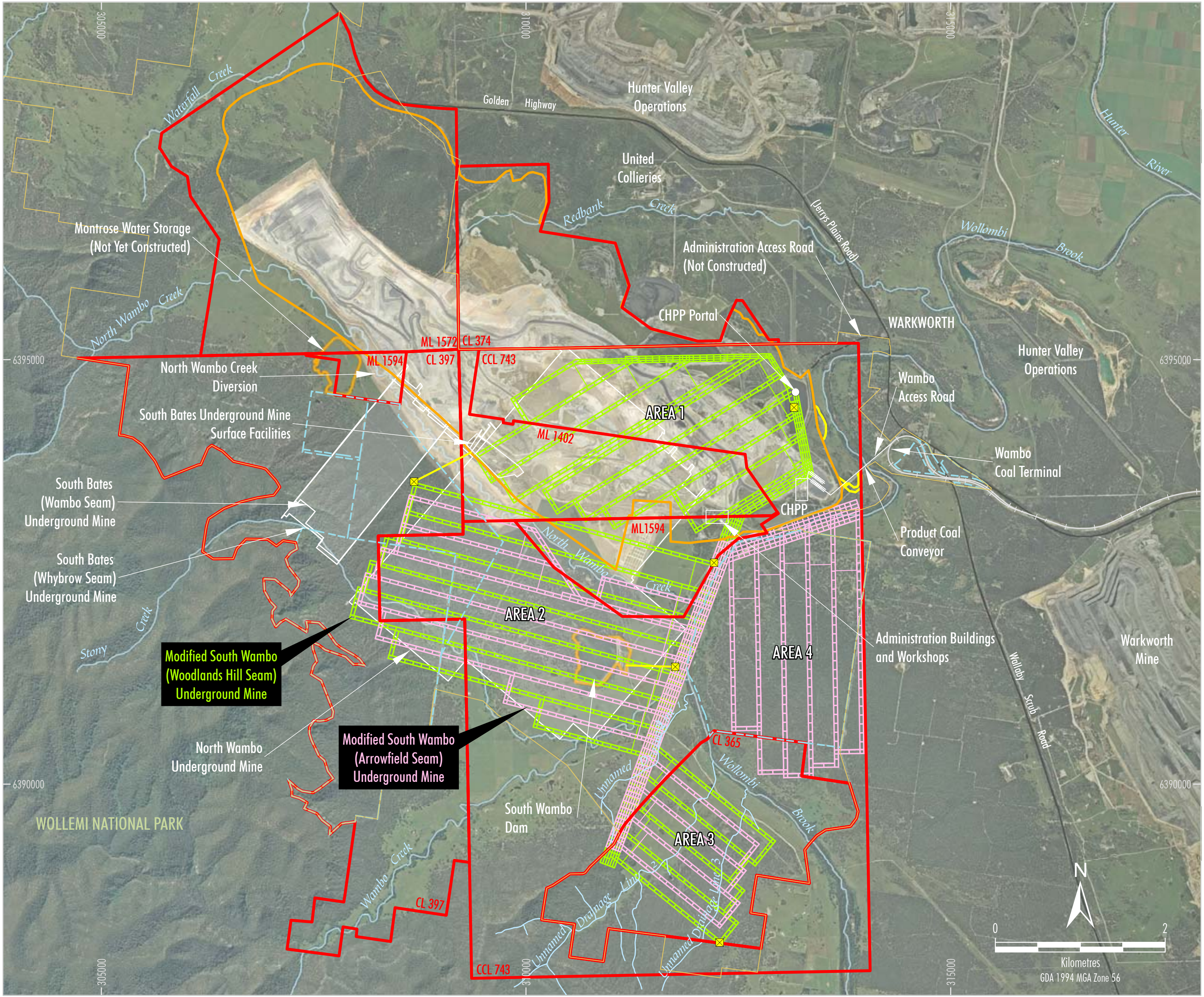
Peabody ENERGY

WAMBO COAL MINE

Approved Wambo Coal Mine General Arrangement

Figure 1.1

WAM-09-15_SWUMM_EA_SW_205A



LEGEND
- Mining and Coal Lease Boundary
- WCPL Owned Land
- Existing/Approved Surface Development Area
- Modified Surface Development Area
- Approved Underground Development
- Modified South Wambo (Woodlands Hill Seam) Underground Mine
- Modified South Wambo (Arrowfield Seam) Underground Mine
- Modified Ventilation Shaft
- Remnant Woodland Enhancement Program (RWEP) Area

Source: Department of Lands (July 2009); WCPL (2015); WCPL Orthophoto (Apr-Oct 2013)

WAM-09-15_SWUMM_EA_SW_204B

Peabody

W A M B O C O A L M I N E

Modified Wambo Coal Mine
General Arrangement

Figure 1.2

The rearrangement of the SWUM would require a minor extension of the approved surface development area (**Figure 1.2**) and result in an extension of the approved mine life by 7 years (i.e. to 2032).

The Modification would include additional surface infrastructure and associated works, comprising:

- the SWUM infrastructure area (**Figure 1.3**);
- an additional access road to facilitate access to the SWUM infrastructure area (**Figure 1.3**); and
- other minor infrastructure.

The SWUM infrastructure area would be an extension to the existing approved surface infrastructure area (**Figure 1.3**) and would include the construction and operation of:

- extended run of mine (ROM) coal facilities area;
- underground equipment laydown area;
- water management infrastructure including water storage dams;
- office complex and bathhouse;
- water and septic tanks;
- communications room and training room;
- electrical infrastructure, workshop, stores and fuel bay; and
- car park.

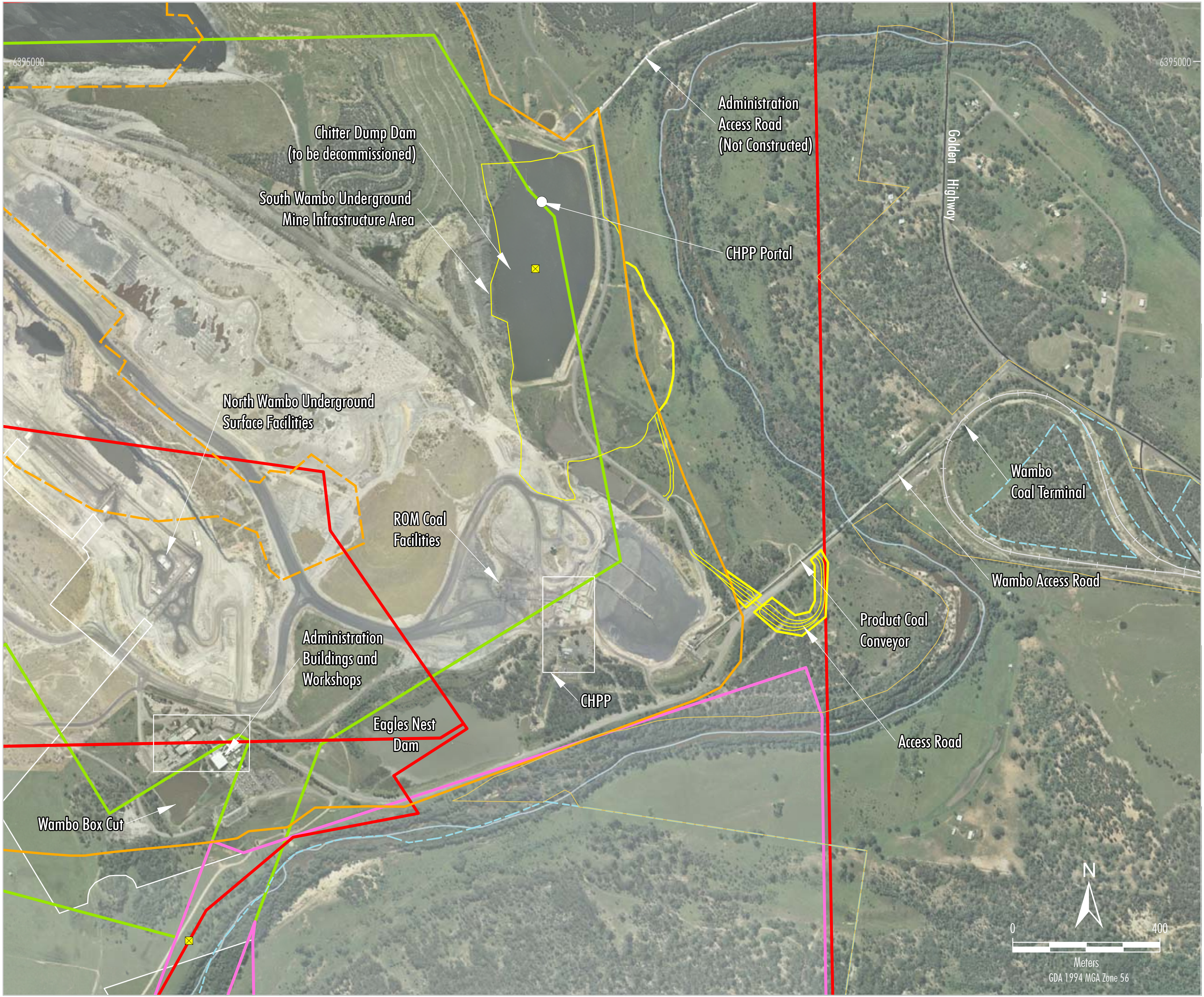
An access road to the South Wambo Underground Mine infrastructure area would be constructed, including upgrades to existing access roads and the construction of a grade separated crossing of the existing Wambo access road.

Minor upgrades to existing utilities (e.g. electricity supply and communications) would be conducted for the Modification as required. Additional minor infrastructure required for the Modification would include:

- electrical infrastructure;
- communications infrastructure;
- service pipelines;
- water management infrastructure;
- flood control works, including levees;
- ventilation and gas management infrastructure; and
- service boreholes.

The underground mine ROM coal production rate would increase from 7.5 to 9.75 million tonnes per annum (Mtpa). The approved total ROM coal production rate (i.e. 14.7 Mtpa) would remain unchanged.

The Modification would not involve changes to any aspects of the approved North Wambo Underground Mine (NWUM) or South Bates Underground Mine (SBUM).



LEGEND

- Mining and Coal Lease Boundary
- WCPL Owned Land
- Existing/Approved Surface Development Area
- Modified Surface Development Area
- Approved Open Cut Limit
- Approved Underground Development
- Modified South Wambo (Woodlands Hill Seam) Underground Mine
- Modified South Wambo (Arrowfield Seam) Underground Mine
- Modified Ventilation Shaft
- Remnant Woodland Enhancement Program (RWEP) Area

Source: Department of Lands (July 2009); WCPL (2015); WCPL Orthophoto (Apr-Oct 2013)

Peabody ENERGY

W A M B O C O A L M I N E

Modified Surface Infrastructure Layout

Figure 1.3

WAM-09-15_SWUMM_EA_SW_207A

The Modification would also include an extension of approved open cut mining operations by 3 years (i.e. up to and including 2020). The Modification would not include any change to the approved open cut ROM coal production limit.

Additional details of the Modification are provided in Section 3 of the Environmental Assessment (EA).

The *Approved Layout* includes the completed NWUM (Wambo Seam), the approved SBUM (Whybrow and Wambo Seams) and the approved SWUM (Arrowfield and Bowfield Seams) (**Figure 1.1**).

The *Modified Layout* includes the completed NWUM (Wambo Seam), the approved SBUM (Whybrow and Wambo Seams) and the modified SWUM (Woodlands Hills and Arrowfield Seams) (**Figure 1.2**).

The "Modification Area" comprises the extent of conventional subsidence resulting from the modified longwall layout and the surface development areas (**Figure 1.2**).

Subsidence effects resulting from longwall mining the Arrowfield and Bowfield Seams in Area 4 were approved as part of the Wambo Development Project Environmental Impact Statement (WCPL, 2003). The modified subsidence impacts in Area 4 are predicted to reduce as only the Arrowfield Seam is proposed to be mined as part of the Modification (Mine Subsidence Engineering Consultants [MSEC], 2016). The potential impacts on surface water resources in Area 4 are therefore also expected to reduce as a result of the Modification and therefore this assessment has not considered Area 4 any further.

1.3 Secretary's Environmental Assessment Requirements for the Modification

Advisian has been commissioned by WCPL to prepare a Surface Water Assessment for the Modification. This assessment has been prepared to assist with addressing the aspects relating to surface water in the following components of the Secretary's Environmental Assessment Requirements (SEARs) for the Modification:

Secretary's Environmental Assessment Requirements	Section in which the Requirement Relating to Surface Water is Addressed
The EA must address the following specific issues:	
- an assessment of the potential impacts of the development on the quantity and quality of the region's surface [water] .... resources, having regard to the requirements of the EPA and DPI (see Attachment 2)	Section 3
- an assessment of the likely impacts of the development on ... watercourses, riparian land, water-related infrastructure, and other water users;	Section 3
- a detailed site water balance and an assessment of any volumetric water licensing requirements, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply infrastructure and water storage structures, having regard to the requirements of DPI (see Attachment 2);	Main text of the Environmental Assessment
- an assessment of the likely flooding impacts of the development, having regard to OEH's requirements (see Attachment 2);	Section 2.8 and 3.7, and the Main text of the Environmental Assessment
- identification of any licensing requirements or other approvals under the *Water Act 1912* and/or *Water Management Act 2000*;	Section 4 and main text of the Environmental Assessment
- demonstration that water for the construction and operation of the proposed modification can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP);	Main text of the Environmental Assessment
- a description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo;	Main text of the Environmental Assessment
- a framework for the avoidance, mitigation, management and monitoring of water quality impacts during construction and operation; and	Section 4.5
- a detailed description of the proposed water management system (including sewerage), water monitoring program and measures to mitigate surface [water] ... impacts;	Section 4

In accordance with the SEARs for the Modification, this assessment has regard to the Department of Primary Industries (DPI), Environment Protection Authority (EPA) and Office of Environment and Heritage's (OEH) input into the SEARs outlined in Attachment 2 of the SEARs.

1.4 Scope

Advisian has been commissioned by WCPL to assess potential surface water impacts to watercourses in the Modification Area, including the following potential impacts attributable to the Modified South Wambo Underground Mine:

- Potential impacts on channel stability as a result of predicted changes in subsidence;
- Potential impacts on existing pools or the creation of new pools as a result of predicted changes in subsidence;

- Alteration to flow in the watercourses caused by changes in the predicted:
  - groundwater depressurisation,
  - subsidence induced ponding,
  - creek bed cracking, and
  - surface water ponding in areas other than the watercourses leading to reduced contributing catchment area;
- Potential changes in water quality arising as a result of the development; and
- Potential changes to impacts on licensed water users.

The impacts of the Modified Layout are assessed as the changes in impact relative to the impacts predicted for the Approved Layout.

This report also considers potential surface water impacts associated with the minor extension of the approved surface development area, and potential changes in flood behaviour in the vicinity of the Modification.

This report has been prepared to support the Modification Application to be submitted to the Department of Planning and Environment.

2 Description of Existing Conditions

2.1 Overview

The Surface Water Assessment principally considers the incremental impacts of the Modification on the surface water resources at Wambo. There are four named watercourses within the Modification Area, along with three unnamed drainage lines in the southern part of the Modification Area. From north to south, these watercourses are:

- North Wambo Creek;
- Stony Creek;
- Wambo Creek;
- Wollombi Brook;
- Unnamed Drainage Line 1 (UW1);
- Unnamed Drainage Line 2 (UW2); and
- Unnamed Drainage Line 3 (UW3).

The locations of these watercourses in relation to the Modification are shown on **Figure 1.2**.

This chapter documents the existing surface water environment at Wambo, including consideration of existing catchment conditions and flow regimes in the potentially affected surface watercourses. The rainfall record for the region is also summarised.

A site inspection, focussed on characterising the relevant reaches of North Wambo Creek, Stony Creek, Wambo Creek and the three unnamed watercourses, was undertaken on 2 November 2015. The characterisation of these watercourses is documented in Section 2.4.

A review of the surface water quality data collected by WCPL under the current Water Management Plan was undertaken and is summarised in Section 2.10.

The current surface water users and surface water licensing regime in the vicinity of Wambo are also considered.

2.2 Site Location, Landforms, Land Use & Drainage

Wambo is located in the Upper Hunter Valley region where landforms are characterised by gently sloping flood plains associated with the Hunter River and the undulating foothills, ridges and escarpments of the Mount Royal Range and Great Dividing Range. Elevations in the vicinity of Wambo range from approximately 60 metres (m) Australian Height Datum (AHD) at Wollombi Brook to approximately 650 m AHD at Mount Wambo within the Wollemi National Park to the west of Wambo (WCPL, 2003). Elevations in the Modification Area range from approximately 60 m AHD near Wollombi Brook to approximately 220 m AHD near the base of the Wollemi Escarpment.

Wambo is situated adjacent to Wollombi Brook, south-west of its confluence with the Hunter River. Wollombi Brook drains an area of approximately 1,950 square kilometres (km^2) and joins the Hunter River some 5 km north-east of Wambo. The Wollombi Brook sub-catchment is bound by the Myall Range to the south-east, Doyles Range to the west, the Hunter Range to the south-west and Broken Back Range to the north-east (Hunter Catchment Management Trust, 2003).

The majority of lands within WCPL mining tenements drain via Wambo, Stony, North Wambo and Redbank Creeks to Wollombi Brook, while Waterfall Creek drains directly to the Hunter River. The majority of lands within the Modification Area drain via Wambo, Stony and North Wambo Creeks to Wollombi Brook. These watercourses are generally characterised by ephemeral and semi-perennial flow regimes (Gilbert & Associates, 2003). Runoff in the area is a relatively low proportion of rainfall and generally follows the pattern of average rainfall with higher runoff occurring in late summer and autumn and lower runoff occurring in spring and winter (Gilbert & Associates, 2003).

Land use in the vicinity of Wambo is characterised by a combination of coal mining operations, Remnant Woodland Enhancement Programme (RWEP) areas, agricultural land use and WCPL-owned lands that are not subject to mining operations used for the agistment of beef cattle. The main agricultural land uses in the vicinity of Wambo include dairy and beef cattle and pasture production, horse breeding, viticulture and wine making (Soil Management Designs, 2016).

Land use in the Modification Area includes coal mining operations, RWEP areas A, B and C, remnant vegetation and agriculture (beef cattle) (Soil Management Designs, 2016).

2.3 Climate & Rainfall

The Wambo area experiences a dry temperate to sub-tropical climate with hot humid summers and cool drier winters, with an average annual rainfall of approximately 650 millimetres (mm) (Bureau of Meteorology [BOM], 2016).

Whilst rainfall is spread throughout the year, it is generally greater in the summer months. The heaviest daily falls have been recorded during winter (June), and in late summer (February).

BOM maintains a number of daily rainfall monitoring stations in the general vicinity of Wambo:

- Doyles Creek (Wood Park) (1920-2015);
- Bulga (South Wambo) (1959-2015); and
- Jerrys Plains Post Office (1889-2013).

At each station there are missing data throughout the period of record. These missing records have been "in-filled" using data from the other stations or, if required, using data from the Singleton and Denman BOM monitoring stations.

Summary mean rainfall statistics for these stations are presented in **Table 2.1**.

Table 2.1: Summary Mean Rainfall Statistics (millimetres)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Doyles Creek (Wood Park)	74.3	80.1	56.8	46.6	37.0	50.8	41.7	36.8	41.3	52.4	67.6	62.8	641.3
Bulga (South Wambo)	83.6	90.3	68.8	49.6	42.1	44.4	32.6	33.9	40.6	55.2	68.7	69.9	679.8
Jerrys Plains	78.0	73.3	59.9	44.1	40.6	49.1	42.9	36.5	42.2	53.4	62.8	67.3	650.0

2.4 Creek Characteristics

2.4.1 Overview

As shown in **Figure 1.2,** the modified SWUM longwalls would undermine reaches of North Wambo Creek, Stony Creek, Wambo Creek and associated tributary drainage lines. Three unnamed drainage lines are located in the south-east (west of Wollombi Brook) of the Modification Area.

North Wambo Creek, Stony Creek and Wambo Creek are ephemeral creeks that originate in the steep hills of the Wollemi National Park. The three unnamed drainage lines are also ephemeral.

Many of these streams include "persistent" pools that may retain water for extended periods after inflow events but can dry-up in extended dry periods. These pools include both natural features and subsidence induced topographic depressions that have developed after previous underground mining at Wambo.

A site inspection of the major watercourses that may be impacted by the Modification was undertaken on 2 November 2015. The objective of the site inspection was to create a baseline characterisation of the streams against which potential impacts of the Modification on the streams can be assessed. The stream traverses focussed on (**Figure 1.2**):

- North Wambo Creek across the Modification Area to the confluence with Wollombi Brook;
- Stony Creek across the Modification Area to the confluence with Wambo Creek;
- Wambo Creek from the confluence with Stony Creek to the confluence with Wollombi Brook; and
- The three unnamed drainage lines in the south-east of the Modification Area.

The full creek characterisation (with photographs) is included in Appendix A.

2.4.2 North Wambo Creek

The North Wambo Creek rises in the Wollemi National Park escarpment west of the Modification Area and extends to the confluence with Wollombi Brook in the east of the Modification Area. Prior to the construction of the North Wambo Creek Diversion to convey flow on the western side of the Wambo Open Cut, the natural catchment had a total area of some 48.5 km^2 at the confluence with Wollombi Brook. The catchment contains two distinct landforms:

- Steep, heavily forested headwaters with elevations ranging from up to 650 m AHD on the ridges down to approximately 140 m AHD where the creek drains onto open country over a distance of approximately 5.5 km. The tributary creeks in this hilly section of the catchment drain predominantly from south-west to north-east and have well defined regular alignment.
- Cleared grassy plains within which sections of the pre-existing creek have been subsumed by the Wambo open cut.

For the purpose of diverting flow away from the area designated for open cut mining, diversion of North Wambo Creek occurred in two main stages commencing at the point near where the original creek turned to drain in a south-westerly direction:

- Stage 2 Diversion (incorporating Stage 1), comprising approximately 3.6 km of meandering channel containing two 'billabongs' was constructed in 2008. The catchment area at the upstream end the Stage 2 Diversion is approximately 26.5 km^2.
- Stage 3 Diversion, comprising a further 5.6 km of meandering channel commencing at the downstream end of the meandering section of Stage 2 was completed in late 2013. As a result of internal drainage to the Wambo Open Cut, the contributing catchment of the creek at the outlet of the Stage 3 Diversion has been reduced from approximately 42.6 km^2 to approximately 34.2 km^2. As a result of the diversion, the catchment of North Wambo Creek at the confluence with Wollombi Brook has been reduced to approximately 40.1 km^2.

The uppermost reach of North Wambo Creek that would be undermined by the modified SWUM longwalls is the downstream end of the Stage 3 Diversion. Immediately downstream of the North Wambo Creek Diversion, the stream bed is reported to comprise material washed out of the Stage 3 Diversion in 2013, and is indicative of a low energy stream with low slope.

The North Wambo Creek flows in a generally easterly direction across the Modification Area. Approximately 600 m downstream of the North Wambo Creek Diversion there is a large persistent pool, approximately 250 to 300 m long.

There are two north-east flowing tributaries to North Wambo Creek. One of these tributaries includes a small number of persistent pools and wetlands. These pools are reported to be the result of prior mine subsidence impacts on these watercourses. The tributaries flow across the alluvial flood plain to North Wambo Creek and the channels in the alluvium are deeply eroded and degraded with little stabilising vegetation.

Downstream of these tributaries, North Wambo Creek flows in a broad, grassed gully, with a meandering incised main channel. The stream bed is mostly composed of sands and silts. There are persistent pools in these areas. The banks of the gully are in the order of 2 m above the main channel through this zone.

The unnamed tributaries that flow in a south-east direction into the downstream reach of North Wambo Creek, prior to its confluence with Wollombi Brook, drain from broad open pasture areas and do not demonstrate any significant channel formation. .

The downstream reaches of North Wambo Creek are located within a grassed, steep sided gully, with the banks in the order of 4 to 5 m above the main channel. This style of formation persists through to the confluence with Wollombi Brook.

An unnamed road crosses North Wambo Creek on concrete box culvert sections, just upstream from the confluence with Wollombi Brook. There is a knickpoint developed immediately below the crossing.

Over many reaches of the North Wambo Creek, the stream bed and banks are generally well vegetated, with vegetation types including grass, reeds and trees.

The confluence with Wollombi Brook lies at a large persistent pool in Wollombi Brook.

2.4.3 Stony Creek

Stony Creek has steep heavily forested headwaters with elevations ranging up to 650 m AHD on the ridges of the Wollemi Escarpment down to approximately 110 m AHD at the point where Stony Creek enters the Modification Area. The catchment area at this point is approximately 8.7 km^2. Downstream of the point where it enters the Modification Area, Stony Creek flows in a south-westerly direction for approximately 4 km to join Wambo Creek, with gradients ranging from 5 percent (%) to less than 1%.

After clearing the steeper gradients of the upstream forested area, the stream emerges into a small cleared area with a gravel stream bed. From this area until the confluence with Wambo Creek, Stony Creek flows across generally open pasture land with isolated stands of trees, and treelines generally following the banks of the stream channel. The stream bed consists mostly of sands and gravels.

In some locations, the stream has eroded an incised channel with vertical eroded banks that can be in the order of 1.5 m high. In these reaches across the grassy plains, the stream bed varies between fine silt/sand and coarser gravels. The stream gradient is generally quite flat. In some locations, bank stabilisation works have been undertaken to inhibit further bank erosion or scour as a result of previous subsidence. There are also reaches where the channel is fully grassed over and the banks are stabilised with vegetation.

The confluence of Stony Creek and Wambo Creek is surrounded by trees. The stream bed of Stony Creek approaching the confluence is dry and covered in tree deadfall.

2.4.4 Wambo Creek

Wambo Creek rises in the Wollemi Escarpment to the west and extends to the confluence with Wollombi Brook east of the Modification Area. The natural catchment upstream of the confluence with Stony Creek has a total area of some 43.2 km^2 which contains two distinct landforms: steep, heavily forested headwaters with elevations ranging up to 450 m AHD on the ridges down to approximately 110 m AHD from where the creek drains onto open country over a distance of approximately 7.5 km to Wollombi Brook across cleared grassy plains with scattered trees and vegetation.

Wambo Creek may be impacted by the Modification in the reach between the confluence with Stony Creek and the confluence with Wollombi Brook, a distance of approximately 1.8 km. The characterisation of Wambo Creek has focussed on the reach downstream of the confluence with Stony Creek.

Wambo Creek immediately downstream of the confluence with Stony Creek is a shallow channel, surrounded by trees. The stream gradient is relatively flat, with a sandy bottom covered by tree deadfall. Moving downstream from the confluence, the channel of Wambo Creek becomes deeper and more defined. There are a number of persistent pools in these reaches. Moving downstream from the sections surrounded by trees, the stream bed is generally sand or gravel and the channel is more incised and the banks are eroded.

In 2000, during the mining of Longwall 9 in the Homestead Mine under Wambo Creek (downstream from its confluence with Stony Creek), there was cracking of the bed rock and inflow of water to the mine workings occurred. Sections of the Wambo Creek where this cracking occurred have had the bed rock grouted to a depth of about 10 metres.

Wambo Creek crosses Wambo Road, and downstream from the crossing the channel becomes deeper, with banks over 2 m high. Just upstream of the confluence with Wollombi Brook there is a rock bar across the stream bed, with some quarried rock in the stream bank. This would appear to be the remains of a former weir structure. There is a permanent pool at the confluence with Wollombi Brook.

2.4.5 Unnamed Drainage Lines

There are three unnamed drainage lines in the southern part of the Modification Area that may be impacted by the Modification. These three drainage lines drain in a generally north-easterly direction into Wollombi Brook. For the purpose of this report, we have designated the streams as Unnamed Drainage Line 1, Unnamed Drainage Line 2, and Unnamed Drainage Line 3, with the numbering running from north to south (Figure 1.1).

Unnamed Drainage Line 1 (UW1) has a total length of approximately 1.8 km. There are a number of persistent pools along the stream, with a large persistent pool just downstream of the crossing of Wambo Road before the confluence with Wollombi Brook. This pool appears to have been augmented by excavation. The crossing of Wambo Road is through two concrete pipes.

Unnamed Drainage Line 2 (UW2) flows out of the forested ridge country in the Wollemi National Park. It begins at an elevation of around 320 m AHD, and flows in a well-defined gully down to an elevation around 100 m AHD where it flows across open grassy plains with no defined channel. It has a length of around 3.5 km to its confluence with Wollombi Brook.

Approximately 700 m upstream from UW2's confluence with Wollombi Brook there is a constructed contour bank across the valley. From this contour bank the stream flows in a constructed channel to a large persistent pool, just upstream of Wambo Road. Wambo Road effectively dams this pool, with the overflow through a concrete culvert and thence flowing in a poorly defined channel to Wollombi Brook.

Unnamed Drainage Line 3 (UW3) rises in the Wollemi National Park at an elevation of approximately 170 m AHD, with a total length of approximately 3 km. The channel is poorly defined over most of the length of the stream, until it reaches two small pools on either side of Wambo Road. A concrete culvert transfers the flow across Wambo Road.

2.5 Stream Order

The Strahler stream ordering system (based on defined watercourses on 1:25,000 topographic maps) is used as the basis in the NSW *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.

Stream order is not a relevant consideration for the North Wambo Creek Diversion as it is a constructed channel. Upstream of the diversion, and therefore upstream of the Modification Area, North Wambo Creek is a 4^{th} order stream. Below the diversion, North Wambo Creek remains a 4^{th} order stream.

Stony Creek is a 4^{th} order stream across the Modification Area, while Wambo Creek is a 5^{th} order stream across the Modification Area. UW1 and UW3 are 2^{nd} order streams, and UW2 is a 3^{rd} order stream.

2.6 Creek Flow in North Wambo, Stony, and Wambo Creeks

2.6.1 Flow Regime

Commencing in late 2008 WCPL has progressively installed nine continuous recording flow gauging stations along North Wambo Creek, Stony Creek and Wambo Creek as shown in **Figure 2.1** and described in Table 2.2. In addition, flow data has been sourced from two gauging stations on Wollombi Brook operated by the NSW Department of Primary Industries-Water (DPI-Water):

- Warkworth (210004); and.
- Bulga (210028).

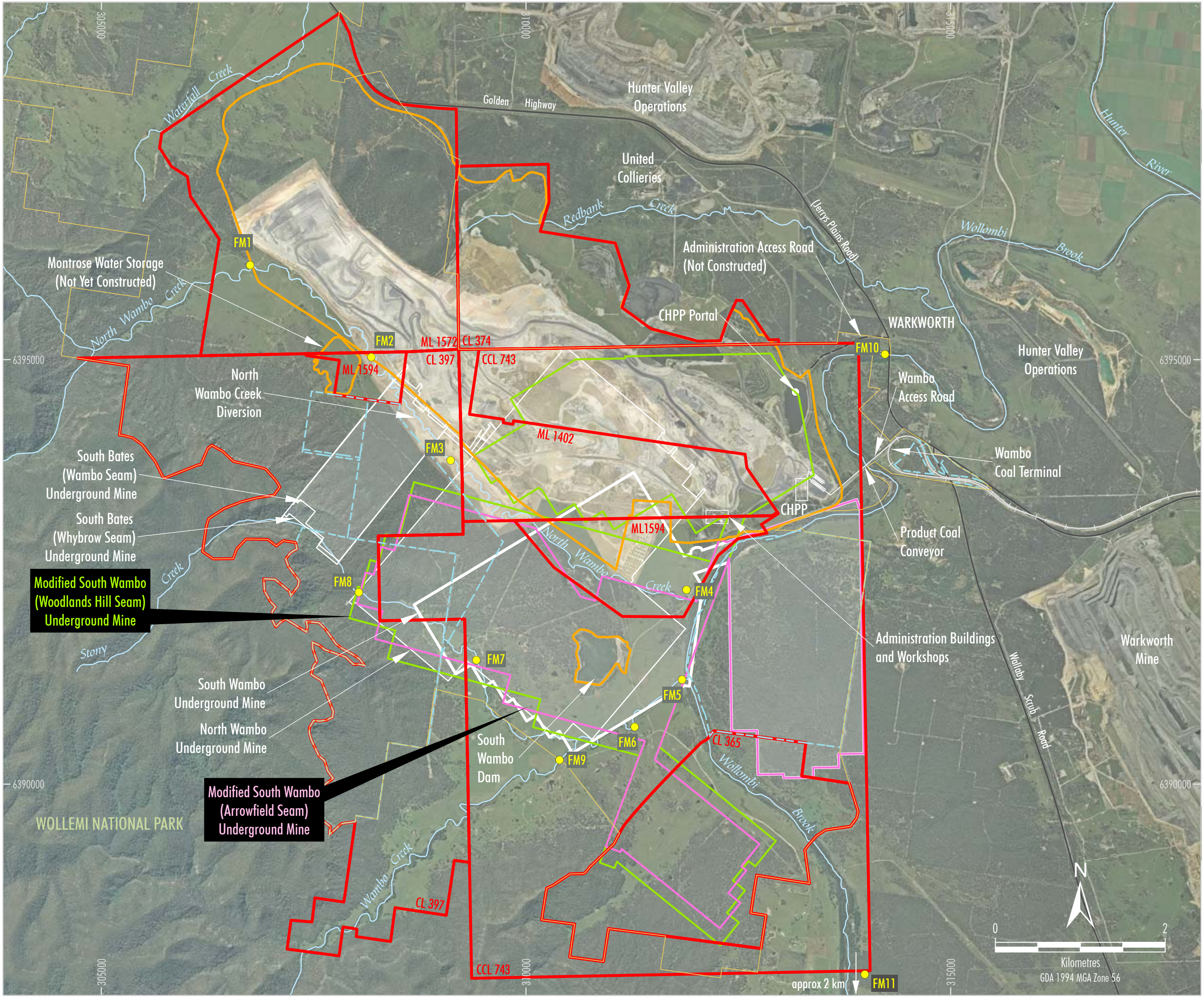
Table 2.2: WCPL Surface Water Flow Monitoring Locations

Creek	Purpose	Site Ref	Approximate Co-ordinates (MGA 94, zone 56)	
			Easting	Northing
North Wambo Creek	Upstream of diversion.	FM1	306752	6396115
	Midstream flow of Stage 2 Diversion	FM2	308181	6395028
	Midstream flow of Stage 3 Diversion	FM3	309114	6393813
	Near confluence with Wollombi Brook	FM4	311890	6392288
Wambo Creek	Upstream of Stony Creek confluence	FM9	308181	6395028
	Downstream of Stony Creek confluence	FM6	311281	6390674
	Near confluence with Wollombi Brook	FM5	311838	6391231
Stony Creek	Upstream	FM8	308033	6392258
	Downstream	FM7	309416	6391459

A summary of the available flow records is provided in Appendix B. These records show that the flow in all the creeks listed in Table 2.2 is highly ephemeral. The ephemeral nature of the flow, the relatively short duration of the records and some missing records due to equipment breakdown mean that the recorded flows do not provide an adequate basis for characterising the expected long term average flow regime in these creeks.

However, records are available from two regional gauging stations (Doyles Creek [210087] and Appletree Creek [201120]), which are operated by DPI-Water. These catchments, which are located west of the North Wambo Creek catchment, are similar in area and topography to North Wambo Creek and Wambo Creek and can be expected to exhibit similar hydrological behaviour.

Gilbert & Associates (2009) analysed the flow data from Doyles Creek and Appletree Creek to derive parameters for a daily water balance model (AWBM) that represents the relationship between rainfall and runoff for these particular catchments.



LEGEND
- Mining and Coal Lease Boundary
- WCPL Owned Land
- Existing/Approved Surface Development Area
- Approved Underground Development
- Modified South Wambo (Woodlands Hill Seam) Underground Mine
- Modified South Wambo (Arrowfield Seam) Underground Mine
- Remnant Woodland Enhancement Program (RWEP) Area
- Surface Water Flow Monitoring Site

Source: Department of Lands (July 2009); WCPL (2015); WCPL Orthophoto (Apr-Oct 2013)

Peabody ENERGY

W A M B O C O A L M I N E

Flow Monitoring Site Locations

Figure 2.1

WAM-09-15_SWUMM_EA_SW_203C

For the purpose of assessing the flow regime in the creeks of relevance in this report, an AWBM model was developed based on the parameters derived by Gilbert & Associates for the Doyles Creek and Appletree Creek AWBM models. Adjustments were made to the derived parameters to take account of the flow records in the North Wambo Creek. Inspection of the available records showed that the longest, most representative record was from Flow Monitoring Site 3 (near the centre of the Stage 3 diversion). That record shows (see Appendix B) that for the period February 2014 to January 2015, there were 31 days on which some flow was recorded. Using daily rainfall data from the Wambo meteorological station, model parameters were adjusted to give total runoff consistent with the volume of runoff based on data from Doyles Creek and Appletree Creek and for the timing of runoff to be consistent with the recorded flow frequency on the North Wambo Creek Diversion.

In order to assess the likely long term flow regime in the creeks, a composite 131 year rainfall record was compiled from long term local daily rainfall collected by BOM in the central Hunter Valley (Doyles Creek, Jerrys Plains, Singleton and Denman). The degree to which this composite long term record was representative of the rainfall conditions at Wambo was assessed by correlation of the available data from Wambo (1/7/2008 to 30/4/2015) with the corresponding data for the composite record. This analysis indicated the correlation coefficient (R^2) between the two records was 0.998, indicating the long term composite record provides a good representation of the rainfall at Wambo.

For the purposes of assessing the flow regime in those sections of the creeks that would be potentially impacted by the Modification, the AWBM model has been used to assess the flow at the locations potentially impacted by the Modification, as listed in Table 2.

Table 2.3: Locations Adopted for Creek Flow Assessment

Creek	Location	Catchment Area (km²)
North Wambo Creek	Downstream of the North Wambo Creek Diversion	34.2
	Upstream of Wollombi Brook	40.1
Wambo Creek	Downstream of Stony Creek confluence	52.9
	Upstream of Wollombi Brook (including Stony Creek)	55.1
Stony Creek	Upstream of Modification Area	8.7
	Downstream of Modification Area	10.1

Figure 2.2, **Figure 2.3** and **Figure 2.4** are flow duration graphs based on the rainfall:runoff modelling described above for North Wambo Creek, Wambo Creek and Stony Creek at the locations listed in Table 2..

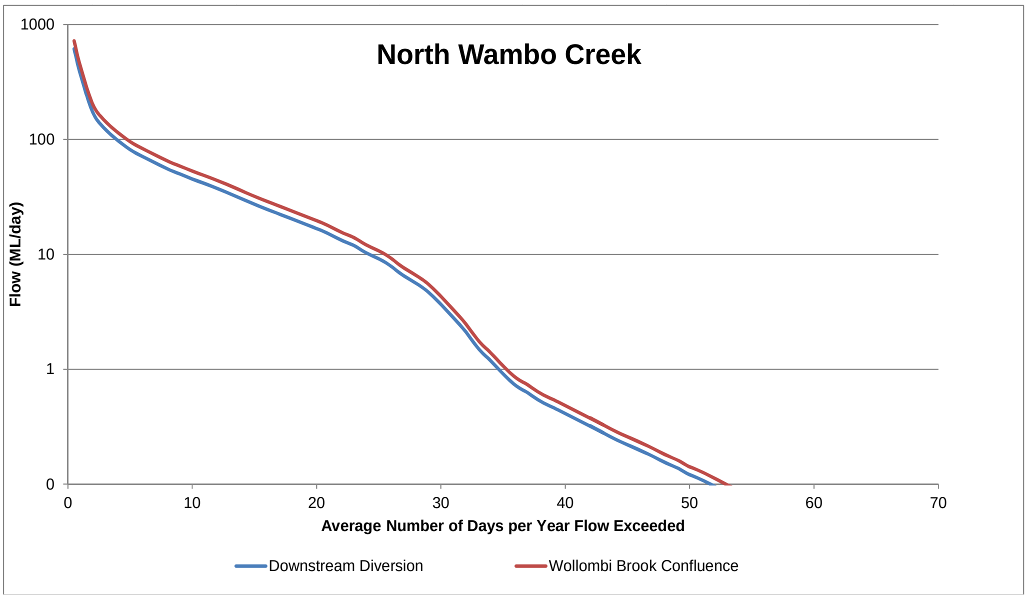


Figure 2.2: Flow Duration Graph for North Wambo Creek

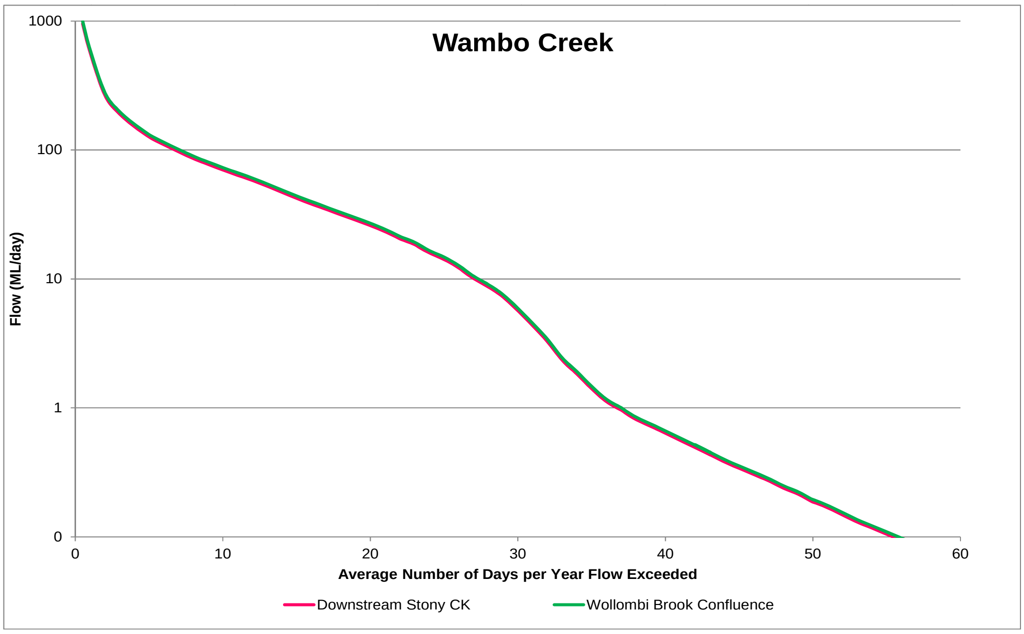


Figure 2.3: Flow Duration Graph for Wambo Creek

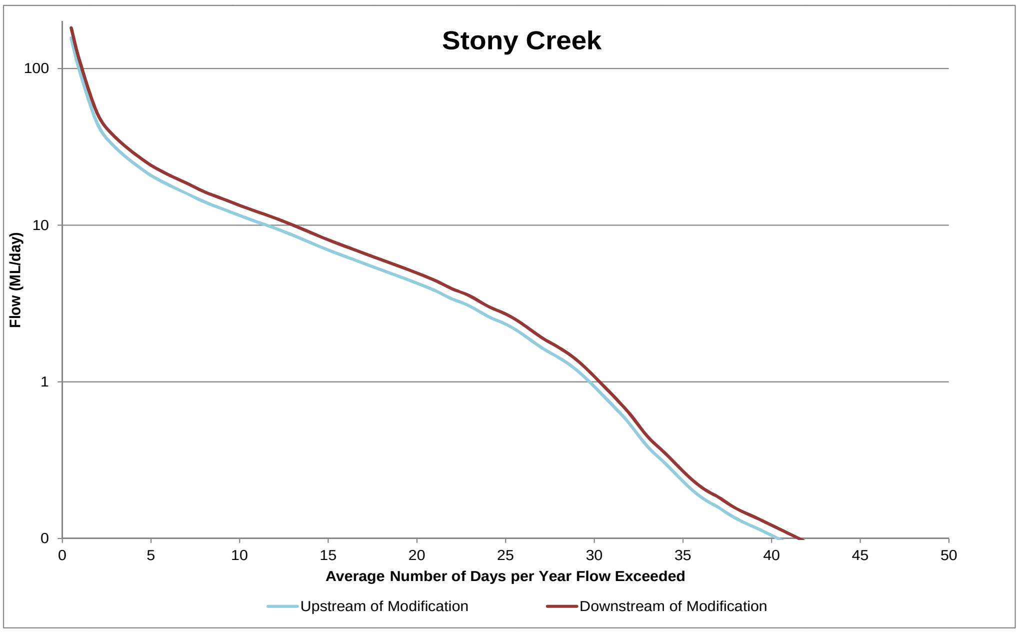


Figure 2.4: Flow Duration Graph for Stony Creek

Figure 2.2, **Figure 2.3** and **Figure 2.4** show that some flow into the creeks can be expected on approximately 40 to 55 days per year on average. However, on many days, the flow would be so small as to not be noticeable and would occur as seepage through the sands and gravels in the creek bed. Flow in excess of 1 megalitre per day (ML/day) (average of 0.01 cubic metres per second [m^3/s]) can be expected on only 34 days per year in North Wambo Creek, 37 days per year in Wambo Creek and approximately 30 days per year in Stony Creek. The modelling also indicates that in 10^{th} percentile dry years, flow greater than 1 ML/day in North Wambo Creek are likely on approximately 23 days per year while in 90^{th} percentile wet years this flow would occur on approximately 46 days per year. This data confirms the ephemeral nature of the flow in the North Wambo Creek, Wambo Creek and Stony Creek.

2.6.2 Peak Discharges

To estimate peak discharges in North Wambo Creek for average exceedance probabilities (AEPs) of 50%, 5% and 1%, Gilbert & Associates (2009) used a runoff routing model (RORB) which was calibrated to recorded floods on Doyles Creek. Subsequent analysis by WRM Water & Environment Pty Ltd (WRM) (WRM, 2016) (see Section 2.8) was undertaken for purposes of assessment of the contribution of local catchment flow on flooding in Wollombi Brook. The WRM analysis used a different flood estimation model (XP-RAFTS) based primarily on catchment characteristics such as area and slope. The WRM analysis only provided estimates of the 1% AEP flows which were larger than the estimates provided by Gilbert & Associates (2009).

Because the analysis undertaken by Gilbert & Associates (2009) estimated flows for a range of more frequent floods that are of relevance to management of the potential impacts of subsidence, estimated flows for Wambo Creek and Stony Creek have been derived using Gilbert & Associates' data. Flow estimates have been derived for different locations of interest by scaling the flows for North Wambo Creek using the general relationship for peak flows set out in *Hydrological Recipes* (Grayson et. al, 1996) ($Q \sim A^{0.63}$). Peak flows for 20%, 10% and 2% AEP events have been estimated by interpolation. **Table 2.4** summarises the flow estimates at relevant locations in the area that would be potentially affected by the Modification.

Table 2.4: Catchment Areas and Estimated Peak Flood Discharges (m^3/s)

Creek	Location	Area (km^2)	Average Recurrence Interval (years)					
			2	5	10	20	50	100
North Wambo Creek	Downstream of diversion	34.2	45	53	62	73	92	109
	Upstream of Wollombi Brook	40.1	49	58	68	80	101	120
Wambo Creek	Downstream of Stony Creek	52.9	59	69	81	95	120	142
	Upstream of Wollombi Brook (including Stony Creek)	55.1	60	71	83	98	124	146
Stony Creek	Upstream of Modification	8.7	19	22	26	31	39	46
	Downstream of Modification	10.1	21	24	29	34	42	50

2.7 Flow in Wollombi Brook

Gauging stations are maintained by DPI-Water on Wollombi Brook at Bulga (GS 210028) and Warkworth (GS 210004). The Bulga station (listed as FM 11 on **Figure 2.1**) is upstream of the Modification Area and the Warkworth Station (listed as FM 10 on **Figure 2.1**) downstream of the Modification Area.

The data record for the Bulga station extends back to July 1949, while the data record for the Warkworth station extends back to February 1908. The common period of valid data is from 19 January 1951 to 26 April 2015, with 33% of data missing within this period.

The catchment area of Wollombi Brook at Bulga is 1,672 km^2. The catchment area of Wollombi Brook at Warkworth is 1,848 km^2 (DPI-Water, 2015).

Figure 2.5 shows the flow duration curves for Wollombi Brook at the DPI-Water gauging stations at Warkworth and Bulga, which have been derived from flow recorded between 1908 and 2016. It is apparent that the distribution of flows in Wollombi Brook upstream and downstream of Wambo has generally been similar but with an increased frequency of low flows at the downstream station (WCPL, 2015a).

The mean annual flow in Wollombi Brook at Bulga is 120,474 megalitres (ML), whilst at Warkworth the mean annual flow is 139,213 ML (DPI-Water, 2015).

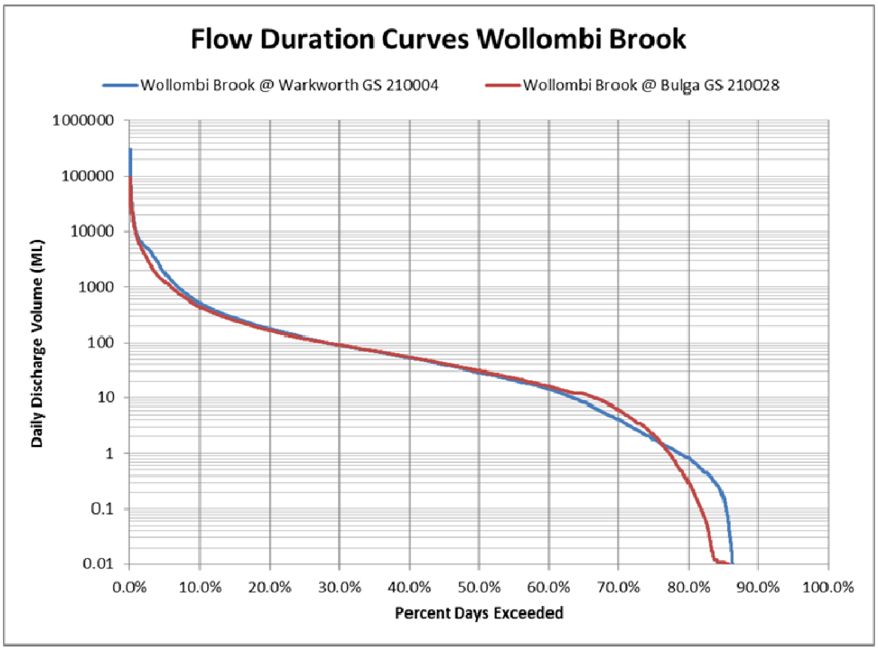


Figure 2.5: Flow Duration Curves for Wollombi Brook Upstream and Downstream of Wambo

2.8 Flooding

Wambo is located in part on the flood plain of Wollombi Brook, and would be affected by both flooding in Wollombi Brook and by flooding in the local tributary creeks (Gilbert & Associates, 2003). The former NSW Government Department of Sustainable Natural Resources (DSNR) has used flood level information from the 1949 flood to assess flood prone areas on the Wollombi Brook floodplain. Flood level information has been collated by the DSNR, based on survey information provided by local landholders.

The 1949 flood is the largest flood recorded in Wollombi Brook and is believed by the DSNR to have been potentially rarer than a 1 in 100-year ARI event. The DSNR have used flood levels from this event as the best available guide to possible flood levels that can be reached during extreme flooding in Wollombi Brook. Flooding in Wollombi Brook, in the vicinity of the Modification Area, is likely to be limited to backwater flooding in North Wambo and Wambo Creeks (Gilbert & Associates, 2003).

There is no Floodplain Management Plan applicable to Wollombi Brook adjacent to Wambo.

WRM (2016) prepared a flood study for the Modification which focussed on the flood regime in Wollombi Brook and the backwater flooding effects on the section of North Wambo Creek downstream of the diversion. As noted in Section 2.6, WRM used the XP-RAFTS, runoff-routing software, to estimate 1% AEP flood design discharges for North Wambo and Wambo Creeks. For Wollombi Brook and the Hunter River flood frequency analysis was used to estimate flood design discharges. WRM has then utilised these design discharges as inputs to the TUFLOW hydrodynamic model to estimate design flood levels in the vicinity of Wambo. As noted by WRM, due to the significant difference in the sizes and response times of the different catchments, it is unlikely that a flood event of the same magnitude will occur simultaneously in the local creeks, Wollombi Brook and the Hunter River. Accordingly, the WRM analysis examined combinations of different frequency floods for local creeks (North Wambo Creek and Wambo Creek) and Wollombi Brook.

The WRM modelling of the extent of potential flooding in the vicinity of Wambo is consistent with the observations of Gilbert & Associates (2009), which is that flooding in the vicinity of the Modification Area is likely to be limited to backwater flooding in North Wambo and Wambo Creeks.

2.9 Water Sharing Plans & Water Users

Wambo (including the Modification Area) is included in the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009* (the Plan). The Plan includes the Hunter unregulated rivers and creeks, the highly connected alluvial groundwater (which are above the tidal limit), and the tidal pool areas (which were not previously covered by the NSW *Water Act 1912*), but excludes Wybong Creek (as a water sharing plan already exists for the Wybong Creek). In total, there are 39 water sources covered by the plan and nine of these are further sub-divided into management zones.

The Modification Area lies within the Lower Wollombi Brook water source which is part of the Hunter Extraction Management Unit under the Plan. The DPI-Water provides details of this Water Sharing Plan on its website[1] . A "Report Card" for the Lower Wollombi Brook water source is also available at the DPI-Water website[2]. The Report Card (dated August 2009) provides details of surface water users within the Lower Wollombi Brook water source. The total surface water entitlement is 6,663 million litres per year (ML/year) (of which 88% is used for irrigation purposes and 10% is used for industrial purposes), with 110 surface water licences, and a Peak Daily Demand of 64.7 ML/day.

A search of the DPI-Water website conducted in January 2016 identified all Water Access Licences (WALs) associated with the Lower Wollombi Brook water source (and any associated Work Approvals). This search also identified the properties (Lot/DP) associated with each of the Work Approvals/WALs. From this data, the WALs that provide access to surface water in the vicinity of Wambo have been plotted in **Figure 2.6**.

There are six WALs associated with surface water extraction that could potentially be impacted by the Modification (along Wollombi Brook downstream of the Modification). These licences are detailed in **Table 2.5**.

Table 2.5: Potentially Affected Surface WALs in the Vicinity of Wambo

WAL	Water Source	Category	Status	Tenure Type	Share Component (ML)
18437*	Lower Wollombi Brook	Unregulated River	Current	Continuing	350
18483	Lower Wollombi Brook	Unregulated River	Current	Continuing	32
18546	Lower Wollombi Brook	Unregulated River	Current	Continuing	12
18549	Lower Wollombi Brook	Unregulated River	Current	Continuing	100
18558	Lower Wollombi Brook	Unregulated River	Current	Continuing	50
18560	Lower Wollombi Brook	Unregulated River	Current	Continuing	56

* WCPL held Water Access Licence.

[1] http://www.water.nsw.gov.au/water-management/water-sharing/plans-commenced/water-source/hunter-unregulated-and-alluvial

[2] http://www.water.nsw.gov.au/__data/assets/pdf_file/0011/548633/wsp_hunter_report_card_wollombi_brook.pdf

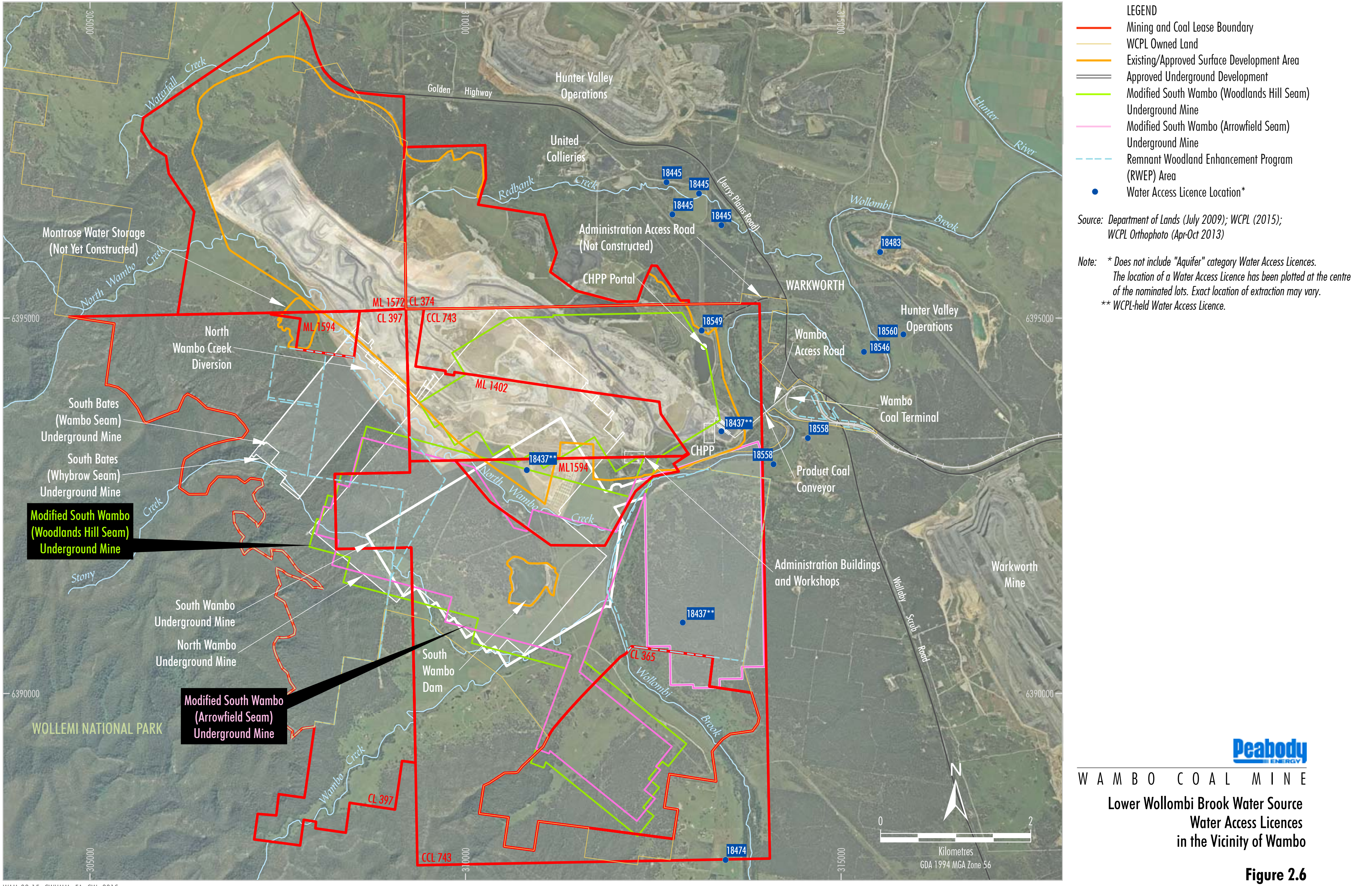


Figure 2.6

WAM-09-15_SWUMM_EA_SW_201C

2.10 Surface Water Quality

A summary of surface water quality monitoring results for the period July 2003 to May 2015 is presented in Table 2.6. The locations of these monitoring sites are depicted in **Figure 2.7**.

The available data indicates that the surface water quality of **Wollombi Brook** near Wambo can be characterised as being:

- Near neutral to slightly alkaline (median pH range from 7.6 to 7.7);
- Having moderate salinity (median electrical conductivity [EC] values ranging from 639 to 952 microSiemens per centimeter [µS/cm]); and
- Having generally low TSS concentrations (median concentrations of 6 to 11 milligrams per litre (mg/L)).

The surface water quality data available for **North Wambo Creek** indicate that:

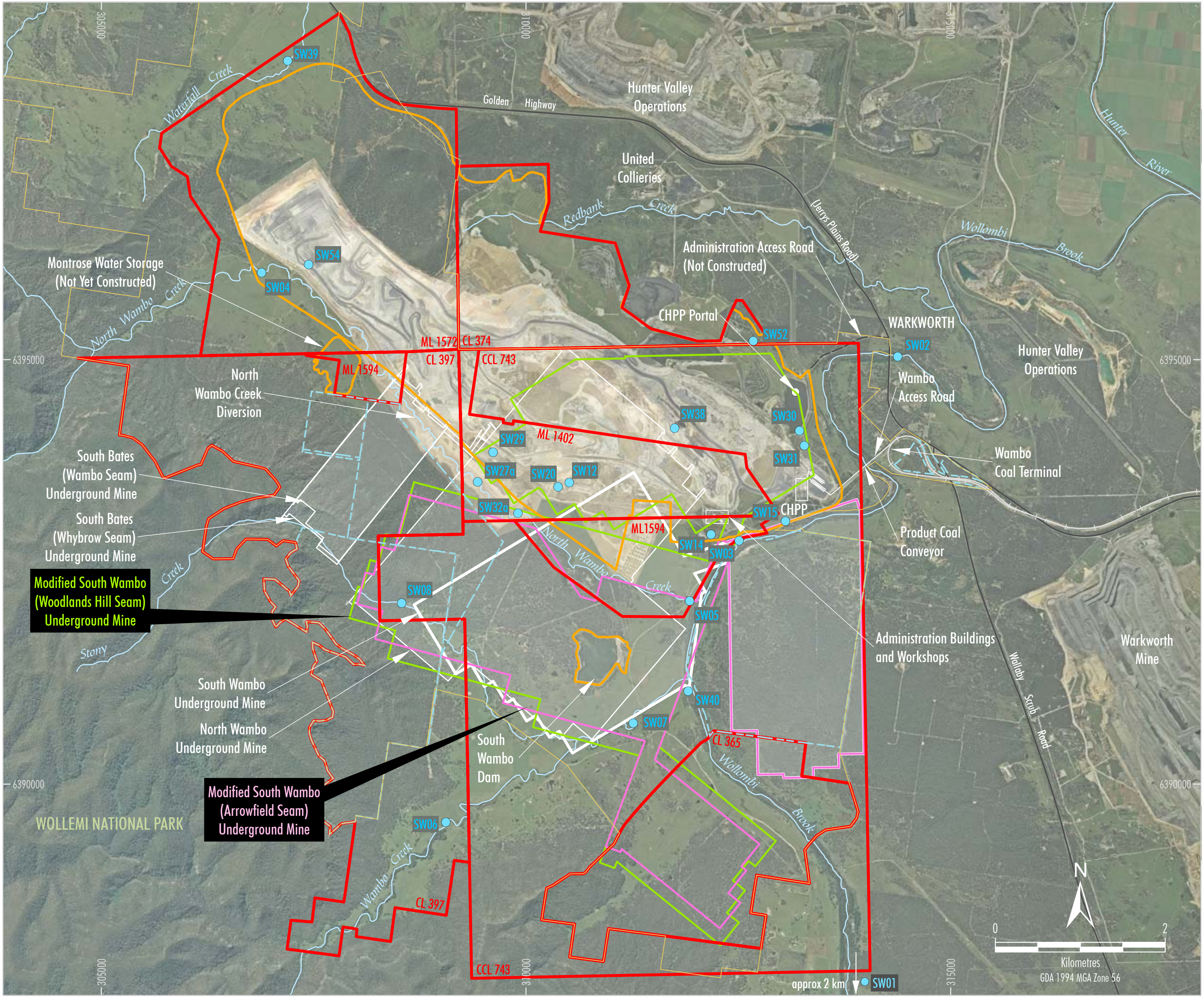
- pH levels have been typically slightly alkaline (median values between 7.61 and 8.10);
- Salinity has been variable, with increasing salinity downstream (median EC values of 315 µS/cm at the upstream site SW04 and 1,980 µS/cm at the downstream site SW05); and
- TSS concentrations are variable ranging from low (median concentration of 14.5 mg/L at the upstream site SW04) to high (median concentration 164 mg/L at SW27a in the mid reaches of North Wambo Creek). Recorded concentrations have been highly variable, ranging from a minimum of 1 mg/L at SW27a, SW32a and SW05, to a maximum of 5,440 mg/L at SW27a.

The surface water quality data available for **Stony Creek** indicate that:

- pH levels have been near neutral (median value of 7.25);
- Salinity has been moderate (median EC value of 332 µS/cm); and
- TSS concentrations have been low (median concentration of 2.5 mg/L).

The surface water quality data available for **Wambo Creek** indicate that:

- pH levels have been neutral to slightly alkaline (median values between 7.4 and 7.6);
- Salinity has been moderate (median EC value of 506 µS/cm at the upstream site SW06 and 614 µS/cm at the downstream site SW07); and
- TSS concentrations have been generally low (median concentrations of 5 mg/L at both SW06 and SW07), with some higher concentrations recorded (maximum concentrations of 286 mg/L at SW06 and 331 mg/L at SW07).



LEGEND

- Mining and Coal Lease Boundary
- WCPL Owned Land
- Existing/Approved Surface Development Area
- Approved Underground Development
- Modified South Wambo (Woodlands Hill Seam) Underground Mine
- Modified South Wambo (Arrowfield Seam) Underground Mine
- Remnant Woodland Enhancement Program (RWEP) Area
- Surface Water Quality Monitoring Site

Source: Department of Lands (July 2009); WCPL (2015); WCPL Orthophoto (Apr-Oct 2013)

0 — 2 Kilometres
GDA 1994 MGA Zone 56

Peabody ENERGY

W A M B O C O A L M I N E

Surface Water Quality Monitoring Locations

Figure 2.7

WAM-09-15_SWUMM_EA_SW_202C

Advisian

WorleyParsons Group

Table 2.6: Wambo Surface Water Quality Summary for Local Watercourses (WCPL, 2015a)

Site	Count	Sampling Period	pH				EC (uS/cm)				TDS (mg/L)				TSS (mg/L)			
			Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median
(SW01) - Wollombi Brook Upstream	135	Jul 03 - May 15	6.45	8.80	7.62	7.60	160	1,969	736	749	60	1,157	405	401	1	128	11	6
(SW40) - Wollombi Brook Upstream of Wambo Creek	100	Nov 05 - Dec 09	6.40	8.80	7.64	7.60	66	1,147	617	639	18	1,090	348	341	1	179	17	7
(SW03) - Wollombi Brook Pump Out	142	Jul 03 - May 15	6.64	9.10	7.64	7.60	106	5,240	1,420	874	3	2,924	717	413	1	1,630	76	11
(SW02) - Wollombi Brook Downstream	137	Jul 03 - May 15	6.77	9.00	7.75	7.70	152	5,290	1,307	952	25	3,238	720	485	1	308	15	6
(SW04) - North Wambo Creek Upstream	4	Jul 03 - May 15	7.30	8.71	8.03	8.05	256	563	362	315	157	2,712	855	275	5	154	47	14.5
(SW27a) - North Wambo Creek Middle Lower	46	Jul 03 - May 15	7.00	9.00	7.95	7.96	52	3,360	973	472	262	4,900	977	804	1	5,440	524	164
(SW32a) - North Wambo Creek Pump	39	Jul 03 - May 15	7.40	9.20	8.12	8.10	220	6,970	936	832	378	4,400	792	580	1	4,190	479	30
(SW05) - North Wambo Creek Downstream	137	Jul 03 - May 15	6.94	8.96	7.67	7.61	111	3,200	1,729	1,980	135	2,162	1,008	1,100	1	1,110	50	19
(SW06) - Wambo Creek Upstream	78	Jul 03 - May 15	6.30	9.10	7.40	7.40	156	970	506	506	28	440	265	261	1	286	18	5
(SW08) - Stony Creek Upstream	26	Jul 03 - May 15	6.20	8.44	7.19	7.25	186	479	342	332	58	276	186	180	1	15	4	2.5
(SW07) - Wambo/Stony Creeks Downstream of confluence	41	Jul 03 - May 15	6.60	9.10	7.61	7.60	159	971	565	614	145	520	312	309	1	331	26	5

EC = electrical conductivity

uS/cm = microSiemens per centimetre

TDS = total dissolved solids

mg/L = milligrams per litre

TSS = total suspended solids

3 Potential Impacts

The potential impacts of the Modified South Wambo Underground Mine on surface water resources are as follows:

- Potential impacts on channel stability as a result of predicted changes in grade due to subsidence;
- Potential impacts on existing pools or the creation of new pools as a result of predicted changes in grade due to subsidence;
- Alteration to flow in the watercourses caused by changes to the predicted:
  - groundwater depressurisation,
  - subsidence induced ponding,
  - creek bed cracking,
  - surface water ponding in areas other than the watercourses leading to reduced contributing catchment area;
- Potential impacts associated with the minor extension of the approved surface development area;
- Potential changes in flood behaviour in the vicinity of the Modification;
- Potential changes in water quality arising as a result of the development; and
- Potential changes to impacts on licensed water users.

These impacts to surface water resources would be caused by the subsidence effects which result from the underground mining in the Woodlands Hill and Arrowfield Seams as proposed in the Modification.

The impacts are assessed as the changes in impact relative to the impacts predicted for the Approved Layout.

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);
- *Wambo Development Project Surface Water Assessment* (Gilbert & Associates, 2003);
- *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);
- *North Wambo Underground Mine Modification Subsidence Assessment* (MSEC, 2013);
- *North Wambo Underground Longwall 10A Modification Subsidence Assessment* (MSEC, 2014a); and
- *Assessment of Potential Environmental Consequences for Surface Water Resources Resulting from Extraction of North Wambo Underground Mine Longwalls 9 and 10* (Gilbert & Associates, 2014).

3.1 Subsidence Effects

MSEC was commissioned by WCPL to prepare a Subsidence Assessment for the Modification. This has been documented in MSEC Report Number MSEC799 (MSEC, 2016). This section describes the predicted subsidence effects on relevant watercourses in the Modification Area and compares the predictions for the Modified Layout with those for the Approved Layout. Subsequent sections provide an assessment of the impacts of the subsidence effects on ponding, channel stability and bed cracking.

The comparison between the maximum predicted total conventional subsidence parameters for the Modification to the west of Wollombi Brook based on the Approved Layout and Modified Layout is provided in Table 3.1.

Table 3.1: Comparison of Maximum Predicted Subsidence Parameters for the Approved Layout and Modified Layout West of Wollombi Brook (MSEC, 2016)

Layout	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Approved Layout	9,000	90	> 3.0	> 3.0
Modified Layout	6,250	75	> 3.0	> 3.0

mm = millimetres
mm/m = millimetres per metre

Table 3.1 shows that the Modified Layout would have maximum subsidence effects that are less than or the same as the Approved Layout. In particular, the Modified Layout would lead to a substantially lower maximum total conventional subsidence.

As described in Section 1.2, subsidence effects resulting from longwall mining the Arrowfield and Bowfield Seams in Area 4 were approved as part of the Wambo Development Project Environmental Impact Statement (WCPL, 2003). The modified subsidence impacts in Area 4 are predicted to reduce as only the Arrowfield Seam is proposed to be mined as part of the Modification (MSEC, 2016). The potential impacts on surface water resources in Area 4 are therefore also expected to reduce as a result of the Modification and therefore this assessment has not considered Area 4 any further.

MSEC has also detailed subsidence predictions for the relevant watercourses in the Modification Area. Comparison of the maximum predicted subsidence parameters for these watercourses due to mining in the Approved Layout and the Modified Layout is provided in Table 3.2.

Table 3.2: Comparison of the Maximum Predicted Subsidence Parameters for the Watercourses due to the Approved Layout and the Modified Layout (after MSEC, 2016)

Watercourse	Layout	Maximum Predicted Subsidence (mm)	Maximum Predicted Total Gradient (%)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Wollombi Brook	Approved Layout	< 20	< 0.05	<0.01	< 0.01
	Modified Layout	< 20	< 0.05	< 0.01	< 0.01
North Wambo Creek Diversion	Approved Layout	20	< 0.05	< 0.01	< 0.01
	Modified Layout	2,400	2.5	0.35	0.30
North Wambo Creek	Approved Layout	8,150	10.0	> 3.0	> 3.0
	Modified Layout	4,050	6.5	> 3.0	2.4
Wambo Creek	Approved Layout	1,650	1.6	0.20	0.15
	Modified Layout	3,100	2.0	0.50	0.40
Stony Creek	Approved Layout	4,900	3.0	0.55	0.75
	Modified Layout	5,600	3.0	0.65	0.70
Unnamed Drainage Line 3 (UW3)	Approved Layout	< 20	5.5	<0.01	<0.01
	Modified Layout	3,500	5.5		

3.1.1 Subsidence Effects on Wollombi Brook

MSEC (2016) has provided the following discussion regarding the effects of subsidence from the Modification on Wollombi Brook:

The banks of Wollombi Brook are located at a distance of 180 metres east of WHLW9, at its closest point to the proposed longwalls. At this distance, Wollombi Brook is predicted to experience less than 20 mm of vertical subsidence. While it is possible that Wollombi Brook could experience very low levels of vertical subsidence, it would not be expected to experience any measurable tilts, curvatures or ground strains.

The alluvium associated with Wollombi Brook is located immediately adjacent to the proposed WHLW6 to WHLW12 and AFLW1 to AFLW6. In this location, the alluvium is predicted to experience up to around 100 mm vertical subsidence. Whilst the alluvium would experience low levels of vertical subsidence, it is not predicted to experience any significant tilts, curvatures of strains. The alluvium is partially located above the proposed WHLW19 and AFLW17. In this location, the alluvium is predicted to experience vertical subsidence up to around 2.2 metres.

The potential impacts of the proposed longwalls on the alluvium associated with Wollombi Brook is discussed by the specialist groundwater consultant in the report by HydroSimulations (2016).

> *It was stated, in the 2003 EIS, that the "Mining of the longwall panels would be constrained by the subsidence exclusion zone limited to an angle of 26.5 degrees from the vertical to "Protected Land" (i.e. within 40 m of Wollombi Brook in accordance with the Rivers and Foreshore Improvement Act, 1948)". The proposed longwalls are located outside this subsidence exclusion zone (i.e. the 40 metre buffer), as illustrated in Fig. 5.1. This cross-section taken where Wollombi Brook is located closest to the proposed longwalls.*
>
> *It is unlikely, therefore, that Wollombi Brook would be adversely impacted as a result of the extraction of the proposed longwalls. Further discussions on the potential impacts on the alluvial aquifer associated with Wollombi Brook are provided in the report by HydroSimulations (2016).*

MSEC has also noted that *"the section of Wollombi Brook in the vicinity of the proposed longwalls has a shallow incision into the alluvium. It is unlikely, therefore, that Wollombi Brook would experience any significant valley related movements resulting from the extraction of the proposed longwalls."* Given the above, potential direct subsidence impacts on Wollombi Brook are not considered any further in this report.

3.1.2 Subsidence Effects on North Wambo Creek and the North Wambo Creek Diversion

Table 3.2 details the predicted maximum subsidence impacts along the North Wambo Creek Diversion and North Wambo Creek. The natural and predicted post-mining surface levels and grades for the Modified Layout are illustrated in **Figure 3.1**. For comparison, the natural and predicted post-mining surface levels for the Approved Layout are illustrated in **Figure 3.2**.

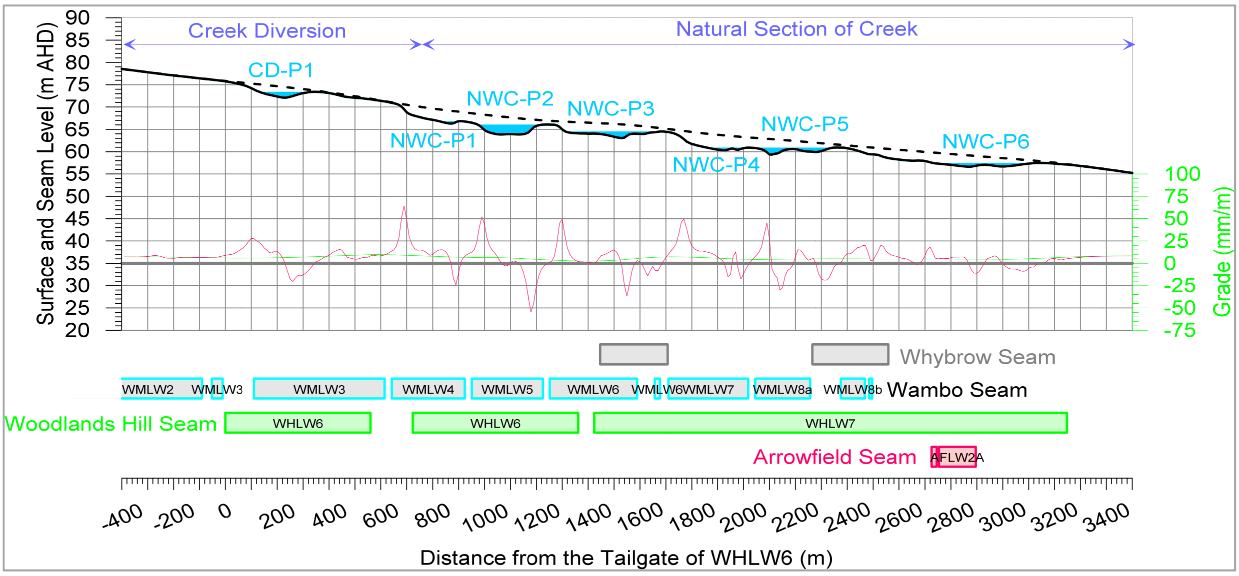


Figure 3.1: Natural and Predicted Subsided Surface Levels and Grades along North Wambo Creek and North Wambo Creek Diversion for the Modified Layout (MSEC, 2016)

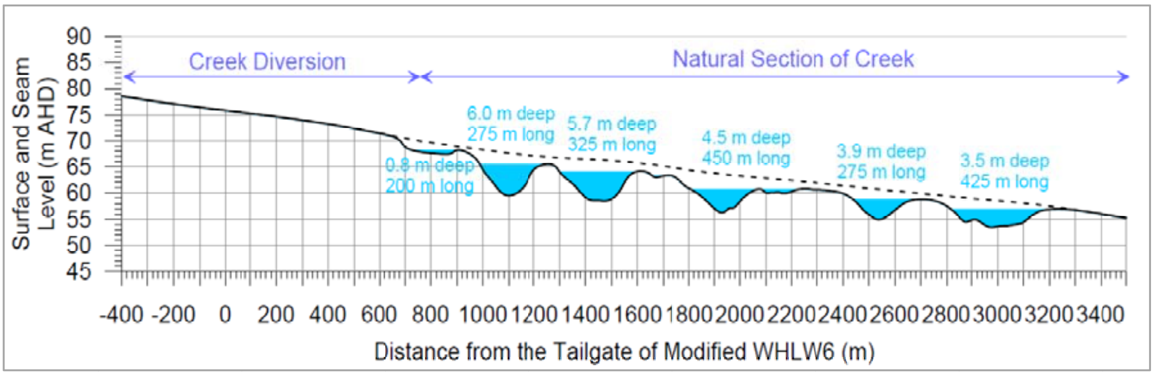


Figure 3.2: Natural and Predicted Subsided Surface Levels along North Wambo Creek and North Wambo Creek Diversion for the Approved Layout (MSEC, 2016)

Table 3.2 shows that the maximum predicted total subsidence and predicted total gradient for the North Wambo Creek Diversion, based on the Modified Layout, are greater than those predicted for the Approved Layout. The North Wambo Creek Diversion was only expected to experience low levels of vertical subsidence based on the Approved Layout, because the approved longwalls were located at a minimum distance of 200 m from the North Wambo Creek Diversion. With the Modified Layout, however, the North Wambo Creek Diversion is located directly above the proposed WHLW6 (MSEC, 2016).

As shown in Table 3.2, the maximum predicted total subsidence and predicted total gradient for North Wambo Creek, based on the Modified Layout, are less than those predicted for the Approved Layout. The reduction in these parameters occurs because the Modification proposes that the longwalls in the Modified Layout would be staggered, compared with the stacked arrangement in the Approved Layout (MSEC, 2016).

3.1.3 Subsidence Effects on Wambo Creek

Table 3.2 details the predicted maximum subsidence impacts along Wambo Creek. The natural and predicted post-mining surface levels and grades for the Modified Layout are illustrated in **Figure 3.3**. For comparison, the natural and predicted post-mining surface levels for the Approved Layout are illustrated in **Figure 3.4.**

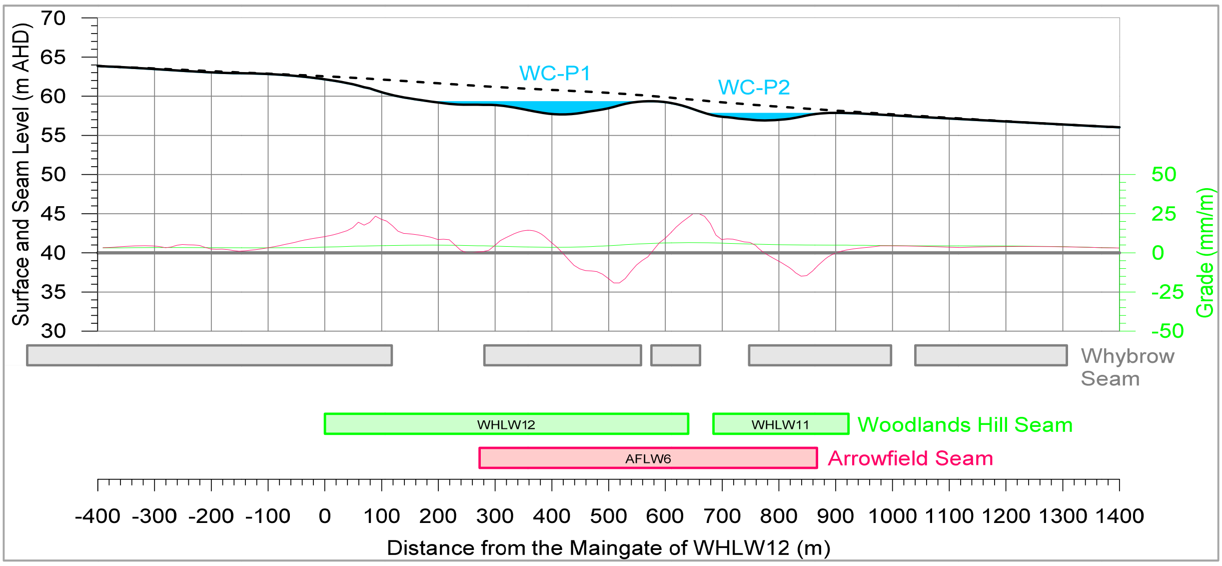


Figure 3.3: Natural and Predicted Subsided Surface Levels and Grades along Wambo Creek for the Modified Layout (MSEC, 2016)

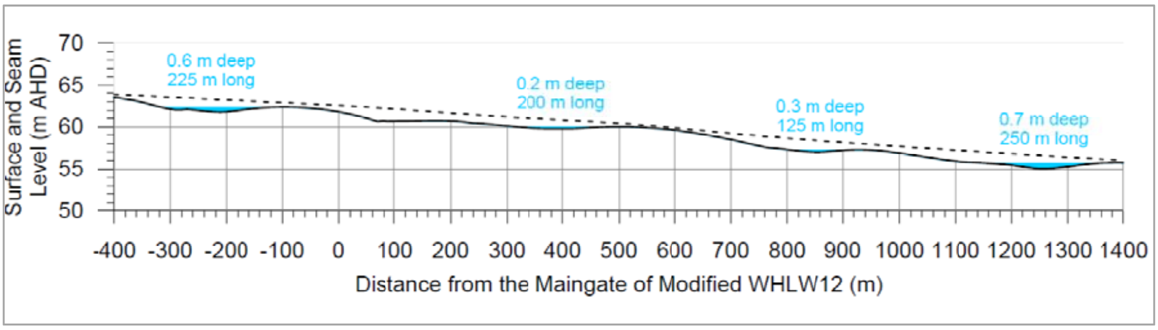


Figure 3.4: Natural and Predicted Subsided Surface Levels along Wambo Creek for the Approved Layout (MSEC, 2016)

Table 3.2 shows that the maximum predicted total subsidence and predicted total gradient for Wambo Creek, based on the Modified Layout, are greater than those predicted for the Approved Layout. The predicted parameters increase because Stony Creek was only partially located above the longwalls in the Approved Layout (MSEC, 2016).

3.1.4 Subsidence Effects on Stony Creek

Table 3.2 details the predicted maximum subsidence impacts along Stony Creek. The natural and predicted post-mining surface levels and grades for the Modified Layout are illustrated in **Figure 3.5**. For comparison, the natural and predicted post-mining surface levels for the Approved Layout are illustrated in **Figure 3.6**.

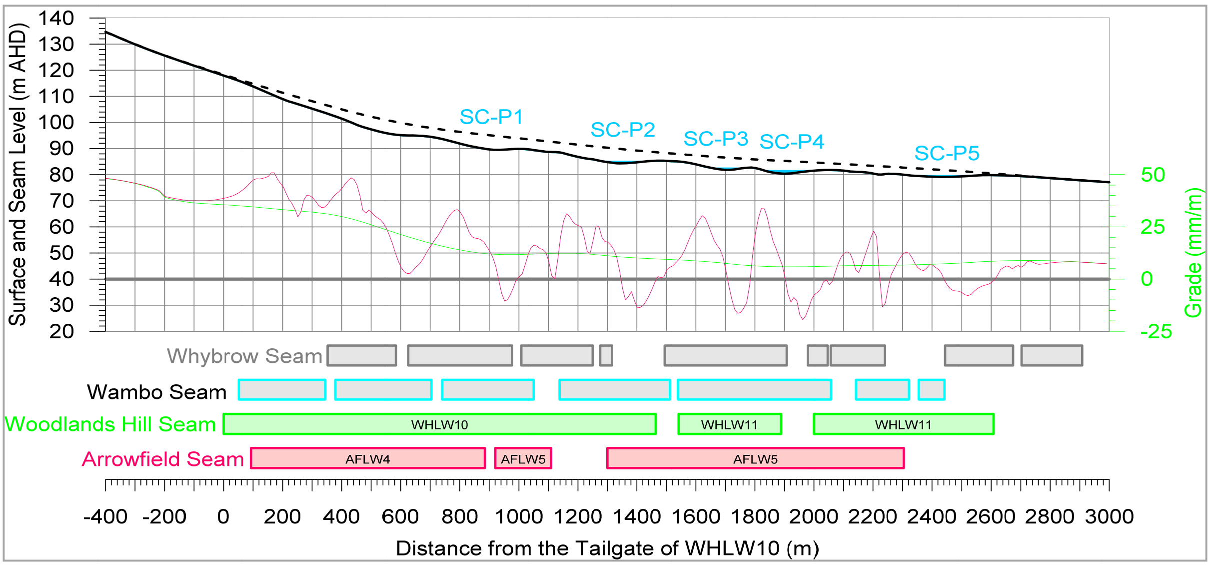


Figure 3.5: Natural and Predicted Subsided Surface Levels and Grades along Stony Creek for the Modified Layout (MSEC, 2016)

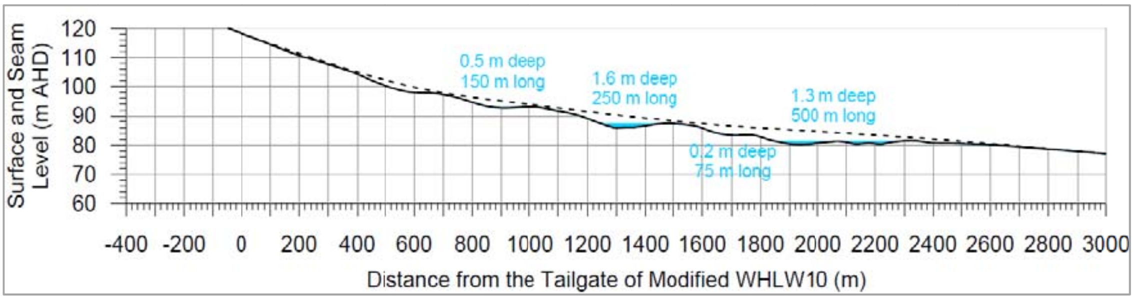


Figure 3.6: Natural and Predicted Subsided Surface Levels along Stony Creek for the Approved Layout (MSEC, 2016)

The maximum predicted total subsidence for Stony Creek, based on the Modified Layout, is greater than that predicted for the Approved Layout, whilst the predicted maximum total gradient is the same. The predicted subsidence increases because Stony Creek was only partially located above the longwalls in the Approved Layout (MSEC, 2016).

3.1.5 Subsidence Effects on the Unnamed Drainage Lines (UW1, UW2, UW3)

The Approved Layout would not cause any direct subsidence impacts on the Unnamed Drainage Lines, as the drainage lines are all located outside of the area of impact of the Approved Layout.

MSEC (2016) has predicted the subsidence impacts along Unnamed Drainage Line 3 (UW3, referred to by MSEC as 'Unnamed Creek'). Table 3.2 details the predicted maximum subsidence impacts along UW3. The natural and predicted post-mining surface levels and grades for the Modified Layout along UW3 are illustrated in **Figure 3.7.**

Whilst the Modification would result in subsidence of UW3, the predicted maximum total gradient is the same.

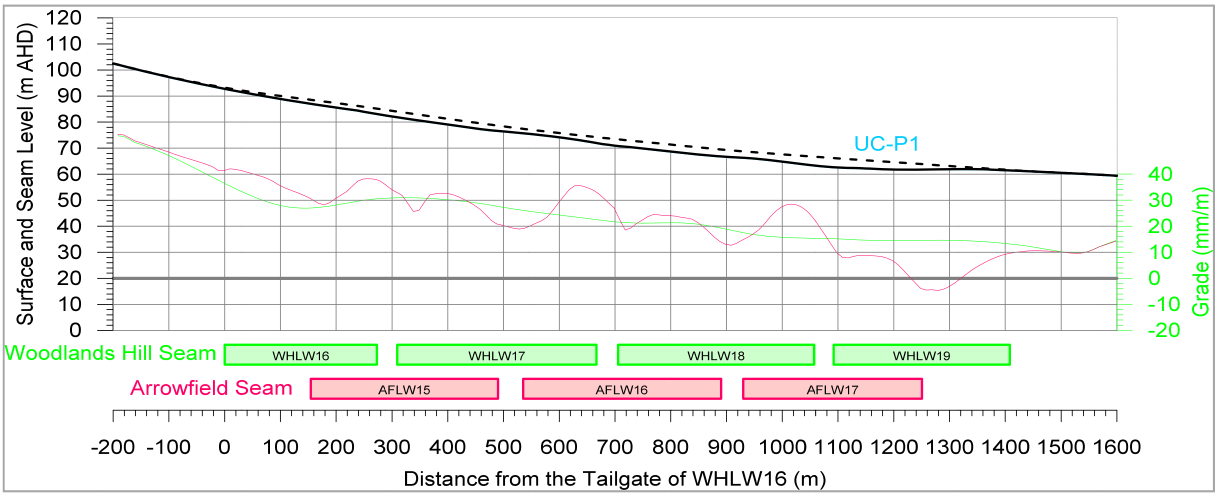


Figure 3.7: Natural and Predicted Subsided Surface Levels and Grades along UW3 for the Modified Layout (MSEC, 2016)

UW1 is located outside of the "Study Area" as defined by MSEC (2016), and as such is not predicted to experience any significant subsidence impacts.

MSEC (2016) has not predicted the formation of any new pool on UW2 as a result of predicted subsidence. As UW2 has a similar orientation to the proposed longwalls relative to UW3 and flows across similar topography, UW2 would be expected to experience similar subsidence impacts to those predicted for UW3.

3.2 Potential Erosion Impacts

Although the subsidence effects of the Modified Layout are generally less than the Approved Layout, **Figure 3.1**, **Figure 3.3** and **Figure 3.5** show that the Modified Layout is predicted to increase the gradient in locations where the watercourses run over the up-slope edge of a mining induced trough. Depending on the relative difference between existing and predicted gradient, these changes in gradient could potentially result in an increased likelihood of scouring of the creek beds at key locations.

The bed material in North Wambo Creek, Wambo Creek and Stony Creek is largely comprised of medium to coarse sand (0.2 mm to 2 mm in diameter) and gravel (up to 60 mm in diameter). In situations where the creek bed is not protected by grass or other 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. However, in many locations, the presence of vegetation significantly improves the resistance to erosion.

3.2.1 Potential Erosion Impacts on North Wambo Creek

Figure 3.1 shows that there are two sections of the North Wambo Creek Diversion where the gradient is predicted to increase from between 0.6% and 0.9% to about 2.8% and 6% respectively, and four locations in the natural section of the creek where the existing creek gradient is predicted to increase from about 0.5% to approximately 5%.

The section of the North Wambo Creek Diversion where gradient is predicted to increase from about 0.6% to approximately 2.8% is located on a straight section of channel approximately 680 m upstream of the downstream end of the North Wambo Creek Diversion. Following the storm in February 2013 that caused extensive scour, this area has been the subject of extensive reconstruction and stabilisation works, including rock stabilisation of the left hand bank (looking downstream). The minor increase in gradient at this location is not expected to require any additional scour protection other than routine maintenance of the channel.

The section of the North Wambo Creek Diversion where the gradient is predicted to increase from about 0.9% to approximately 6% is located close to the downstream end of the diversion. This area has existing extensive rock protection in the bed of the creek and additional stabilisation works are unlikely to be required.

In the remaining natural section of North Wambo Creek downstream of the diversion, there are four locations where there is predicted to be an increase of up to 5% in the gradient. In these locations, the lengths of channel predicted to be greater than 2.5% range from approximately 25 m to 50 m. The bed materials in these sections of the creek are largely sands and fine gravel which could be subject to localised scour due to an increase in velocity. However, backwater effects from downstream pools are likely to minimise velocity increase in larger flows. Notwithstanding, these areas would require monitoring and, if necessary, localised scour protection similar to that already employed at the downstream end of the North Wambo Creek Diversion.

3.2.2 Potential Erosion Impacts on Wambo Creek

Figure 3.3 shows that there are two sections of Wambo Creek where the gradient is predicted to increase to approximately 2.5% (compared to the natural gradient of about 0.5%) and 0ne section where the gradient is predicted to increase to approximately 1.4% (from a natural gradient of about 0.4%).

The sections where the gradient is predicted to increase above the natural grade extend for between 100 m and 200 m. Accordingly, the progressive change in grade along the creek would be slight and hard to distinguish other than by means of topographic survey.

The bed materials in Wambo Creek are largely sands and fine gravel which could be subject to localised scour due to any increase in velocity. However, the relatively gradual change in grade is unlikely to lead to significant scour. Notwithstanding, these areas would require monitoring and, if necessary, localised scour protection similar to that already employed elsewhere at Wambo.

3.2.3 Potential Erosion Impacts on Stony Creek

Figure 3.5 shows that there are eight locations along Stony Creek where the gradient is predicted to increase by a maximum of 1.5% above the natural gradient which varies from 4% to 1% over the zone that would be affected by the Modification.

These minor changes in grade are not expected to lead to significant scour. However, in the event of scour developing, monitoring would be necessary, and if required, the employment of localised scour protection.

3.2.4 Potential Erosion Impacts on Un-named Drainage Lines

As noted above, UW1 is not expected to experience any significant subsidence impacts.

Figure 3.7 shows that there are five locations along UW3 where the gradient is predicted to increase by a maximum of 1.5% above the natural gradient which varies from 5.5% (upstream) to 1% (downstream) over the zone that would be affected by the Modification. UW2 would be expected to experience similar impacts.

These minor changes in grade are not expected to lead to significant scour. However, in the event of scour developing, monitoring would be necessary, and if required, the employment of localised scour protection.

3.2.5 Potential Erosion Impacts associated with the Minor Extension of the Approved Surface Development Area

Potential erosion impacts associated with the minor extension of the approved surface development areas would relate primarily to:

- Disturbance of *in-situ* soil resources within additional Modification surface development areas; and
- Increased erosion and sediment movement due to exposure of soils during construction of infrastructure.

Management of erosion impacts at Wambo are currently conducted in accordance with the Wambo Erosion and Sediment Control Plan (WCPL, 2015). The primary objectives of the Erosion and Sediment Control Plan are:

- Identify activities that could cause soil erosion and generate sediment;
- Describe the location, function and capacity of erosion and sediment control structures; and
- Describe measures to minimize soil erosion and the potential for migration of sediments to downstream waters.

Specific control strategies outlined in the Erosion and Sediment Control Plan for soil erosion and sediment migration include (WCPL, 2015):

- Separation of disturbed and undisturbed catchment runoff, where practicable;
- Construction of sediment control structures (e.g. dams) to contain runoff from disturbed areas;
- Utilisation of existing topography and adoption of construction practices that minimise soil erosion and sediment discharge from the area;

- Installation of diversion drains, hay bales, rock structures, sediment fences and sediment dams to control erosion;
- Maintenance of erosion and sediment control measures to ensure they remain in proper working order; and
- Progressive rehabilitation and stabilisation of disturbed areas.

It is recommended that these objectives and specific control strategies in the Erosion and Sediment Control Plan be adopted for the Modification. With the implementation of the Erosion and Sediment Control Plan, it is considered that the potential for any significant additional erosion impacts is low.

3.3 Potential Ponding Impacts

As shown in **Figure 3.1**, **Figure 3.3** and **Figure 3.5**, topographic depressions are predicted to occur where mining induced stream gradients oppose, and are greater than, the natural stream gradients.

MSEC (2016) has provided predicted maximum depths and lengths of the topographic depressions along the creeks. These predictions are detailed in Table 3.3. The formation of new topographic depressions as a result of the Modification is illustrated in **Figure 3.8.** MSEC (2016) notes the potential for ponding to form in topographical depressions is dependent on a number of other factors, including rainfall, catchment sizes, surface water runoff, permeation and evaporation and, therefore the actual extents and depths of ponding are expected to be smaller than the topographical depressions.

MSEC (2016) has predicted the formation of one new topographic depression in the North Wambo Creek Diversion as a result of the Modification. Ponds have been included as design features in the construction of the North Wambo Creek Diversion, so the formation of a new topographic depression that could form a pond may be beneficial, as it may further enhance the diversity of habitat along the diversion.

MSEC (2016) has predicted the formation of six topographic depressions along the natural section of North Wambo Creek due to the Modified Layout. This is illustrated in **Figure 3.1**.

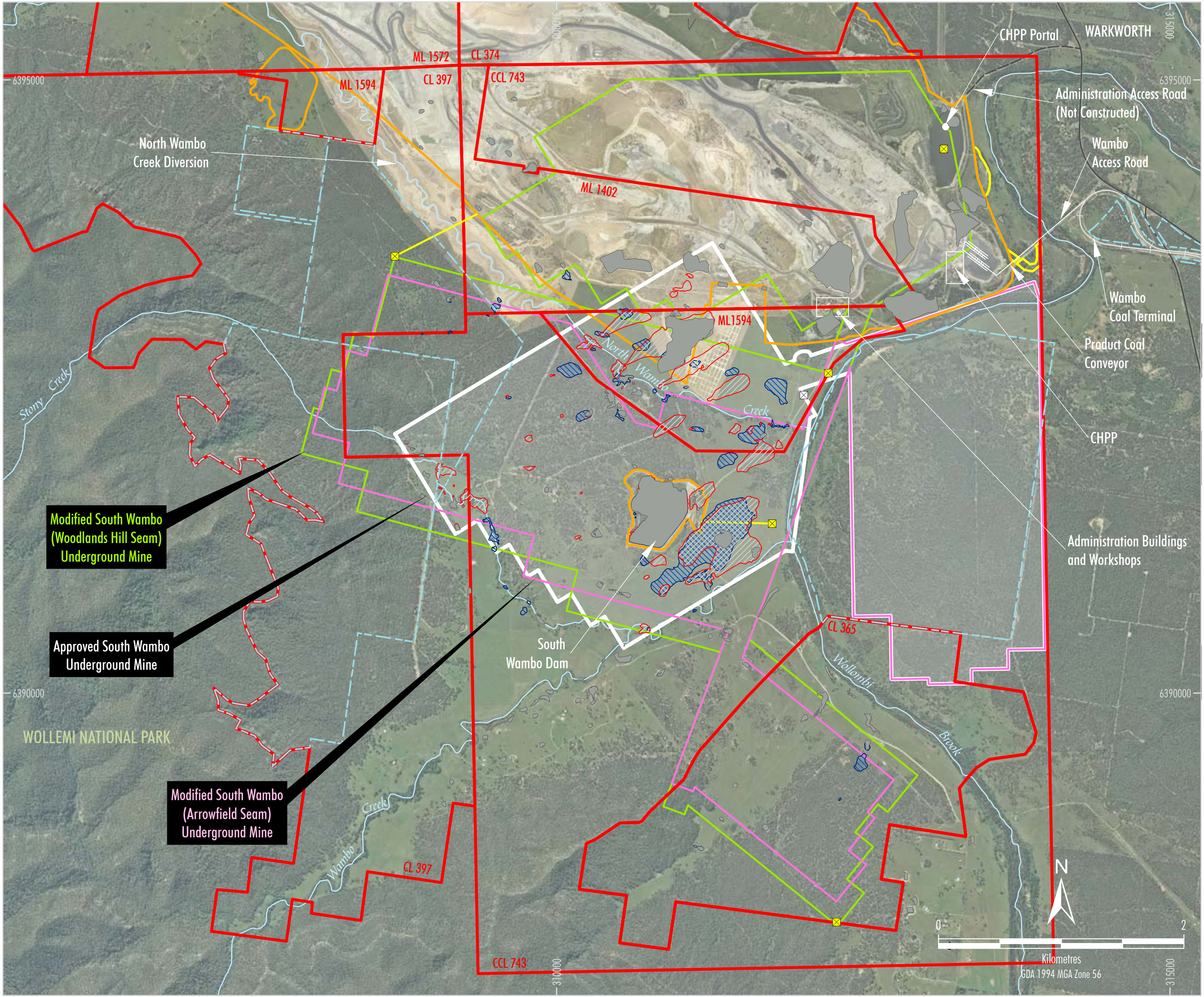
The extent of predicted topographic depressions along North Wambo Creek, based on the Modified Layout, is less than that predicted based on the Approved Layout. The reason for this is that the proposed longwalls are staggered based on the Modified Layout, which results in less subsidence when compared with the stacked arrangement based on the Approved Layout. There are six topographic depressions predicted to develop along North Wambo Creek, based on the Modified Layout, having maximum depths between 0.6 metres and 2.2 metres and overall lengths between 100 m and 450 m. Topographic depressions with maximum depths of up to 6.0 m along North Wambo Creek were predicted under the Approved Layout (MSEC, 2016).

Based on the Approved Layout, four topographic depressions are predicted to develop along Wambo Creek, having maximum depths between 0.2 m and 0.6 m and overall lengths between 125 m and 250 m. The number of topographic depressions that would develop along Wambo Creek, as a result of the Modified Layout is expected to reduce to two, however these topographic depressions would be larger. The Modified Layout is predicted to result in topographic depressions with maximum depths up to 1.7 m and overall lengths up to 400 m (MSEC, 2016). This is illustrated in **Figure 3.3** and Table 3.3.

Table 3.3: Predicted Maximum Depths and Lengths of the Topographic Depressions along the Creeks (Approved and Modified Layouts) (after MSEC, 2016)

Creek	Topographic Depression	Predicted Extent Due to Approved Layout	Predicted Extent Due to Modified Layout
North Wambo Creek Diversion	CD-P1	-	1.3 m deep x 200 m long
North Wambo Creek	NWC-P1	0.8 m deep x 200 m long	0.6 m deep x 100 m long
	NWC-P2	6.0 m deep x 275 m long	2.2 m deep x 275 m long
	NWC-P3	5.7 m deep x 325 m long	1.5 m deep x 375 m long
	NWC-P4	4.5 m deep x 450 m long	0.6 m deep x 150 m long
	NWC-P5	3.9 m deep x 275 m long	1.6 m deep x 350 m long
	NWC-P6	3.5 m deep x 425 m long	0.9 m deep x 450 m long
Wambo Creek	WC-P1	0.6 m deep x 225 m long	1.7 m deep x 400 m long
	WC-P2	0.2 m deep x 200 m long	1.0 m deep x 250 m long
	WC-P3	0.3 m deep x 125 m long	-
	WC-P4	0.7 m deep x 270 m long	-
Stony Creek	SC-P1	0.5 m deep x 150 m long	0.4 m deep x 100 m long
	SC-P2	1.6 m deep x 250 m long	1.0 m deep x 200 m long
	SC-P3	0.2 m deep x 75 m long	0.9 m deep x 150 m long
	SC-P4	1.3 m deep x 500 m long	1.4 m deep x 250 m long
	SC-P5	-	0.8 m deep x 300 m long
UW3	UC-P1	-	0.3 m deep x 150 m long

There are four topographic depressions predicted to develop along Stony Creek, based on the Approved Layout, having maximum depths between 0.2 m and 1.6 m and overall lengths between 75 m and 500 m. The Modified Layout is predicted to result in an additional topographic depression with similar size to that predicted for the Approved Layout. The five topographic depressions are predicted to have maximum depths between 0.4 m and 1.4 m and overall lengths between 100 m and 300 m (MSEC, 2016).



Source: Department of Lands (July 2009); WCPL (2015); WCPL Orthophoto (Apr-Oct 2013)

Peabody ENERGY

WAMBO COAL MINE

Predicted Approved and Modified Topographic Depressions Post Mining

Figure 3.8

WAM-09-15_SWUMM_EA_SW_206B

MSEC (2016) has predicted the formation of one topographic depression on UW3 after the completion of the proposed longwalls. This topographic depression would have a maximum depth of 0.3 m and an overall length of 150 m. This is the only new topographic depression predicted to develop as a result of the Modified Layout on the unnamed drainage lines. The unnamed drainage lines were not predicted to be impacted by the Approved Layout.

As noted above, the formation of new pools in topographic depressions along the natural creek alignment may be beneficial due to creation of new and diverse habitat, and noting these watercourses are ephemeral streams, retained pools may add to the diversity of aquatic ecology at the site. If however, adverse impacts develop, local regrading of the stream bed could be undertaken as described in Section 4.3.

3.4 Potential Cracking of Creek Beds

MSEC (2016) provides the following discussion about the incidence of ground deformations caused by longwall mining:

> *Longwall mining can result in surface cracking, heaving, buckling, humping and stepping at the surface. The extent and severity of these mining induced ground deformations are dependent on a number of factors, including the mine geometry, depth of cover, overburden geology, locations of natural joints in the bedrock, the presence of near surface geological structures and multi-seam mining conditions.*
>
> *Fractures and joints in bedrock occur naturally during the formation of the strata and from subsequent disturbance, tectonic movements, igneous intrusions, erosion and weathering processes. Longwall mining can result in additional fracturing in the bedrock, which tends to occur in the tensile zones, but fractures can also occur due to buckling of the surface beds in the compressive zones. The incidence of visible cracking at the surface is dependent on the pre-existing jointing patterns in the bedrock as well as the thickness and inherent plasticity of the soils that overlie the bedrock.*
>
> *As subsidence occurs, surface cracks will generally appear in the tensile zone, i.e. within 0.1 to 0.4 times the depth of cover from the longwall perimeters. Most of the cracks will occur within a radius of approximately 0.1 times the depth of cover from the longwall perimeters. The cracks will generally be parallel to the longitudinal edges or the ends of the longwalls.*
>
> *At shallower depths of cover, it is also likely that transient surface cracks will occur above and parallel to the moving extraction face, i.e. at right angles to the longitudinal edges of the longwall, as the subsidence trough develops. This cracking, however, tends to be transient, since the tensile phase of the travelling wave, which causes the cracks to open up, is generally followed by a compressive phase, which partially recloses them. It has been observed in the past, however, that surface cracks which occur during the tensile phase of the travelling wave do not fully close during the compressive phase, and tend to form compressive ridges at the surface.*

> *The incidence of surface cracking is dependent on the location relative to the extracted longwall goaf edges, the depth of cover, the extracted seam thickness and the thickness and inherent plasticity of the soils that overlie the bedrock. The widths and frequencies of the cracks are also dependent upon the pre-existing jointing patterns in the bedrock. Large joint spacing can lead to concentrations of strain and possibly the development of fissures at rockhead, which are not necessarily coincident with the joints.*

It is expected that fracturing of the topmost bedrock would develop along the sections of the watercourses located directly above the proposed longwalls. The existing fractures along the section of North Wambo Creek located above the previously extracted longwalls within the Wambo Seam would also be reactivated (MSEC, 2016).

The watercourses have shallow incisions into the natural surface soils. Cracking in the beds of the creeks would be visible at the surface where the depths of the surface soils are shallow, or where the bedrock is exposed.

Mining induced compression could also result in dilation and the development of bed separation in the topmost bedrock. The dilation is expected to develop predominately within the top 10 m to 20 m of the bedrock. The watercourses are ephemeral and, therefore, surface water flows only occur during and for short periods after rainfall events. In times of heavy rainfall, the majority of the runoff would flow over the natural surface soil beds and would not be diverted into the dilated strata below. In times of low flow and prior to remediation, however, surface water flows could be diverted into the dilated strata below the beds (MSEC, 2016).

It is expected that the discontinuous fractured zone above the proposed longwalls would extend up to existing workings in the overlying Whybrow and Wambo Seams. It is not expected, however, that there would be a direct hydraulic connection between the surface and proposed longwalls, as this has not been previously observed at Wambo. This includes the extraction of the Homestead/Wollemi workings in the Whybrow Seam directly beneath Stony Creek and the extraction of WMLW1 to WMLW8A in the Wambo Seam directly beneath both North Wambo and Stony Creeks (MSEC, 2016).

It is also noted that the Approved Layout includes areas directly under North Wambo, Wambo and Stony Creeks (i.e. the potential for connectivity with these creeks is currently approved).

The Unnamed Drainage Lines UW2 and UW3 are located directly above Woodlands Hill Seam Longwall (WHLW) 16 to WHLW19 and Arrowfield Seam Longwall (AFLW) 15 to AFLW17 in the Modified Layout. These drainage lines have a shallow incision in the surface soils. The depth of cover above these longwalls varies between approximately 260 m and 430 m. The combination of the shallow incision and the depth of cover make it unlikely that any significant cracking would be observed in these drainage lines at the surface.

A discussion of the potential monitoring and remediation techniques to address the potential cracking of creek beds can be found in Section 4.4.

3.5 Potential Water Quality Impacts

The main potential impact of the subsidence associated with both the Approved Layout and the Modified Layout on downstream water quality relates to the potential for bed and bank sediment to be mobilised as a result of erosion/scour from locations where the gradient of the creek bed is predicted to increase.

As noted in Section 3.2, increases in creek gradient are predicted to occur in short sections of all creeks and watercourses near the upstream edge of the longwalls. Because the change in gradient is minor or very localised, significant increase in erosion and sediment load is not expected, particularly with the implementation of the measures outlined in Section 4.2. Should any sediment be eroded from these areas, it would be captured in the downstream ponds. No significant impact on the sediment load reaching Wollombi Brook is expected as a result of the Modification.

Subsidence is not expected to lead to any change in the pH or EC of the flow in any of the creeks.

The Modification would also include minor extensions to the approved surface development area (Section 1.2). As described in Section 3.2.5, with the implementation of the Erosion and Sediment Control Plan, it is considered that the potential for any significant additional erosion impacts from the additional surface development areas is low.

The site water management strategy for Wambo is based on the containment and re-use of mine water. It is recommended that the minor extensions to the surface development area be incorporated into the existing site water management system (i.e. runoff from the additional surface development areas would be contained on-site).

Given the above, potential water quality impacts associated with the minor extensions to the approved surface development areas would be low.

3.6 Potential Reduction in Creek Flows due to Groundwater Depressurisation

HydroSimulations (2016) has estimated the potential changes to baseflow in the creeks as a result of both the Approved Layout and the Modified Layout. These impacts are illustrated in **Figure 3.9, Figure 3.10**, **Figure 3.11**, and **Figure 3.12.**

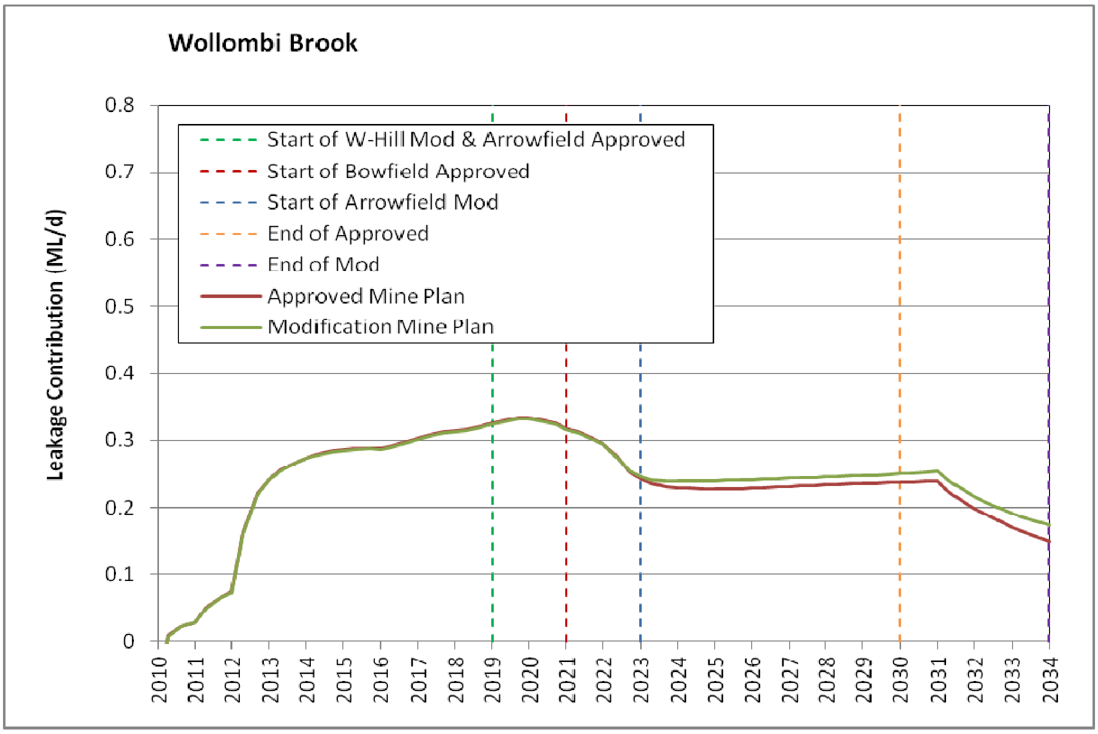


Figure 3.9: Baseflow Variation in Wollombi Brook (HydroSimulations, 2016)

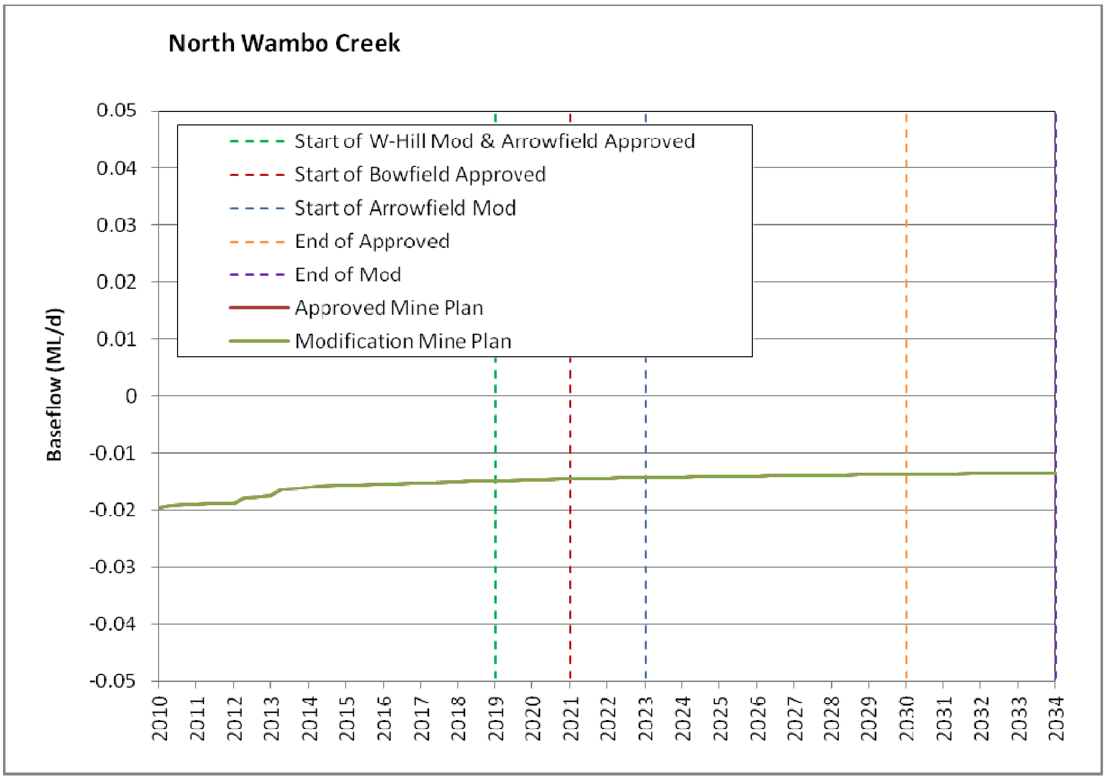


Figure 3.10: Baseflow Variation in North Wambo Creek (HydroSimulations, 2016)

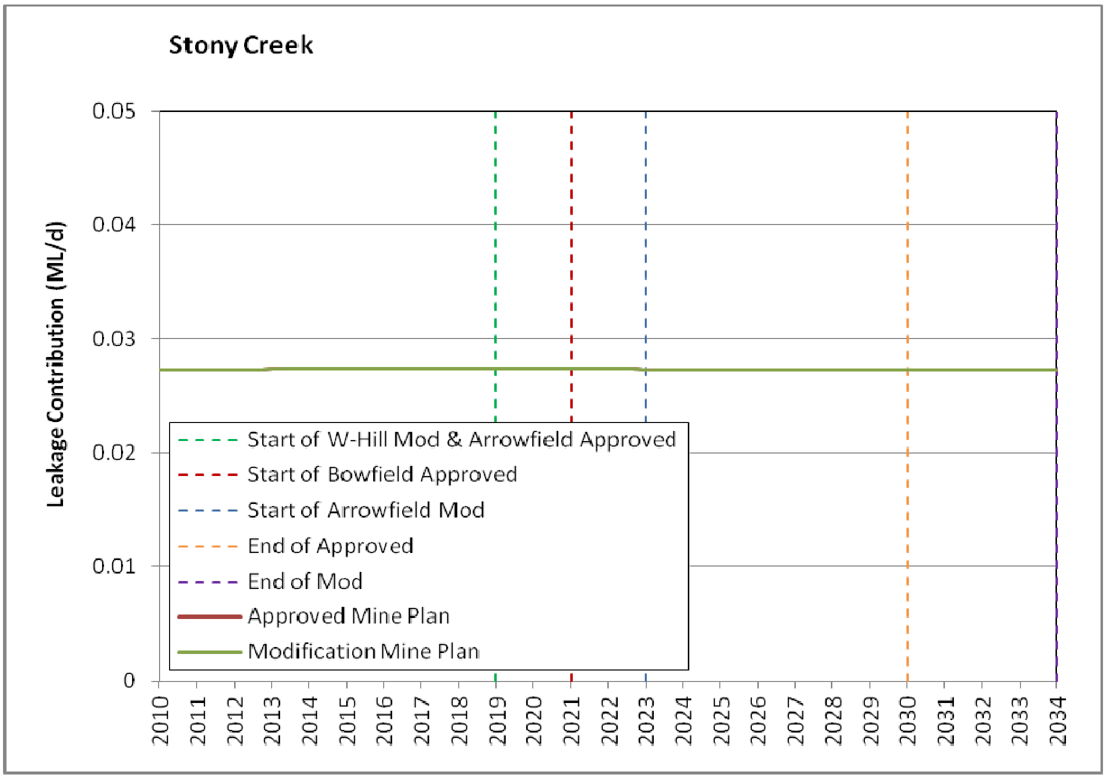


Figure 3.11: Baseflow Variation in Stony Creek (HydroSimulations, 2016)

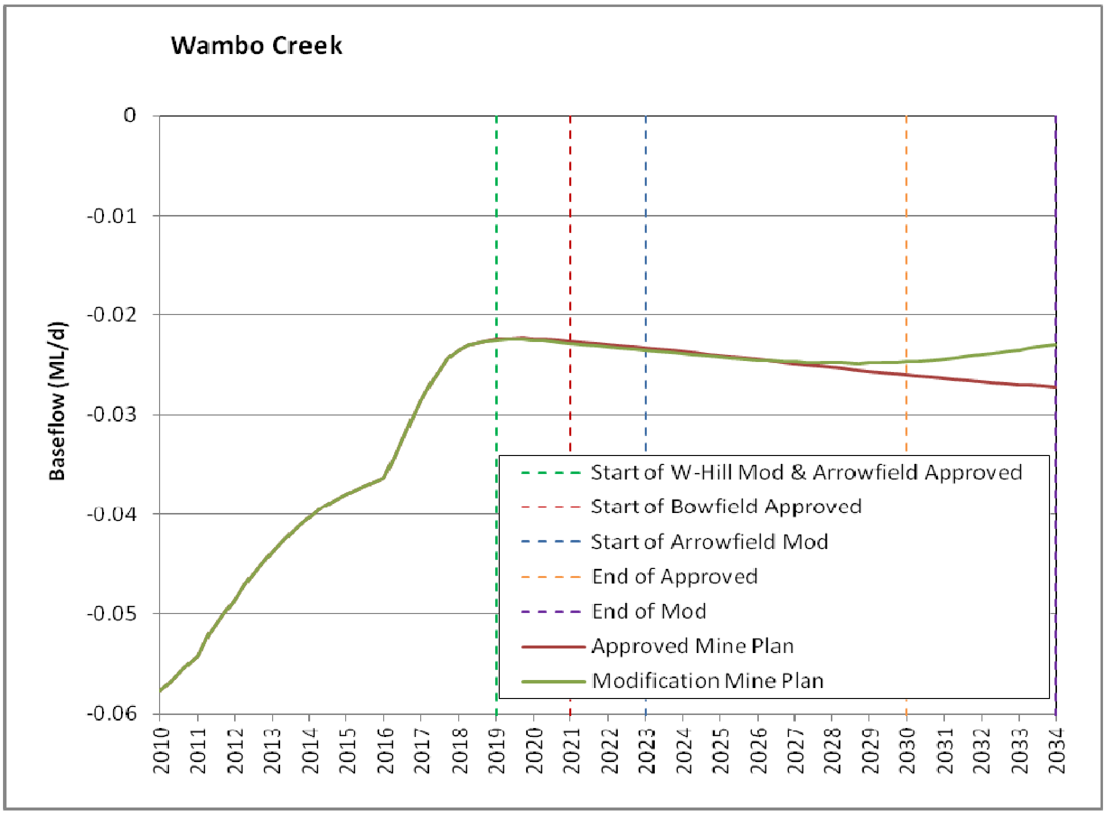


Figure 3.12: Baseflow Variation in Wambo Creek (HydroSimulations, 2016)

As can be seen from these figures, there is no appreciable difference in impact between the Modified Layout and the Approved Layout on either North Wambo Creek or Stony Creek. The predicted impact on North Wambo Creek would see an increase of approximately 5 ML/year in baseflow. The predicted impact on Stony Creek would see a decrease of approximately 10 ML/year in baseflow.

The predicted impact on baseflow in Wambo Creek would see an increase of some 8 ML/year, with the Modified Layout having a slightly lesser contribution to baseflow in the later years of the Modification.

The predicted impact on baseflow in Wollombi Brook is a maximum decrease of approximately 125 ML/year, with the Modified Layout seeing a slightly higher decrease than the Approved Layout in the latter years of the Project. In the context of the mean annual flow in Wollombi Brook of some 139,213 ML (Section 2.7), this would represent an impact of less than 0.1% on the flow in Wollombi Brook.

3.7 Potential Changes to Flood Behaviour

The WRM (2016) flood study has identified the need for a levee to be constructed between Wollombi Brook and the proposed surface infrastructure area and box cut. The levee is required to prevent inundation of these areas due to a flood event in Wollombi Brook. WRM considers that the maximum flood impact that could be experienced in the vicinity of the Modification in a 1% AEP event would be attributable to flooding in Wollombi Brook itself, and not caused by backwater flooding from the Hunter River.

The impact of constructing the levee to mitigate against inundation from such an event has been modelled by WRM. The modelling shows that a potential increase of less than 0.05m is predicted to occur adjacent to the Wambo Mine access road.

The Modification would not increase the risk of flooding or materially affect the flood hazard or flood behaviour in the vicinity of the Modification as compared to the Approved Layout.

3.8 Potential Impacts on Licensed Water Users

As described in Section 2.9, six WALs associated with surface water extraction were identified in the vicinity of Wambo (**Figure 2.6**).

It is not expected that there would be a direct hydraulic connection between the surface and proposed longwalls, as this has not been previously observed at Wambo (MSEC, 2016) (Section 3.4). Therefore, any potential reduction in flow in Wollombi Brook would either be due to evaporation from increased pond areas or from any baseflow reduction to the streams. HydroSimulations (2016) has provided an analysis of the baseflow changes predicted as a result of the Modification (Section 3.6).

As shown in Table 3.3 the predicted topographic depression lengths for the Approved Layout are about 10% greater than the Modified Layout, but, on average, are significantly deeper. Assuming that the water surface area of any ponding is related to both length and depth (deeper pools will be wider), the data in Table 3.3 indicates that the total water surface areas of the ponds for the Modified Layout would be approximately 50% of the area of the ponds for the Approved Layout. This would mean that any evaporation from ponds in topographic depressions attributable to the Modified Layout would be about half of the evaporation loss for the Approved Layout.

HydroSimulations has predicted a maximum reduction in baseflow in Wollombi Brook of some 125 ML/year, and this is less than 0.1% of the mean annual flow in Wollombi Brook.

The mean annual flow in Wollombi Brook, from which water is extracted under the WALs (total entitlements of 600 ML per year, see **Table 2.5**), is 139,213 ML (Section 2.7). The potential loss of approximately 125 ML/year due to the loss of baseflow in Wollombi Brook would have a negligible effect on the water resource available to licensed water users.

As described in Section 3.5, the Modification is not expected to change water quality downstream of Wambo and therefore no significant impact on surface water users is expected as a result of the Modification.

4 Monitoring and Management

The following sections provide recommended impact management and monitoring measures.

4.1 Geomorphological Survey

As recommended by Gilbert & 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.

4.2 Bed and Bank Stability

An increase in velocity due to the increase in creek slope as a result of subsidence has the potential to mobilise the finer material and possibly also the coarser gravel. Some parts of the areas subject to changes in grade identified in Section 3.2 may potentially require stabilisation.

The degree of erosion that occurs would also depend on ground conditions, including vegetation cover. During the site inspection, it was observed that the banks were generally well vegetated, with vegetation types including grass, reeds and trees. In addition, the bed material of all creeks ranged from grassed soil to gravel and small boulders. In some locations along Wambo Creek, larger vegetation (e.g. trees) was growing within the channel.

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 trees, may initiate channel instability when they are uprooted in larger floods.

As discussed in Section 3.2, the areas most vulnerable to scour are confined to short sections of channel, particularly on North Wambo Creek downstream of the North Wambo Creek Diversion.

It is recommended that the potential areas of erosion 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 shallow banks and then establishing vegetated ground cover. Where the existing banks are near vertical, toe protection by means of anchored mesh fencing may be required. 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. These works should be undertaken with consideration of the *Guidelines for instream works on water front land* (NOW, 2012).

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 luehmannii* (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, 2014).

4.3 Ponding

Where ponding in a topographic depression is deemed desirable for the provision of aquatic and riparian habitat, it is preferable to minimise any works to re-grade the creek in order to allow drainage of the topographic depression. Any such works have the potential to lead to other problems, such as erosion of the creek bed.

If subsidence creates pools in topographic depressions that are 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, similar to those outlined in the *Land Management Plan for North Wambo Underground Mine Longwalls 8 to 10A* (WCPL, 2015b).
- Channel excavation and stabilization works to re-grade a downstream section of channel in order to eliminate or reduce the length of the pool.

4.4 Stream Bed Cracking

There is potential for fracturing of the upper bedrock along the sections of the North Wambo Creek Diversion; North Wambo, Stony, and Wambo Creeks; and Unnamed Drainage Lines 2 and 3 located directly above the proposed longwalls. Existing fractures along the sections of North Wambo Creek that were located above the longwalls previously extracted in the NWUM would also be reactivated (Section 3.4).

As discussed in Section 3.1.1, the potential for subsidence impacts on Wollombi Brook as a result of the Modification is negligible. Therefore, the potential for cracking along the bed of Wollombi Brook is negligible and has not been considered further here.

4.4.1 Monitoring and Management of Stream Bed Cracking in the North Wambo Creek Diversion

Within the section of the North Wambo Creek Diversion which would be undermined by WHLW6, fracturing and dilation of the topmost bedrock is expected to develop (MSEC, 2016). As the North Wambo Creek Diversion has very little soil material above the bedrock, this fracturing would be visible at the surface.

WHLW6 would directly undermine the North Wambo Creek Diversion over a distance of approximately 600 m (which would be expected to occur over approximately 2 months). During this time the North Wambo Creek Diversion should be actively monitored for the presence of fracturing.

During this period, remediation works should be undertaken to reduce the hydraulic conductivity of any cracks that might open up. All significant cracks are expected to be visible and should be sealed using the following sequence of actions commencing as soon as cracks appear:

- Washing a slurry containing well graded sandy-silt into the cracks to fill cracks in the underlying rock. Water for this operation should be pumped from the mine workings.
- Infilling larger surface cracks with typical alluvial material.

It is unlikely that significant bedrock cracking would occur as a result of the Modification. However, if it were to happen, it could warrant grouting of the underlying bedrock. This would be implemented in consultation with regulatory agencies in the unlikely event significant cracking occurred. Similar grouting has been undertaken at Wambo previously.

4.4.2 Monitoring and Management of Stream Bed Cracking in the Natural Watercourses

Visual monitoring of the creek channels should be undertaken on a regular basis during the periods in which the creeks are actively undermined.

It is expected that any fracturing that develops in the underlying bedrock would gradually be filled with surface soils during subsequent flow events.

The *Land Management Plan for North Wambo Underground Mine Longwalls 8 to 10A* (WCPL, 2015b) recommends that minor surface cracks be in-filled with soil or other suitable materials (e.g. mulch) and the surface area re-graded and re-compacted. Erosion protection measures, such as vegetation planting, could also be used. However, natural filling of these cracks over time 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 delivered by haulage trucks.

The nature of the potential impacts to the creeks and the methods of remediation used previously at Wambo are not expected to change significantly as a result of the Modification. While Wambo Creek may require more remediation than was proposed for the Approved Layout, the remediation works that may be necessary for North Wambo Creek as a result of the Modified Layout are expected to be less than may have been required for the Approved Layout.

4.5 Erosion and Sediment Control for Surface Development Area

It is recommended that the current Wambo Erosion and Sediment Control Plan (WCPL, 2015c) be updated and revised to include the additional Modification surface development area.

The following specific control strategies outlined in the Erosion and Sediment Control Plan for soil erosion and sediment migration should continue to be implemented (WCPL, 2015):

- Separation of disturbed and undisturbed catchment runoff, where practicable.
- Construction of sediment control structures (e.g. dams) to contain runoff from disturbed areas.
- Utilisation of existing topography and adoption of construction practices that minimise soil erosion and sediment discharge from the area.
- Installation of diversion drains, hay bales, rock structures, sediment fences and sediment dams to control erosion.
- Maintenance of erosion and sediment control measures to ensure they remain in proper working order.
- Progressive rehabilitation and stabilisation of disturbed areas.

4.6 Surface Water Quality

As discussed in Section 3.5, the main potential impact of the subsidence associated with both the Approved Layout and Modified Layout on downstream water quality relates to the potential for bed and bank sediment to be 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 discussed in Sections 4.1 and 4.2 are intended to minimise the mobilisation of sediment and thereby mitigate downstream water quality impacts.

No significant changes in pH or EC measured in the creeks are expected as a result of the Modified Layout.

It is recommended that WCPL maintain its current surface water monitoring program (WCPL, 2015a).

Additional water quality monitoring points should be considered on Unnamed Drainage Lines 2 and 3 (UW2 and UW3). These monitoring points should be near the downstream end of the drainage line, and should be commenced at least one year prior to the commencement of longwall mining in the panels that are located beneath the drainage lines.

If three successive analysis results for any parameter at any of the surface water monitoring points on the potentially impacted creeks exceeds the 80th percentile value of historical monitoring, then WCPL should commence an investigation of the cause of the potential change to water quality and take remedial action as necessary.

4.7 Extraction Plan

An Extraction Plan would be developed for the SWUM. It is recommended that the Extraction Plan include Trigger Action Response Plans with a process to determine appropriate triggers and remedial actions for:

- changes in grade and erosion and scour risk, including a process to determine whether instream works are required;
- pool development, including contingency remedial measures should subsidence create a pool that is significantly larger than predicted; and
- surface cracking, consistent with erosion and sediment management in the approved Erosion and Sediment Control Plan.

5 Conclusions

Compared to currently approved longwall extraction in the Wambo, Arrowfield and Bowfield seams (the Approved Layout), the Modified Layout is not expected to lead to significantly greater subsidence impacts and correspondingly significantly greater surface water impacts.

The maximum predicted conventional subsidence parameters for the Modified Layout are less than those predicted for the Approved Layout:

Layout	Maximum Predicted Vertical Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)
Approved	9,000	90
Modified	6,250	75

The North Wambo Creek Diversion is predicted to experience greater subsidence as a result of the Modified Layout. However, this is less than that predicted for other sections of the North Wambo Creek Diversion as a result of other approved longwalls at Wambo (i.e. Longwalls 11 to 16 at the South Bates Underground Mine). An additional topographical depression is expected to develop along the North Wambo Creek Diversion.

The subsidence impacts predicted for the natural section of North Wambo Creek are less than those predicted for the Approved Layout. Six topographical depressions are predicted to develop as a result of mining in both layouts, however the topographical depressions and depths are smaller in the Modified Layout.

The subsidence impacts predicted for Stony Creek as a result of the Modified Layout are greater than those predicted for the Approved Layout (subsidence of 5,600 mm compared with 4,900 mm, and with similar tilt). This is not expected to lead to significantly greater impacts on surface water, however one additional topographical depression is predicted to develop.

The subsidence impacts predicted for Wambo Creek as a result of the Modified Layout are greater than those predicted for the Approved Layout (subsidence of 3,100 mm compared with 1,650 mm, and tilt of 20mm/m compared with 16 mm/m). This is not expected to lead to significantly greater impacts on surface water, however two fewer topographical depressions with deeper and longer pools are predicted to develop.

The Unnamed Drainage Lines 2 and 3 would not experience subsidence as a result of the Approved Layout. These drainage lines would be impacted by the Modified Layout, including the development of a topographical depression on UW3. No significant impacts on surface water in the drainage lines is expected as a result of the Modified Layout.

The development of pools in topographical depressions along the creeks may be desirable for the development of riparian and aquatic habitat. However, if the formation of a new pool is deemed undesirable, then the preferred management measure is to minimise any works to re-grade the creek in order to allow drainage of the pond. Any such works have the potential to lead to other problems, such as erosion of the creek bed.

Any potential for bed or bank scouring as a result of the predicted subsidence and changes in gradient are within the range that is capable of being mitigated by a range of mitigation techniques previously applied at Wambo on other sections of Stony and Wambo Creeks.

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 the 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.

The Modified Layout is expected to have negligible impact on Wollombi Brook, as is the case with the Approved Layout.

The Modified Layout is not expected to have any significant impact on licensed surface water users in the Lower Wollombi Brook Source of the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources. Approximately 125 ML/year has been identified as a potential loss to the flow in Wollombi Brook, which has a mean annual flow of some 139,213 ML at Warkworth.

The Modified Layout is not expected to have any significant impact on the risk of flooding, or on flood behaviour in the vicinity of Wambo.

With revision and updating to cater for the proposed surface works in the Modification, the Wambo Erosion and Sediment Control Plan would control erosion and sediment migration.

The development of an Extraction Plan for the Modification would include Trigger Action Response Plans with processes to determine appropriate triggers and remedial actions for changes in grade and erosion and scour risk, pool development, and surface cracking.

Advisian
WorleyParsons Group

6 References

Bureau of Meteorology (BOM) 2016, Weather Station Directory http://www.bom.gov.au/climate/data/stations/

Coffey 1999, *Wambo and Stony Creek Management Plan.*

Department of Primary Industries – Water 2015, *Real Time Data, Hunter River Basin,* http://realtimedata.water.nsw.gov.au/water.stm?ppbm=210_hunter&rs&2&rsvm_org

Department of Primary Industries – Water 2015, *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources,* http://www.water.nsw.gov.au/water management/water sharing/plans commenced/water source/hunter unregulated and alluvial

G.E. Holt & Associates Pty Ltd 2003, *Wambo Development Project Subsidence Assessment.*

Gilbert & Associates Pty Ltd 2003, *Wambo Development Project – Surface Water Assessment.*

Gilbert & Associates Pty Ltd 2009, *North Wambo Creek – Stage 3 Diversion Design Report*

Gilbert & Associates Pty Ltd 2014, *Assessment of Potential Environmental Consequences for Surface Water Resources Resulting from Extraction of North Wambo Underground Mine Longwalls 9 and 10.*

Grayson et al. 1996, *Hydrological Recipes – Estimation Techniques in Australian Hydrology*, Cooperative Research Centre for Catchment Hydrology.

Hunter Catchment Management Trust 2003, *Integrated catchment management plan for the Hunter catchment 2002.*

Hydrosimulations 2016, *South Wambo Underground Mine Modification Groundwater Assessment.*

Mine Subsidence Engineering Consultants 2013, *North Wambo Underground Mine Modification Subsidence Assessment.*

Mine Subsidence Engineering Consultants 2014, *North Wambo Underground Longwall 10A Modification Subsidence Assessment.*

Mine Subsidence Engineering Consultants 2016, *South Wambo Underground Modification Mine Subsidence Assessment.*

New South Wales Office of Water 2012, *Guidelines for Instream Works on Water Front Land.*

Soil Management Designs 2016, *Agricultural Resource Assessment: South Wambo Underground Mine Modification; Singleton, NSW.*

Wambo Coal Pty Limited 2003, *Wambo Development Project Environmental Impact Statement.*

Wambo Coal Pty Limited 2012, *Environmental Assessment for the Modification of DA 305-7-2003 (Mod 13) the Addition of North wambo Underground Mine Longwallos 9 and 10.*

Wambo Coal Pty Limited 2014, *Flora and Fauna Management Plan.*

Wambo Coal Pty Limited 2015a, *Surface Water Monitoring Program (Water Management Plan).*

Wambo Coal Pty Limited 2015b, *Land Management Plan for North Wambo Underground Mine Longwalls 8 to 10A.*

Wambo Coal Pty Limited 2015c, *Wambo Erosion and Sediment Control Plan*

WRM Water & Environment Pty Ltd 2016, *South Wambo Underground PFS Flood Study and Concept Water Management System.*

Appendix A

Existing Creek Conditions – Record of Site Inspection

Table of Contents

A1. Existing Creek Conditions.......... 2

A1.1 Overview.......... 2

A1.2 North Wambo Creek.......... 4

A1.2.1 Photographic Record of Inspection of North Wambo Creek.......... 5

A1.3 Stony Creek.......... 13

A1.3.1 Photographic Record of Inspection of Stony Creek.......... 14

A1.4 Wambo Creek.......... 28

A1.4.1 Photographic Record of Inspection of Wambo Creek.......... 29

A1.5 Unnamed Drainage Line 1.......... 35

A1.6 Unnamed Drainage Line 2.......... 38

A1.7 Unnamed Drainage Line 3.......... 40

A1. Existing Creek Conditions

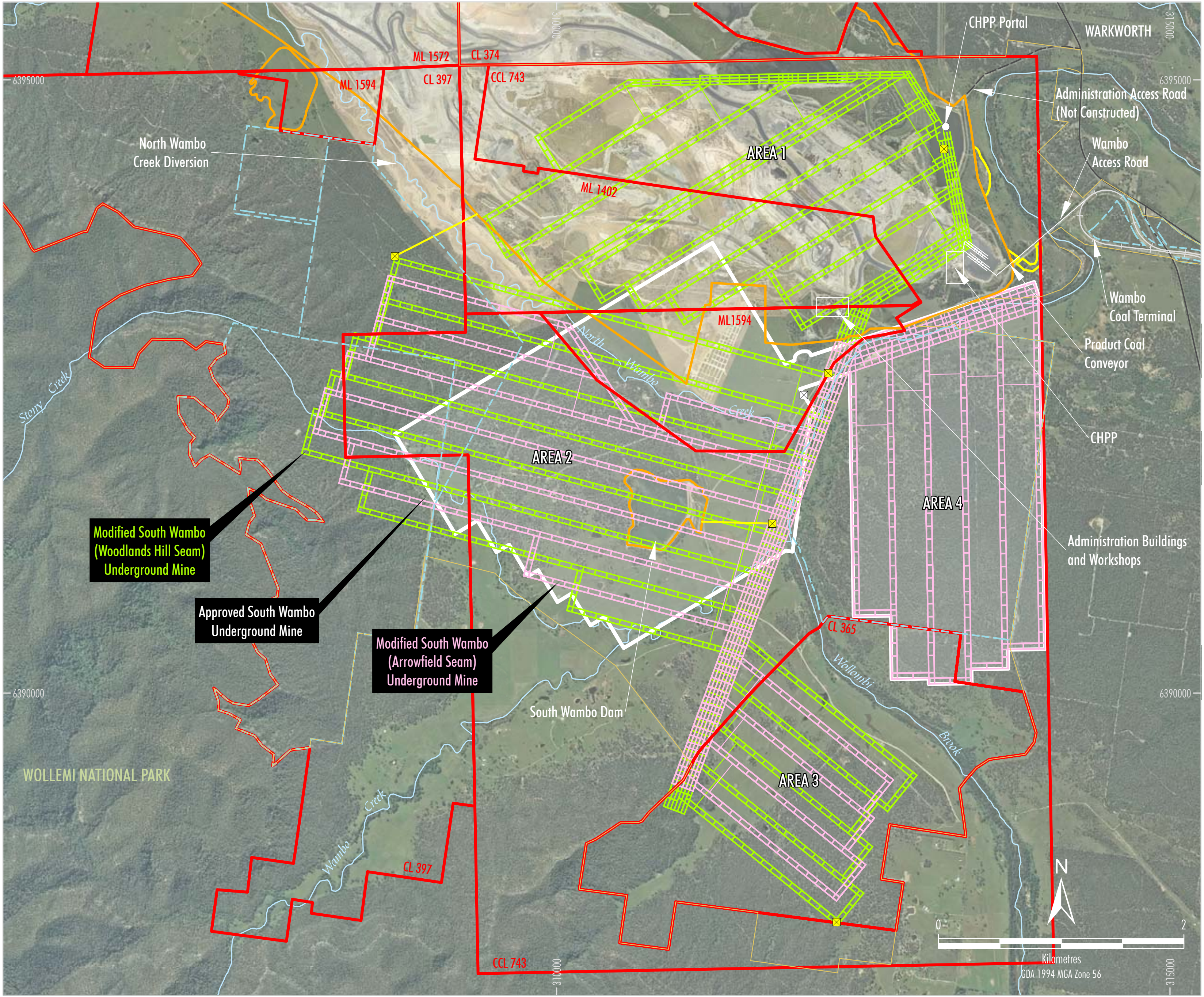
A1.1 Overview

As shown in Figure A-1, the proposed underground mining area for the Modification would undermine reaches of North Wambo Creek, Stony Creek, Wambo Creek, and three unnamed drainage lines in the south east (west of Wollombi Brook). There are also a number of minor drainage lines that drain in an easterly direction across the proposed Modification area.

North Wambo Creek, Stony Creek, and Wambo Creek are ephemeral creeks that originate in the steep hills of the Wollemi National Park. The other minor drainage lines are also ephemeral.

A site inspection of the major watercourses that may be impacted by the Modification was undertaken on 2 November 2015. The objective of the site inspection was to create a baseline characterisation of the streams against which potential impacts of the Modification on the streams can be assessed. The stream traverses focussed on:

- North Wambo Creek, across the Modification Area to the confluence with Wollombi Brook;
- Stony Creek, across the Modification Area to the confluence with Wambo Creek;
- Wambo Creek from the confluence with Stony Creek to the confluence with Wollombi Brook; and
- The three unnamed watercourses in the south east of the Modification Area.



WAM-09-15_SWUMM_EA_SW_208A

LEGEND

- Mining and Coal Lease Boundary
- WCPL Owned Land
- Existing/Approved Surface Development Area
- Modified Surface Development Area
- Approved South Wambo Underground Mine Development
- Modified South Wambo (Woodlands Hill Seam) Underground Mine
- Modified South Wambo (Arrowfield Seam) Underground Mine
- Approved Ventilation Shaft
- Modified Ventilation Shaft
- Remnant Woodland Enhancement Program (RWEP) Area

Note: Refer to Figure 2 for location of North Wambo Underground Mine and South Bates Underground Mine.

Source: Department of Lands (July 2009); WCPL (2015); WCPL Orthophoto (Apr-Oct 2013)

Peabody ENERGY

W A M B O   C O A L   M I N E

Approved and Modified South Wambo Underground Mine General Arrangement

Figure A-1

A1.2 North Wambo Creek

The North Wambo Creek rises in the Wollemi National Park escarpment west and north of the mine area and extends to the confluence with Wollombi Brook in the east of the Modification area. The natural catchment had a total area of some 48.5 square kilometres (km^2) which contains two distinct landforms:

- Steep, heavily forested, headwaters with elevations ranging up to 650 metres Australian Height Datum(m AHD) on the ridges down to about 140 m AHD where the creek drains onto open country over a distance of about 5.5 kilometres (km). The tributary creeks in this hilly section of the catchment drain predominantly from south-east to north-west and have well defined regular alignment.

- Cleared grassy plains within which sections of the pre-existing creek have been subsumed by the open-cut mine.

For purposes of diverting flow away from the area designated for open-cut mining, diversion of North Wambo Creek occurred in two main stages commencing at the point near where the original creek turned to drain in a south-westerly direction:

- Stage 2 Diversion (incorporating Stage 1) comprising about 3.6 km of meandering channel containing two 'billabongs' was constructed in 2008. The catchment area at the upstream end the Stage 2 Diversion is about 26.5 km^2.

- Stage 3 Diversion, comprising a further 5.6 km of meandering channel commencing at the downstream end of the meandering section of Stage 2 was completed in late 2013. As a result of internal drainage to the mine pit, the contributing catchment of the creek at the outlet of the Stage 3 Diversion has been reduced from about 42.6 km^2 to approximately 34.2 km^2, and the total catchment at the junction with Wollombi Brook has been reduced to 40.1 km^2.

The Modification would undermine a section of the Stage 3 Diversion and sections of the remaining natural creek, extending to approximately 250 metres from the confluence with Wollombi Brook. Immediately downstream of the Diversion, the stream bed is reported to comprise material washed out of the Stage 3 Diversion in 2013, and is indicative of a low energy stream with low slope.

The North Wambo Creek flows in a generally easterly direction across the Modification Area. There are two north-east flowing tributaries to North Wambo Creek. One of these tributaries includes a small number of permanent pools and wetlands, these permanent pools are reported to be the result of prior mine subsidence impacts on these watercourses.

The tributaries flow across the alluvial flood plain to North Wambo Creek and the channels in the alluvium are deeply eroded and degraded with little stabilising vegetation.

Downstream of these tributaries, North Wambo Creek flows in a broad, grassed gully, with a meandering incised main channel. The stream bed is mostly composed of sands and silts. There are persistent pools in these areas. The banks of the gully are in the order of 2 metres above the main channel through this zone.

The unnamed tributaries that flow in a SE direction into the downstream reach of North Wambo Creek, prior to its confluence with Wollombi Brook, do not demonstrate any significant channel formation. They are drainages from broad open pasture areas.

The downstream reaches of North Wambo Creek are located within a grassed, steep sided gully, with the banks in the order of four to five metres above the main channel. This style of formation persists through to the confluence with Wollombi Brook.

An unnamed road crosses North Wambo Creek on concrete box culvert sections, just upstream from the confluence with Wollombi Brook. There is a knickpoint developed immediately below the crossing.

The confluence with Wollombi Brook lies at a large permanent pool in Wollombi Brook.

A1.2.1 Photographic Record of Inspection of North Wambo Creek

The uppermost reach of North Wambo Creek that would be undermined by the Modification is the downstream end of the Stage 3 Diversion as shown in Plate 1.

Plate 1: Downstream end of North Wambo Creek Stage 3 Diversion (looking upstream)

Below the Diversion, North Wambo Creek flows across a zone of imported large rocks to stabilise the area where the Diversion discharges into the natural channel. This is shown in Plate 2.

Plate 2: Discharge zone from North Wambo Creek Stage 3 Diversion (looking upstream)

Below the diversion, North Wambo Creek flows into an open channel with low banks and a sandy bed, as shown in Plate 3.

Plate 3: North Wambo Creek channel below Diversion (looking upstream)

For approximately 250 metres below the Diversion, North Wambo Creek flows in this style of channel. The creek bed is generally sandy, with some gravels, some grass cover and low sloping banks. The sandy bed in this reach, which is reported to comprise material washed out of the Stage 3 Diversion in 2013, is indicative of a low energy stream with low slope.

The creek crosses a rock bar at approximately S32°35'4.58" E150°58'38.96", this rock bar is shown in Plate 4.

Plate 4: Rock Bar in North Wambo Creek (S32°35'4.58" E150°58'38.96", looking upstream)

Below this rock bar, North Wambo Creek continues to flow in an open channel, with a sand or gravel stream bed, some grass cover and low sloping banks. The stream is generally surrounded by trees, with mature eucalypts predominant on the northern bank and casuarinas in the channel and on the southern bank.

At approximately S32°35'9.08" E150°58'38.89", a small north east flowing tributary joins North Wambo Creek. This tributary flows in a generally degraded channel, with erosion evident, through an open casuarina woodland into North Wambo Creek. The style of channel and erosion is shown in Plate 5.

Plate 5: Small unnamed tributary of North Wambo Creek, with degraded channel and erosion (looking downstream)

Downstream on North Wambo Creek from this tributary one sees the first of some persistent pools and associated vegetation such as reeds. This is shown in Plate 6.

Plate 6: Persistent pool on North Wambo Creek (approx. S32°35'17.99" E150°58'52.26", looking upstream)

Previous underground mining has led to ponding on the north east flowing tributaries to North Wambo Creek, with the formation of small wetland areas as shown in Plate 7.

Plate 7: Small wetland SW of North Wambo Creek (S32°35'20.04" E150°58'50.80", looking west)

The tributary flows north east from this wetland to North Wambo Creek, again in a very degraded and eroded channel, as shown in Plate 8.

Plate 8 Small tributary flowing NE to North Wambo Creek (from wetland in Plate 6, looking downstream)

At the confluence of this small tributary and North Wambo Creek, the main channel is a broad open area, with a grassed bed, but with a near vertical bank on the south eastern side, as shown in Plate 9.

Plate 9 North Wambo Creek main channel, near confluence with small tributary (S32°35'18.57" E150°58'53.67", looking downstream)

Downstream North Wambo Creek continues to flow in a broad open gully, with a grass cover cover over most of the channel bed, however the main channel tends to be unvegetated, consisting mostly of sand and coarse gravel with a bed of casuarina needles as shown in Plate 10 and Plate 10: Bed of North Wambo Creek (S32°35'17.50" E150°58'55.48")

.

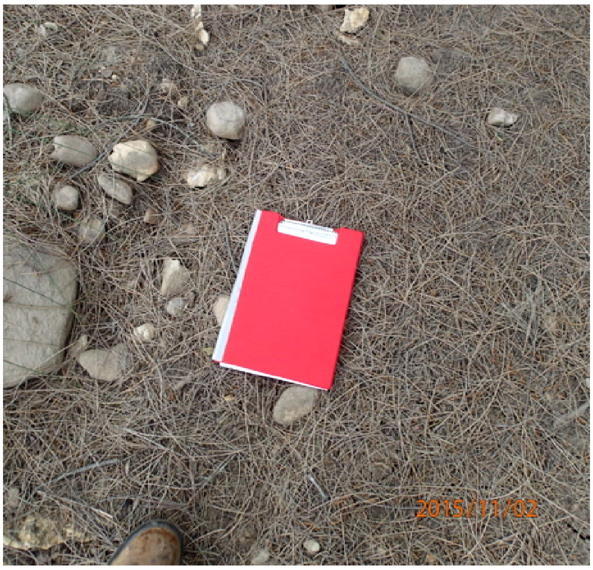


Plate 10: Bed of North Wambo Creek (S32°35'17.50" E150°58'55.48")

Plate 11: Main Channel of North Wambo Creek (S32°35'17.87" E150°58'56.67") (looking downstream)

The next tributary flows into North Wambo Creek through a wetland area as shown in Plate 12.

Plate 12: Wetland Area on Tributary to North Wambo Creek (S32°35'21.14" E150°58'56.59", looking upstream)

Downstream of these tributaries, North Wambo Creek flows in a broad, grassed gully, with a meandering incised main channel. The stream bed is mostly composed of sands and silts. There are persistent pools in these areas. Plate 13 shows the typical gully and incised main channel. The banks of the gully are in the order of 2 metres above the main channel through this zone.

Plate 13; North Wambo Creek downstream of NE flowing tributaries (looking upstream)

The unnamed tributaries that flow in a SE direction into the downstream reach of North Wambo Creek, prior to its confluence with Wollombi Brook, do not demonstrate any significant channel formation. They are drainages from broad open pasture areas.

The downstream reaches of North Wambo Creek are located within a grassed, steep sided gully, with the banks in the order of four to five metres above the main channel. This style of formation persists through to the confluence with Wollombi Brook.

An unnamed road crosses North Wambo Creek on concrete box culvert sections, just upstream from the confluence with Wollombi Brook. There is a knickpoint developed immediately below the crossing, as shown in Plate 14.

Plate 14: Road Crossing on North Wambo Creek (looking upstream)

Downstream from the crossing there is a rock bar in North Wambo Creek as shown in Plate 15.

Plate 15: Rock bar in North Wambo Creek (S32°35'31.15" E150°59'48.49", looking upstream)

The confluence with Wollombi Brook lies at a large permanent pool in Wollombi Brook as shown in Plate 16.

Plate 16: Pool in Wollombi Brook at confluence with North Wambo Creek (looking downstream)

A1.3 Stony Creek

Stony Creek has steep heavily forested headwaters with elevations ranging up to 650 m AHD on the ridges down to about 110 m AHD at the point where Stony Creek enters the Modification Area. The catchment area at this point is about 8.7 km^2. The creek gradient in the section upstream of the Modification area ranges from 5% to 12%. Downstream of the point where it enters the Modification Area, the creek flows in a south-westerly direction for about 4 km to join Wambo Creek, with gradients ranging from 5% to less than 1%.

Stony Creek upstream of the Modification area has a steep gradient with the stream bed comprised of quite large boulders and coarse gravels, this style of channel continues for approximately the first 600 metres of the Modification Area. Through this section of Stony Creek there are a few small rock bars.

After clearing the steeper gradients of the upstream forested area, the stream emerges into a small cleared area with a gravel stream bed. From this area until the confluence with Wambo Creek, Stony Creek flows across generally open pasture land with isolated stands of trees, and treelines generally following the banks of the stream channel. The stream bed consists mostly of sands and gravels.

In some locations, the stream has eroded an incised channel with vertical eroded banks that can be in the order of 1.5 metres high. In these reaches across the grassy plains, the stream bed varies between the fine silt/sand and the coarser and gravels. The stream gradient is generally quite flat.. In some locations, bank stabilisation works have been undertaken to inhibit further bank erosion or scour. There are also reaches where the channel is fully grassed over and the banks are stabilised with vegetation.

The confluence of Stony Creek and Wambo Creek is surrounded by trees, mostly casuarinas. The stream bed of Stony Creek approaching the confluence is dry and covered in casuarina deadfall.

A1.3.1 Photographic Record of Inspection of Stony Creek

Plate 17: Stony Creek upstream of the Modification Area (looking upstream)

As can be seen in Plate 17, Stony Creek upstream of the Modification area has a steep gradient with the stream bed comprised of quite large boulders and also coarse gravels as shown in Plate 18.

Plate 18 Stream bed of Stony Creek at upstream end of modification area

For approximately 600 metres after entering the Modification area, Stony Creek has a generally generally steep gradient with a stream bed consisting of coarse gravel and boulders as shown in

shown in Plate 19 and Plate 19 Stony Creek upstream sections (S32°35'27.71" E150°57'16.49", looking upstream)

.

Plate 19 Stony Creek upstream sections (S32°35'27.71" E150°57'16.49", looking upstream)

Plate 20 Stony Creek Upstream Section (looking upstream)

Through this section of Stony Creek there are a few small rock bars, such as those shown in Plate 21 and Plate 21 Rock bar in Stony Creek at S32°35'30.49" E150°57'24.69" (looking upstream)

.

Plate 21 Rock bar in Stony Creek at S32°35'30.49" E150°57'24.69" (looking upstream)

Plate 22 Rock bar in Stony Creek upstream section (looking upstream)

After clearing the steeper gradients of the upstream forested area, the stream emerges into a a small cleared area with a gravel stream bed, as shown in Plate 23 and Plate 23Stony Creek in first clearing (looking downstream)

.

Plate 23Stony Creek in first clearing (looking downstream)

Plate 24 Stony Creek in clearing (S32°35'32.00" E150°57'38.00", looking upstream)

From this area until the confluence with Wambo Creek, Stony Creek flows across generally open pasture land with isolated stands of trees, and treelines generally following the banks of the stream channel. The stream bed consists mostly of sands and gravels, as shown in Plate 25 and Plate 25: Stony Creek Crossing open field (S32°35'37.00" E150°57'42.97", looking downstream).

Plate 25: Stony Creek Crossing open field (S32°35'37.00" E150°57'42.97", looking downstream)

Plate 26: Typical Sand/Gravel Stream Bed at the location shown in Plate 25

In some locations, the stream has eroded an incised channel with vertical eroded banks as shown in Plate 27 and Plate 27: Eroded vertical banks to main channel in Stony Creek (looking downstream)

. The eroded banks can be in the order of 1.5 metres high.

Plate 27: Eroded vertical banks to main channel in Stony Creek (looking downstream)

Plate 28: Eroded vertical banks on Stony Creek main channel, approximately 1.5m high (looking downstream)

In these reaches across the grassy plains, the stream bed varies between the fine silt/sand shown shown in Plate 29 and the coarser sand and gravels as seen in Plate 30: Eroded main stream channel Stony Creek (S32°35'38.98" E150°57'52.78", looking downstream)

.

Plate 29: Fine sand stream bed in main channel of Stony Creek

Plate 30: Eroded main stream channel Stony Creek (S32°35'38.98" E150°57'52.78", looking downstream)

Plate 31: Coarse gravel and sand stream bed in Stony Creek

Plate 32: Stony Creek (S32°35'43.77" E150°57'54.19", looking upstream)

Plate 33: Fine silt/sand stream bed downstream of reach shown in Plate 32

Plate 34: Coarse gravel and sand stream bed downstream of Plate 32: Stony Creek (S32°35'43.77" E150°57'54.19", looking upstream)

Plate 35: Stony Creek main channel with sand/gravel stream bed, low eroded banks and flat gradient (looking downstream)

In some locations, such as shown in Plate 36, bank stabilisation works have been undertaken to inhibit further bank erosion or scour.

Plate 36: Bank stabilisation works in Stony Creek (S32°36'10.81" E150°58'13.73", looking downstream)

There are also reaches such as shown in Plate 37 and Plate 37: Grass cover over main channel of Stony Creek (S32°35'47.53" E150°58'3.11", looking downstream)

, where the channel is fully grassed over and the banks are stabilised with vegetation.

Plate 37: Grass cover over main channel of Stony Creek (S32°35'47.53" E150°58'3.11", looking downstream)

Plate 38: Defined main channel with sloping banks and grass cover (S32°35'48.13" E150°58'5.11", looking downstream)

The stream bed varies greatly between the fully grassed over locations as shown above, and the sand or gravel stream bed as shown in Plate 39.

Plate 39: Main channel with grassed banks and gravel stream bed (S32°35'50.14" E150°58'7.85", looking downstream)

Plate 40: Eroded banks and incised main channel (S32°35'54.65" E150°58'8.48", looking upstream)

Plate 41: Main channel of Stony Creek with eroded banks and gravel stream bed (looking upstream)

Plate 42: Sandy stream bed just upstream of confluence with Wambo Creek (looking downstream)

The confluence of Stony Creek and Wambo Creek surrounded by trees, mostly casuarinas as shown in Plate 43 and Plate 44.

Plate 43: Confluence of Stony Creek and Wambo Creek (looking downstream)

Plate 44: Casuarinas at confluence of Stony Creek and Wambo Creek

The stream bed at the confluence of the creeks is generally dry, and covered in casuarina deadfall.

Plate 45: Confluence of Stony Creek and Wambo Creek (looking upstream on Stony Creek)

A1.4 Wambo Creek

The Wambo Creek rises in the Wollemi National Park escarpment west of the mine area and extends to the confluence with Wollombi Brook in the east of the Modification area. The natural catchment has a total area of some 43.2 square kilometres (km^2) which contains two distinct landforms: steep, heavily forested, headwaters with elevations ranging up to 450 metres Australian Height Datum(m AHD) on the ridges down to about 110 m AHD where the creek drains onto open country over a distance of about 7.5 kilometres (km) to Wollombi Brook across cleared grassy plains with scattered trees and vegetation.

Wambo Creek may be impacted by the Modification in the reach between the confluence with Stony Creek and the confluence with Wollombi Brook, a distance of approximately 1.8 kilometres (km). The characterisation of Wambo Creek has focussed on the reach downstream of the confluence with Stony Creek.

Wambo creek immediately downstream of the confluence with Stony Creek is a shallow channel, surrounded by casuarinas. The stream gradient is relatively flat, wth a sandy bottom covered by casuarina deadfall. Moving downstream from the confluence, the channel of Wambo Creek becomes deeper and more defined. There are a number of permanent pools in these reaches. Moving downstream from the sections surrounded by casuarinas, the stream bed is generally sand or gravel. The channel is more incised and the banks are eroded.

Wambo Creek crosses Wambo Road, and downstream from the crossing the channel becomes deeper, with banks over 2 metres high. Just upstream of the confluence with Wollombi Brook there is a rock bar across the stream bed, with some quarried rock in the stream bank, this would appear to be the remains of a former weir structure.

There is a permanent pool at the confluence with Wollombi Brook.

A1.4.1 Photographic Record of Inspection of Wambo Creek

As shown in Plate 46, Wambo creek immediately downstream of the confluence with Stony Creek is a shallow channel, surrounded by casuarinas. The stream gradient is relatively flat, wth a sandy bottom covered by casuarina deadfall.

Plate 46: Wambo Creek Channel downstream of Confluence with Stony Creek (looking downstream)

Moving downstream from the confluence, the channel of Wambo Creek becomes deeper and defined. There are a number of permanent pools, as shown in Plate 47 and Plate 47:Permanent pool in Wambo Creek (looking upstream)

.

Plate 47:Permanent pool in Wambo Creek (looking upstream)

Plate 48: Permanent pool in Wambo Creek, incised channel with silt/sand stream bed (looking downstream)

Moving downstream from the sections surrounded by casuarinas, the stream bed is generally a or gravel, as shown in Plate 49, Plate 49: Wambo Creek with eroded banks and gravel stream bed (looking upstream)

, and Plate 50: Gravel stream bed in Wambo Creek

.

Plate 49: Wambo Creek with eroded banks and gravel stream bed (looking upstream)

Plate 50: Gravel stream bed in Wambo Creek

Plate 51; Sand stream bed in Wambo Creek

Moving downstream towards the crossing at Wambo Road, the channel becomes broader and open, as shown in Plate 52 and Plate 52: Wambo Creek – permanent pool and eroded banks upstream of Wambo Road (looking upstream)

. In some areas the banks are eroded, and there are permanent pools.

Plate 52: Wambo Creek – permanent pool and eroded banks upstream of Wambo Road (looking upstream)

Plate 53: Wambo Creek – open channel upstream of Wambo Road, grass cover and sand/gravel bed (looking upstream)

Downstream of the Wambo Road crossing, the channel becomes deeper, with banks over 2 metres high, as shown in Plate 54.

Plate 54: Wambo Creek –incised channel and eroded banks downstream of Wambo Road (looking upstream)

Just upstream of the confluence with Wollombi Brook there is a rock bar across the stream bed, with some quarried rock in the stream bank as shown in Plate 55. This would appear to be the remains of a former weir structure.

Plate 55: Wambo Creek – rock bar and quarried rock just upstream of confluence with Wollombi Brook (looking downstream)

There is a permanent pool at the confluence with Wollombi Brook, as shown in Plate 56.

Plate 56: Wambo Creek – permanent pool at confluence with Wollombi Brook

Plate 57: Confluence of Wambo Creek and Wollombi Brook

Plate 58: Wambo Creek and Wollombi Brook Confluence

A1.5 Unnamed Drainage Line 1

There are three unnamed watercourses in the southern part of the Modification area that may be impacted by the Modification. These three streams drain in a generally north-easterly direction into Wollombi Brook. For the purpose of this report, we have designated the streams as Unnamed Drainage Line 1, Unnamed Drainage Line 2, and Unnamed Drainage Line 3, with the numbering running from north to south.

Unnamed Drainage Line 1 (UW1) is a first order stream, with a total length of approximately 1.8 kilometres (km). There are a number of permanent pools along the stream, with a large permanent pool just downstream of the crossing of Wambo Road before the confluence with Wollombi Brook. This pool appears to have been augmented by excavation. The crossing of Wambo Road is through two concrete pipes.

Plate 59: UW1 looking towards Wambo Road

Plate 60: UW1 – Minor erosion upstream of Wambo Road

Plate 61: UW1 Culvert crossing of Wambo Road, downstream side

Plate 62: UW1 Upstream side of culvert under Wambo Road

Plate 63: UW1, downstream side of culvert, large permanent pool

Plate 64 UW1 – permanent pool downstream of Wambo Road

A1.6 Unnamed Drainage Line 2

Unnamed Drainage Line 2 (UW2) is a second order stream, flowing out of the forested ridge country in the Wollemi National Park. It begins at an elevation of around 320 metres AHD, and flows in a well-defined gully down to an elevation around 100 metres AHD where it flows across open grassy plains with no defined channel. It has a length of around 3.5 kilometres to its confluence with Wollombi Brook.

Approximately 700 metres upstream from Wollombi Brook there is a constructed contour bank across the valley. From this contour bank the stream flows in a constructed drain channel to a large permanent pool, just upstream of Wambo Road. Wambo Road effectively dams this pool, with the overflow through a concrete culvert and thence flowing in a poorly defined channel to Wollombi Brook.

Plate 65: UW2 – contour bank across stream path looking North

Plate 66: UW2 – looking downstream over permanent pool to Wambo Road and Wollombi Brook in background

Plate 67: UW2 – looking upstream from Wambo Road over permanent pool

A1.7 Unnamed Drainage Line 3

Unnamed Drainage Line 3 (UW3) is a first order stream, rising in the Wollemi National Park at an elevation of approximately 170 metres AHD, with a total length of about 3 kilometres (km). The channel is poorly defined over most of the length of the stream, until it reaches two small pools on either side of the Wambo Road. A concrete culvert transfers the flow across Wambo Road.

Plate 68: UW3 – Looking upstream from Wambo Road over permanent pool

Plate 69: UW3 – Culvert under Wambo Road

Plate 70: UW3 – looking downstream from Wambo Road to Wollombi Brook

Appendix B

Creek Flow Records – North Wambo, Stony and Wambo Creeks

B.1 Flow Monitoring on North Wambo, Stony and Wambo Creeks

WCPL operate nine flow gauging stations located along North Wambo Creek, Stony Creek and South Wambo Creek as shown in **Figure 2.1** and described in Table 2.2. The ephemeral nature of these creeks has resulted in extended no-flow periods. A summary of the stream flow data for the WCPL operated stations is provided in Table B.1.

The available flow monitoring data for North Wambo Creek show that the creek is ephemeral and typically only flows in response to intense rainfall. This can be seen in the following plots (**Figures B.1 to B.3**) which show monitored (non-zero) daily flow data and concurrent daily rainfall measured at the WCPL climate station (WCPL, 2015a).

Stony Creek and Wambo Creek are also ephemeral and typically only flow in response to intense rainfall.

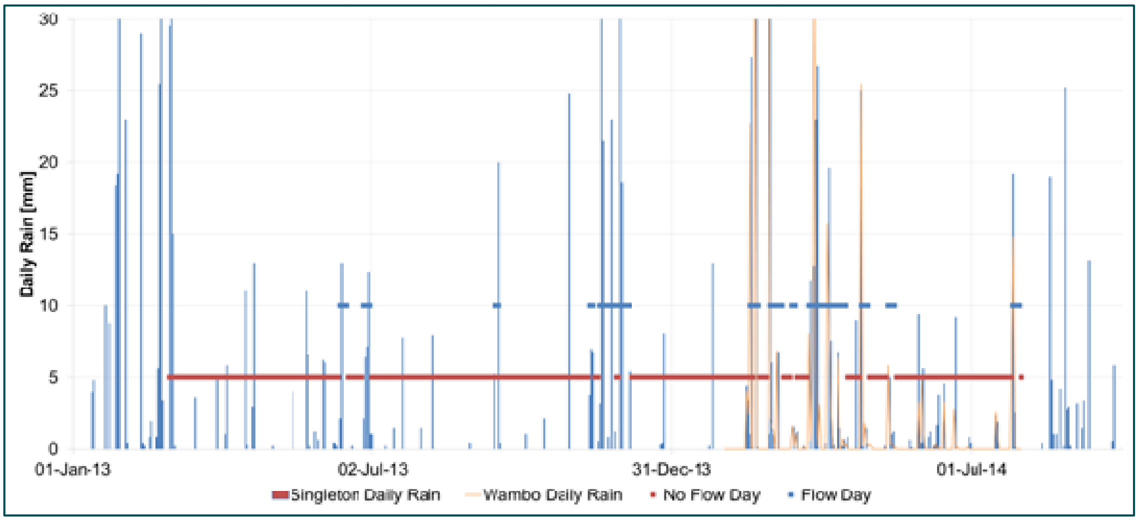


Figure B.1 Recorded Daily Rainfall and Flow and No Flow Days – North Wambo Creek at FM2 (WCPL, 2015a)

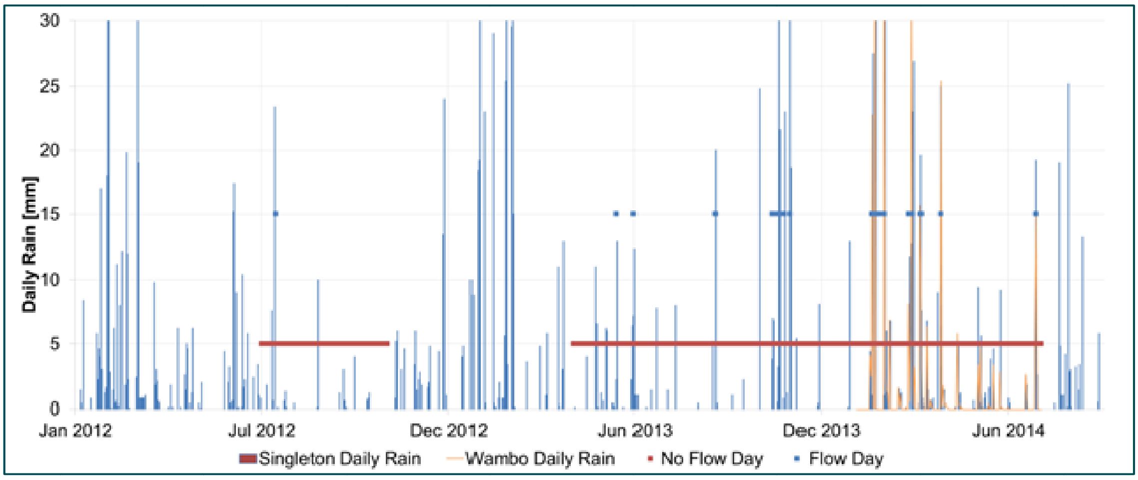


Figure B.2 Recorded Daily Rainfall and Flow and No Flow Days – North Wambo Creek at FM3 (WCPL, 2015a)

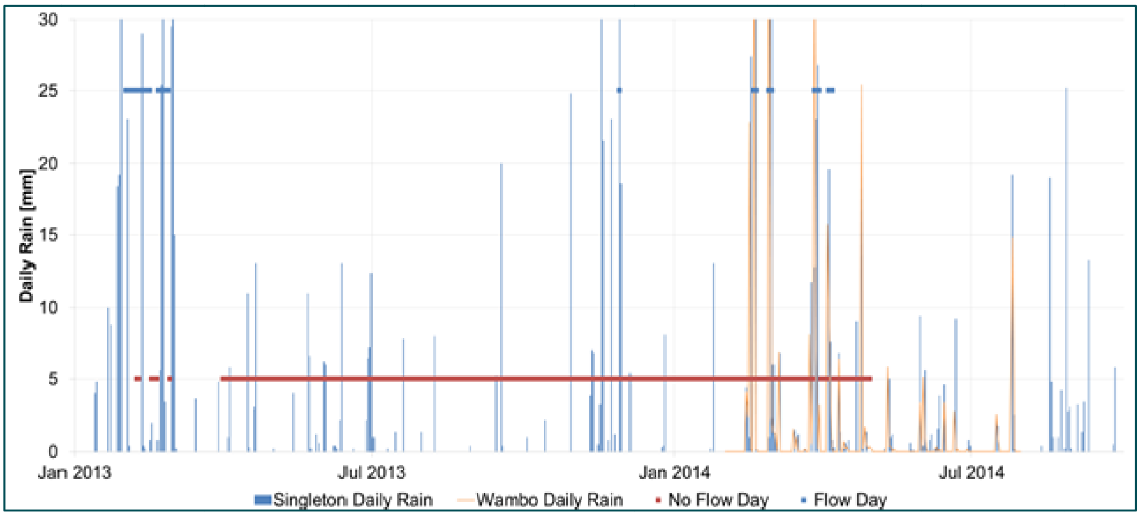


Figure B.3 Recorded Daily Rainfall and Flow and No Flow Days – North Wambo Creek at FM4 (WCPL, 2015a)

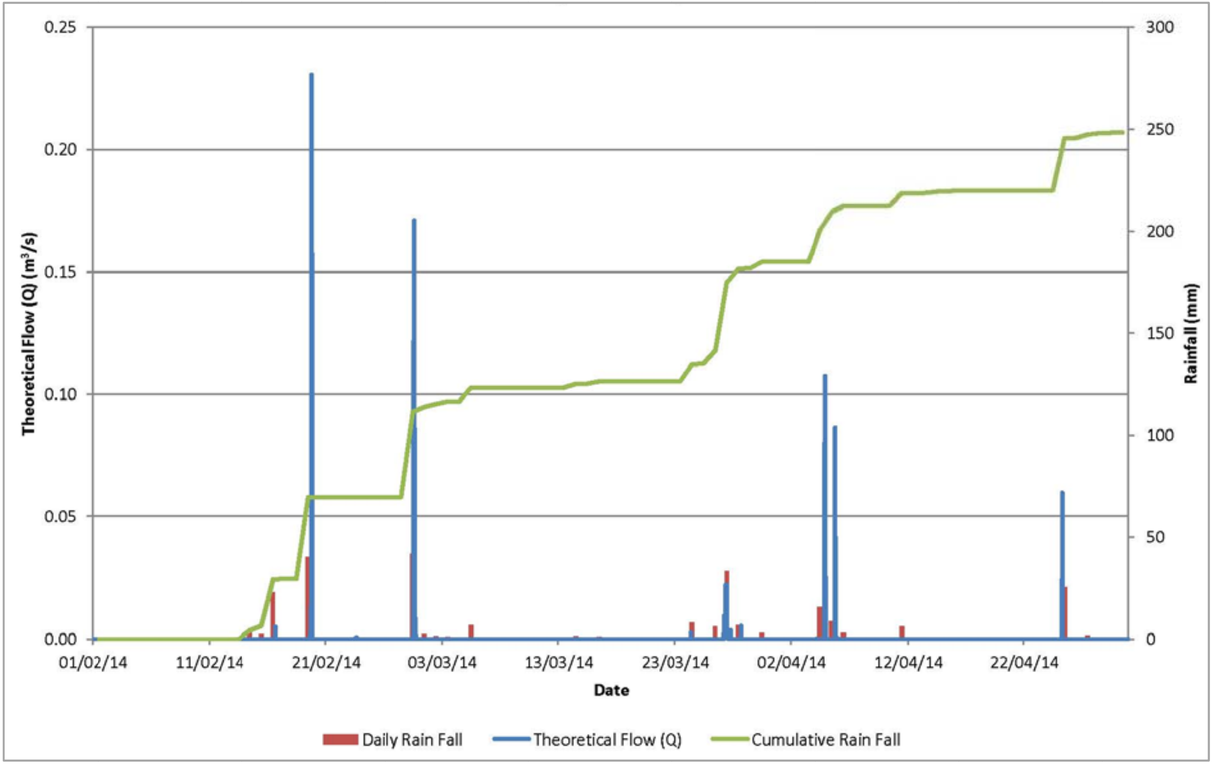
Table B.1 Stream Flow Summary (WCPL, 2015a)

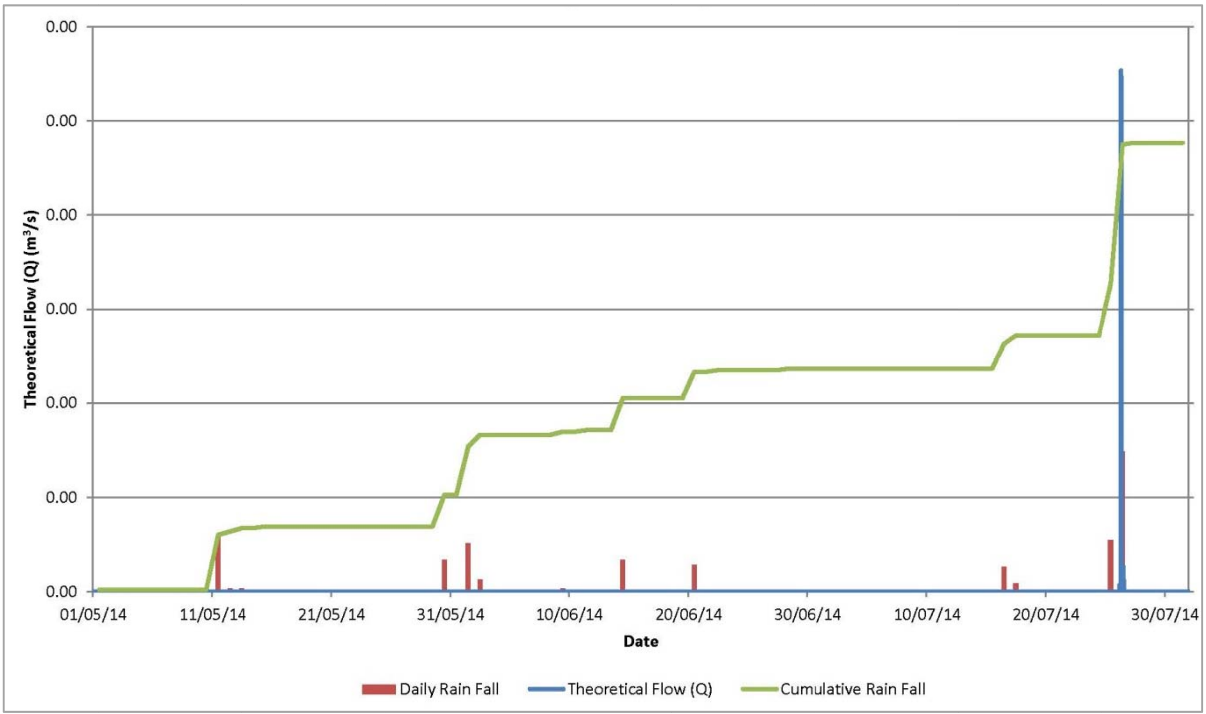
Site	Period of Record	Flow Days	Max Flow (ML/Day)	Mean Flow Per Day (ML/Day)	Percentage of Results with No Data
FM1	21/10/2008 to 01/12/2009	31	264.81	0.77	NA
	02/12/2009 to 30/06/2012	No flow data available			
	01/07/2012 to 30/06/2013	NA	1.296	0.086	16.70%
	01/07/2013 to 31/01/2014	NA	NA	NA	85.70%
	01/02/2014 to 19/08/2014	No flow data available			
FM2	12/04/2009 to 01/12/2009	6.5	0.05	NA	NA
	02/12/2009 to 30/06/2012	No flow data available			
	01/07/2012 to 30/06/2013	9	0.39	<0.09	66.70%
	01/07/2013 to 31/01/2014	NA	18.1	0.69	0.00%
	01/02/2014 to 19/08/2014	42	22.59	1.57	Negligible
FM3	12/04/2009 to 01/12/2009	6	0.08	NA	NA
	02/12/2009 to 30/06/2012	No flow data available			
	01/07/2012 to 30/06/2013	2	320	69.1	50.00%
	01/07/2013 to 31/01/2014	NA	20.4	0.04	0.00%
	01/02/2014 to 19/08/2014	2	19.65	5.34	Negligible
FM4	21/10/2008 to 01/12/2009	391	237.14	1.36	NA
	02/12/2009 to 30/06/2012	No flow data available			
	01/07/2012 to 30/06/2013	21	200.8	86.8	58.30%
	01/07/2013 to 31/01/2014	0	0	0	14.30%
	01/02/2014 to 19/08/2014	6	291.28	59.07	Negligible
FM5	21/10/2008 to 01/12/2009	36	361.91	1.34	NA
	02/12/2009 to 30/06/2012	No flow data available			
	01/07/2012 to 30/06/2013	No flow data available			
	01/07/2013 to 31/01/2014	No flow data available			
	01/02/2014 to 19/08/2014	No flow data available			
FM6	21/10/2008 to 01/12/2009	113	252.59	0.78	NA
	02/12/2009 to 30/06/2012	No flow data available			
	01/07/2012 to 30/06/2013	NA	7536	906	50.00%
	01/07/2013 to 31/01/2014	No flow data available			
	01/02/2014 to 19/08/2014	No flow data available			
FM7	21/10/2008 to 01/12/2009	100	56.81	0.33	NA
	02/12/2009 to 30/06/2012	No flow data available			
	01/07/2012 to 30/06/2013	NA	0	0	33.30%
	01/07/2013 to 31/01/2014	No flow data available			
	01/02/2014 to 19/08/2014	No flow data available			
FM8	21/10/2008 to 01/12/2009	108	46.04	0.31	NA
	02/12/2009 to 30/06/2012	No flow data available			
	01/07/2012 to 30/06/2013	NA	11.8	8.94	33.30%
	01/07/2013 to 31/01/2014	No flow data available			
	01/02/2014 to 19/08/2014	No flow data available			
FM9	Installed on 01/12/2009	NA	NA	NA	NA
	02/12/2009 to 30/06/2012	No flow data available			
	01/07/2012 to 30/06/2013	NA	6.05	3.46	25.00%
	01/07/2013 to 31/01/2014	No flow data available			
	01/02/2014 to 19/08/2014	No flow data available			

Advisian
WorleyParsons Group

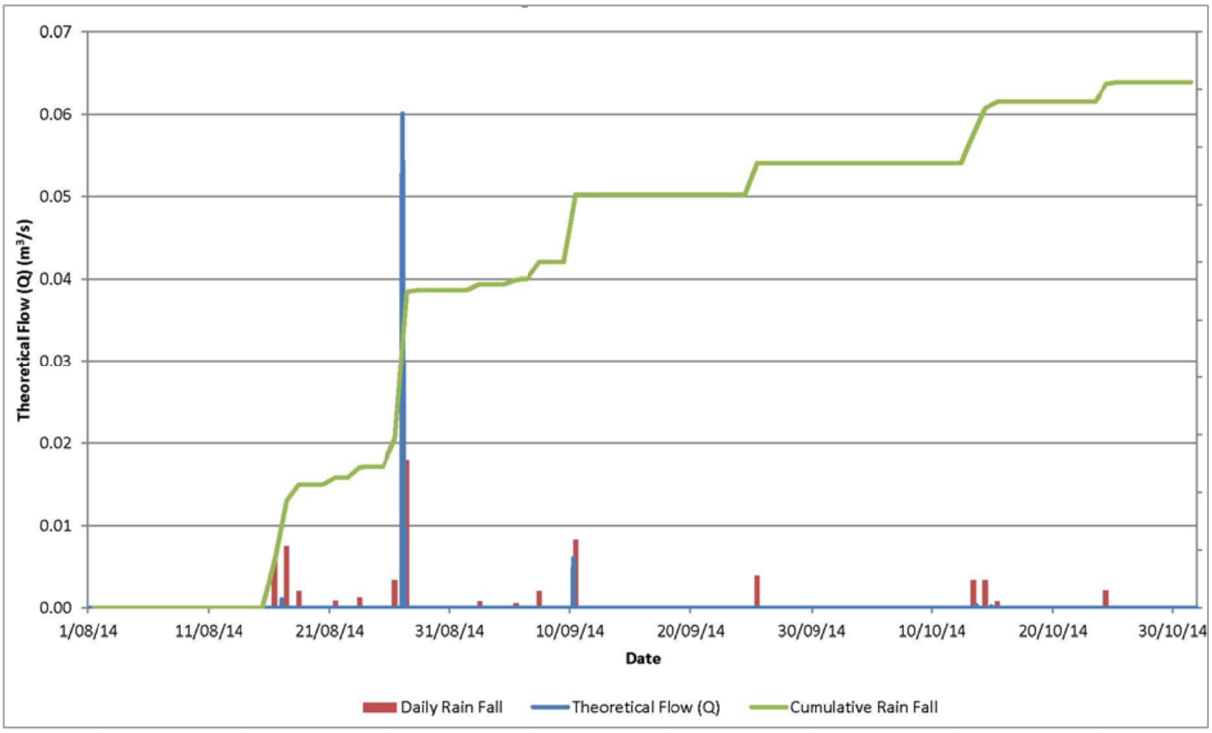
Rainfall and Flow Records for North Wambo Creek Flow Monitoring Station 3

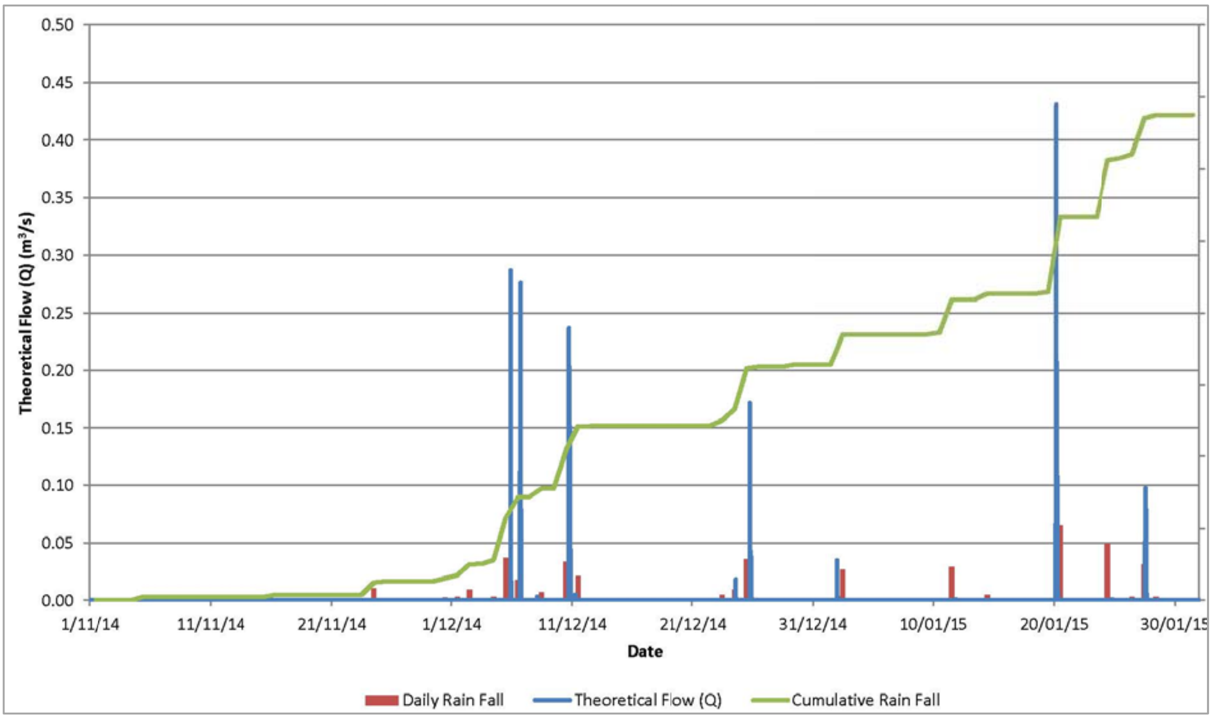
Note that 'Theoretical Flow' refers to flow calculated based on the recorded water level

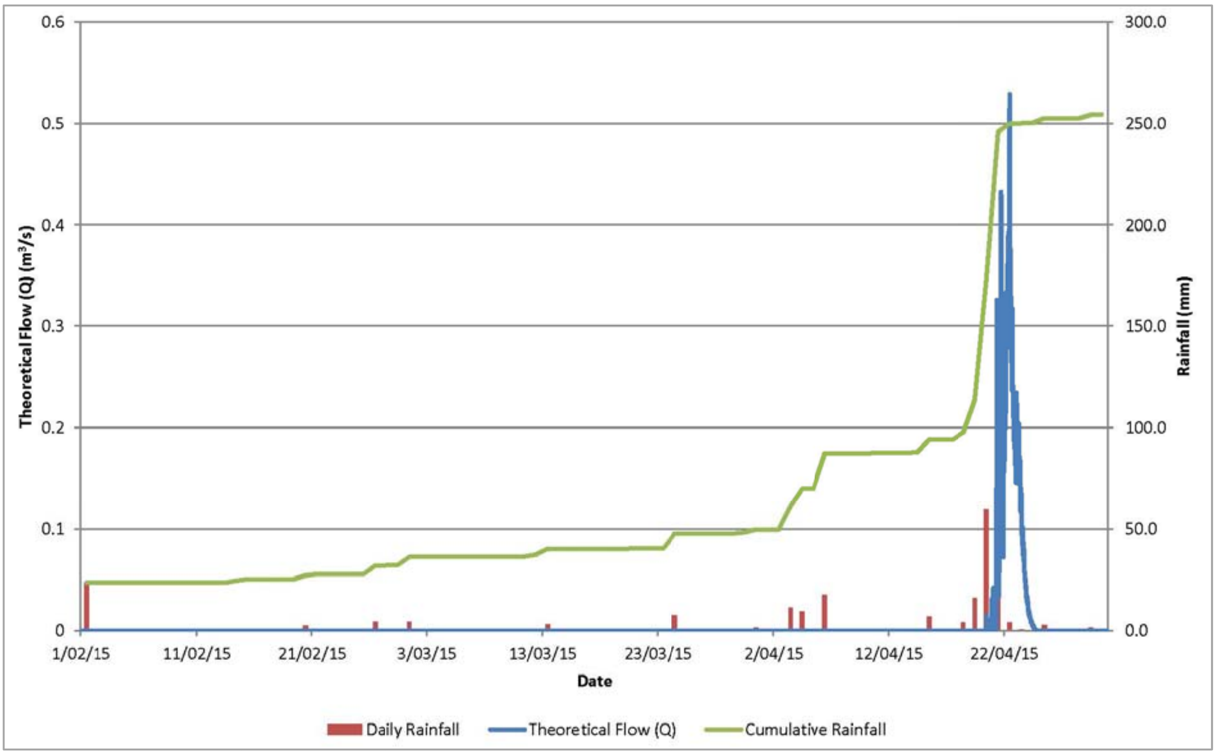




Advisian
WorleyParsons Group






0.6
0.5
0.4
0.3
0.2
0.1
0
Theoretical Flow (Q) (m³/s)
300.0
250.0
200.0
150.0
100.0
50.0
0.0
Rainfall (mm)
1/02/15
11/02/15
21/02/15
3/03/15
13/03/15
23/03/15
2/04/15
12/04/15
22/04/15
Date
Daily Rainfall
Theoretical Flow (Q)
Cumulative Rainfall