APPENDIX 1

Statement of Authorship

Statement of Authorship

EA prepared by	
Name:	Tim Crosdale, Group Manager
Qualifications:	Bachelor of Natural Resources, Honours Class 1 Bachelor of Urban and Regional Planning Master of Business Administration (Distinction)
Address:	Umwelt (Australia) Pty Limited 75 York Street Teralba NSW 2284
In respect of:	Invincible Southern Extension Project Environmental Assessment - Section 75W Modification
Applicant Name:	Castlereagh Coal (Shoalhaven Coal Pty Ltd)
Applicant Address:	6 Frank St Gladesville NSW 2111
Land to be developed:	See Environmental Assessment (EA) for the Schedule of Lands.
Proposed Development:	Invincible Southern Extension Area as described in the accompanying Environmental Assessment.
Environmental Assessment	An EA is attached.
Certification	I certify that I have prepared the contents of this environmental assessment and to the best of my knowledge: • it is in accordance with the relevant provisions of the *Environmental Planning and Assessment Act 1979*, and • it is true in all material particulars and does not, by its presentation or omission of information, materially mislead.
Signature:	
Name:	Tim Crosdale
Date:	19 September 2016

Schedule of Lands

Lot	DP
Part Ben Bullen State Forest	
1	180294
113	877190
112	877190

APPENDIX 2

Project Team

Project Team

Umwelt (Australia) Pty Limited – EA Preparation	
Tim Crosdale, Group Manager - NSW B Nat Res (Hons), B UrbRegPlan, MBA	Project Director
David Holmes, Principal Environmental Consultant B Nat Res (Hons), LLB (Hons), Grad Dip Legal Practice	Project Manager
Naiomi Finlayson, Environmental Planner B Urb & Env Plan, M Env Bus Mgt	Project Coordinator
Allison Riley Principal Ecologist B Sc	Ecological Assessment
Shaun Corry, Senior Ecologist B Sc (Biology), Dip Cons & Land Mgt, Cert 3 Cons & Land Mgt	Ecological Assessment
Susan Shield, Manager Water Resources Engineering/Associate B E (Hons), M E (Water)	Surface Water Assessment and Water Balance Assessment
Kris Longmore, Senior Environmental Engineer B Eng (Mech) (Hons), M Env Eng Sc, M Arts	Surface Water Assessment
Chris Bonomini, Senior Environmental/Process Engineer B Eng (Chem)	Surface Water Assessment and Water Balance Assessment
Tim Procter, Manager Engineering Services/Associate B Eng (Chem) (Hons)	Noise Impact Assessment
Glen Homes, Principal Acoustic Consultant BE Mech (Hons), MIEAust CPEng	Noise Impact Assessment
Anthony van der Horst, Process/Environmental Engineer B Eng (Chem) (Hons)	Noise Impact Assessment
Nicola Roche, Principal Archaeologist BA (Anthropology), BA (Anthropology) (Hons)	Aboriginal Cultural Heritage and Archaeological Assessment

Umwelt (Australia) Pty Limited – EA Preparation	
Alison Lamond, Archaeologist BA (Hons), B Sc (Geology and Geophysics)	Aboriginal Cultural Heritage and Archaeological Assessment
Malcolm Sedgwick, Principal Energy & Greenhouse Specialist B Sc	Greenhouse Gas and Energy Assessment
Dr Sheridan Coakes, Practice Lead Social Assessment and Community Engagement B App Sc (Hons) Psych, PhD Psych	Social Impact Assessment
Narelle Wolfe, Principal Social Consultant, B Sc (Hons)	Social Impact Assessment
Kristine Bencke, Senior Social Scientist B Soc Sc	Social Impact Assessment
Ian Kennedy, Design, Drafting & GIS Manager	Visual Impact Assessment Modelling, Graphic Design, Drafting
Michael Ong, Senior Draftsperson	Drafting
Joelle Brockman, Project Administrator	Report Formatting and document Control

Other Specialist Investigations	
Australasian Groundwater and Environmental Consultants Pty Ltd Costante Conte	Groundwater Impact Assessment
Jacobs Group (Australia) Pty Ltd Shane Lakmaker	Air Quality Impact Assessment
Enviro Strata Consulting Pty Ltd Thomas Lewandowski Katarina Lewandowski	Blasting Impact Assessment
Transport & Urban Planning Pty Ltd Terry Lawrence	Traffic Impact Assessment
Cadence Economics Pty Ltd George Michalas	Economic Impacts Assessment

The assistance of the following Castlereagh Coal personnel during the preparation of this EA is gratefully acknowledged. In addition, personnel from Castlereagh Coal provided details regarding the project and participated in the community consultation process.

Castlereagh Coal	
Brett Moore	Project Manager
Graham Goodwin	Mine Manager

APPENDIX 3

Agency Correspondence

Planning Services
Resource Assessments

Tel: 02 9228 6587
Email: paul.freeman@planning.nsw.gov.au

Our Ref: 11/11161

Mr David Holmes
Principal Environmental Consultant
Umwelt (Australia) Pty Limited
75 York Street
TERALBA NSW 2284

Dear Mr Holmes

Invincible Colliery 07_0127
Section 75W Modification

I refer to your letter dated 24 November 2015 requesting the Department's advice on the approval pathway for a proposed modification to the Invincible Colliery.

The Department has carefully reviewed the information you provided in support of the request to modify the project approval using Section 75W of the *Environmental Planning and Assessment Act 1979*.

The Department notes the scale of the proposal, and that it only involves a minor extension to the south of the existing open-cut pit at the Invincible Mine. The Department notes that the proposal would not change any other aspects of the approved operations at the mine, including the coal production rate, coal handling and transport arrangements. Accordingly, the Department confirms that Section 75W is the appropriate approval pathway for the proposed modification.

The Department will not issue formal Environmental Assessment Requirements for the proposed modification, as it considers the assessment approach and issues detailed in your letter are reasonable. However, the company should ensure that the level of environmental assessment is commensurate with the scale of the proposed modification and the likely environmental impacts.

The Department will review the Environmental Assessment (EA) to see if it has adequately assessed the environmental impacts of the proposal, in accordance with applicable NSW Government policies and guidelines, before placing it on public exhibition.

I would appreciate it if you could contact the Department at least 2 weeks before you intend to lodge the modification application and EA, to:

- confirm the applicable fee (in accordance with clause 245K of the *Environmental Planning and Assessment Regulation 2000*); and
- determine the number of copies of the EA required for the public exhibition.

If you wish to discuss the matter further, please contact Paul Freeman, on (02) 9228 6587.

Yours sincerely

Mike Young
Director
Resource Assessments
(as nominee of the Secretary)

8.2.16.

APPENDIX 4

Surface Water Assessment

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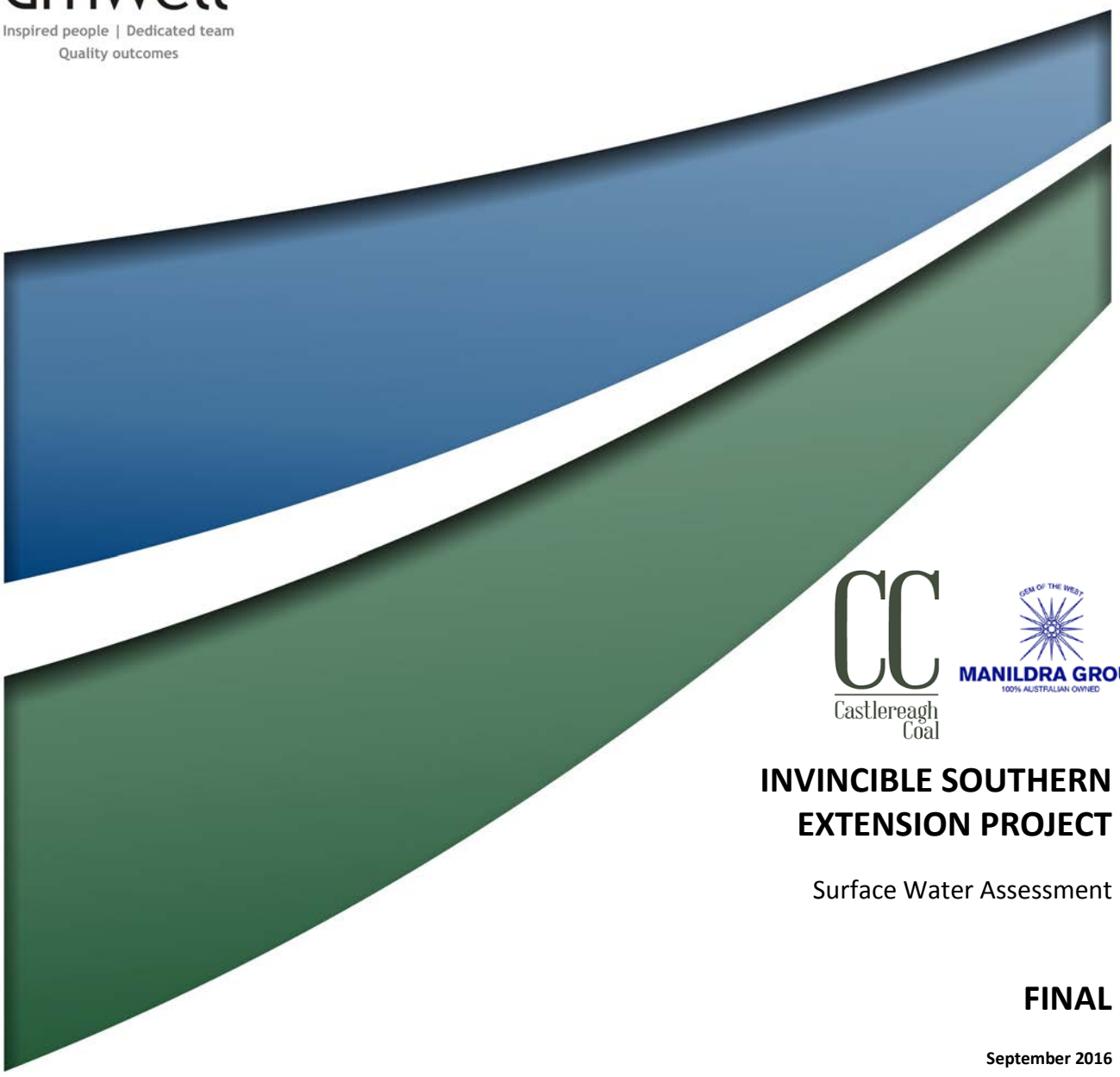
Inspired people | Dedicated team
Quality outcomes



Castlereagh Coal

MANILDRA GROUP
100% AUSTRALIAN OWNED

INVINCIBLE SOUTHERN EXTENSION PROJECT

Surface Water Assessment

FINAL

September 2016

INVINCIBLE SOUTHERN EXTENSION PROJECT

Surface Water Assessment

FINAL

Prepared by
Umwelt (Australia) Pty Limited
on behalf of
Castlereagh Coal

Project Director:	Tim Crosdale
Project Manager:	David Holmes
Technical Director:	Susan Shield
Report No.	3622/R07/FINAL
Date:	September 2016

Newcastle

75 York Street
Teralba NSW 2284

Ph. 02 4950 5322

www.umwelt.com.au

This report was prepared using Umwelt's ISO 9001 certified Quality Management System.

Table of Contents

Figures

Tables

1.0 Introduction

1.1 Project Overview

The Invincible Southern Extension Project (Southern Extension Project) is an extension of open cut mining operations to the south of the existing approved mining area at Invincible Colliery (Invincible). Invincible is located approximately 25 kilometres north-west of Lithgow in NSW. **Figure 1.1** shows the location of the Southern Extension Project in its regional context.

The Southern Extension Project includes:

- Extending the period in which mining can continue for a period of 8 years from approval of the modification application.
- Extending the open cut mining area immediately south of the existing mining disturbance area. Extraction of coal from all seams down to, and including the Lithgow seam. No highwall mining or open cut mining in any other areas of Invincible is proposed as part of the Project
- Continued use of existing Invincible infrastructure (including operation of, and maintenance work on, the existing Coal Preparation Plant)
- Use of existing open cut voids and former underground workings for water storage.
- No change to currently approved mining production rates
- No change to currently approved product coal transport arrangements with coal to be transported from the site by road truck to either the Shoalhaven Starches Plant or Mt Piper Power Station.
- Rehabilitation of the proposed Southern Extension Area and all existing disturbance areas at Invincible by reshaping mining areas to remove voids and revegetating the reshaped landform with locally endemic woodland and forest communities.

The key features of the Southern Extension Project are shown on **Figure 1.2**.

The purpose of the Project is to provide Manildra's Shoalhaven Starches Plant with a reliable and cost effective source of specialty nut coal for its Bomaderry operations on the NSW South Coast. The Lithgow Seam resources, when washed, will provide approximately 300 kt of nut coal for the Shoalhaven Starches Plant. The current demand per annum for nut coal at Shoalhaven Starches is approximately 85 ktpa. The nut coal resource available in the Lithgow Seam in the Southern Extension Area equates to approximately 4 years supply of nut coal for the Shoalhaven Starches Plant if Invincible is the sole source of supply. Coal from the Lidsdale and Irondale seams which is unsuitable for use in Shoalhaven Starches plant will be sold to the Mt Piper Power Station.

Castlereagh Coal are seeking approval for the extension of mining to occur over a period of up to 8 years to provide for flexibility in the supply of nut coal through:

- providing an option for Manildra to source all required nut coal directly from Invincible
- continuing to source nut coal from a range of other existing sources supplemented by supply from Invincible where necessary or cost effective to do so
- utilising a blended product using coal from the other seams within the Southern Extension Area where this can be used at the Shoalhaven Starches Plant.

This assessment has assumed a conservative mining scenario of up to maximum limits of production to provide a conservative assessment of impacts over the life of the Project.

Table 1.1 summarises the key features of the Southern Extension Project and compares these to the existing approved operations at Invincible.

The existing operations are shown on **Figures 1.3** and **1.4**.

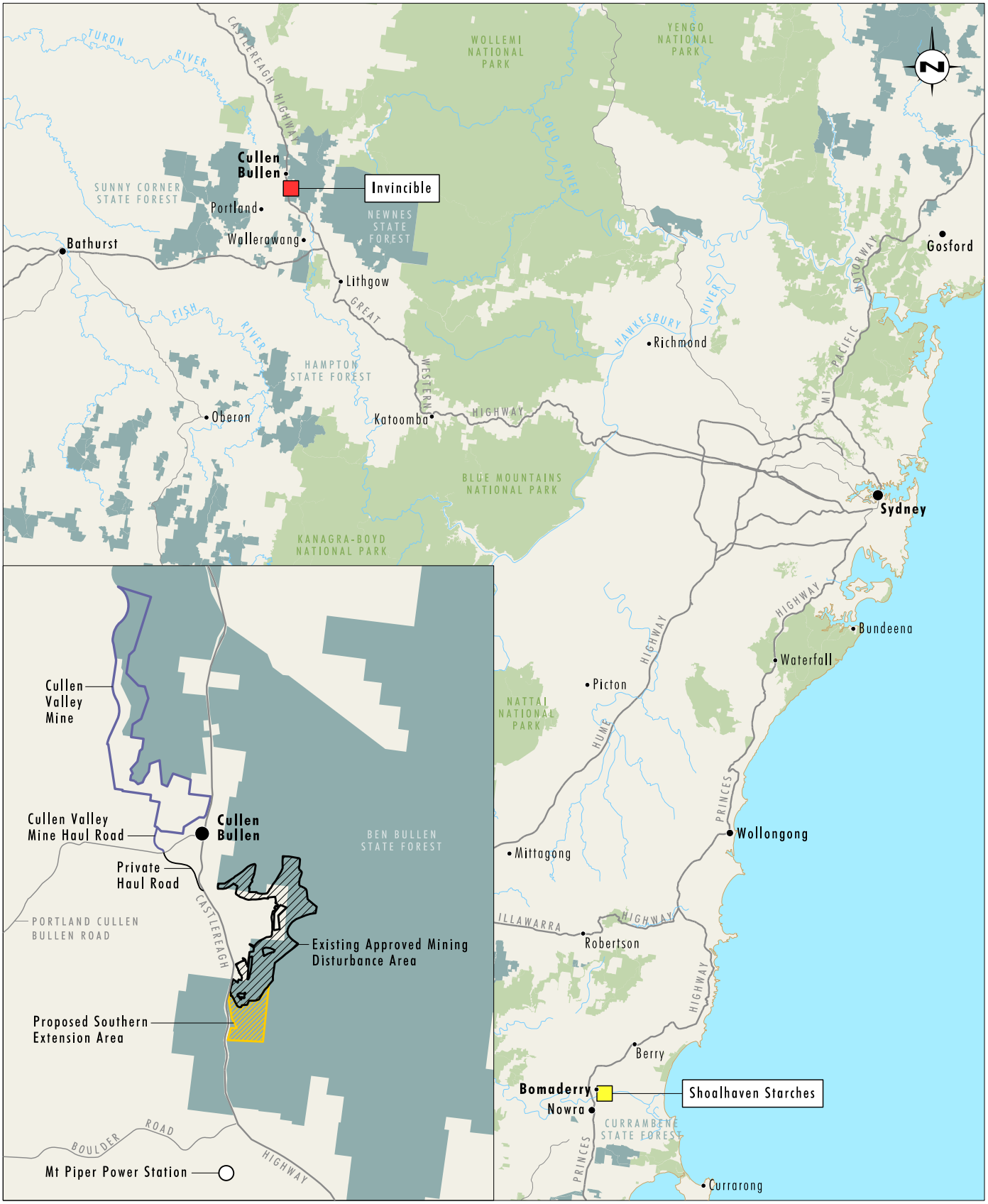


FIGURE 1.1

Locality Plan

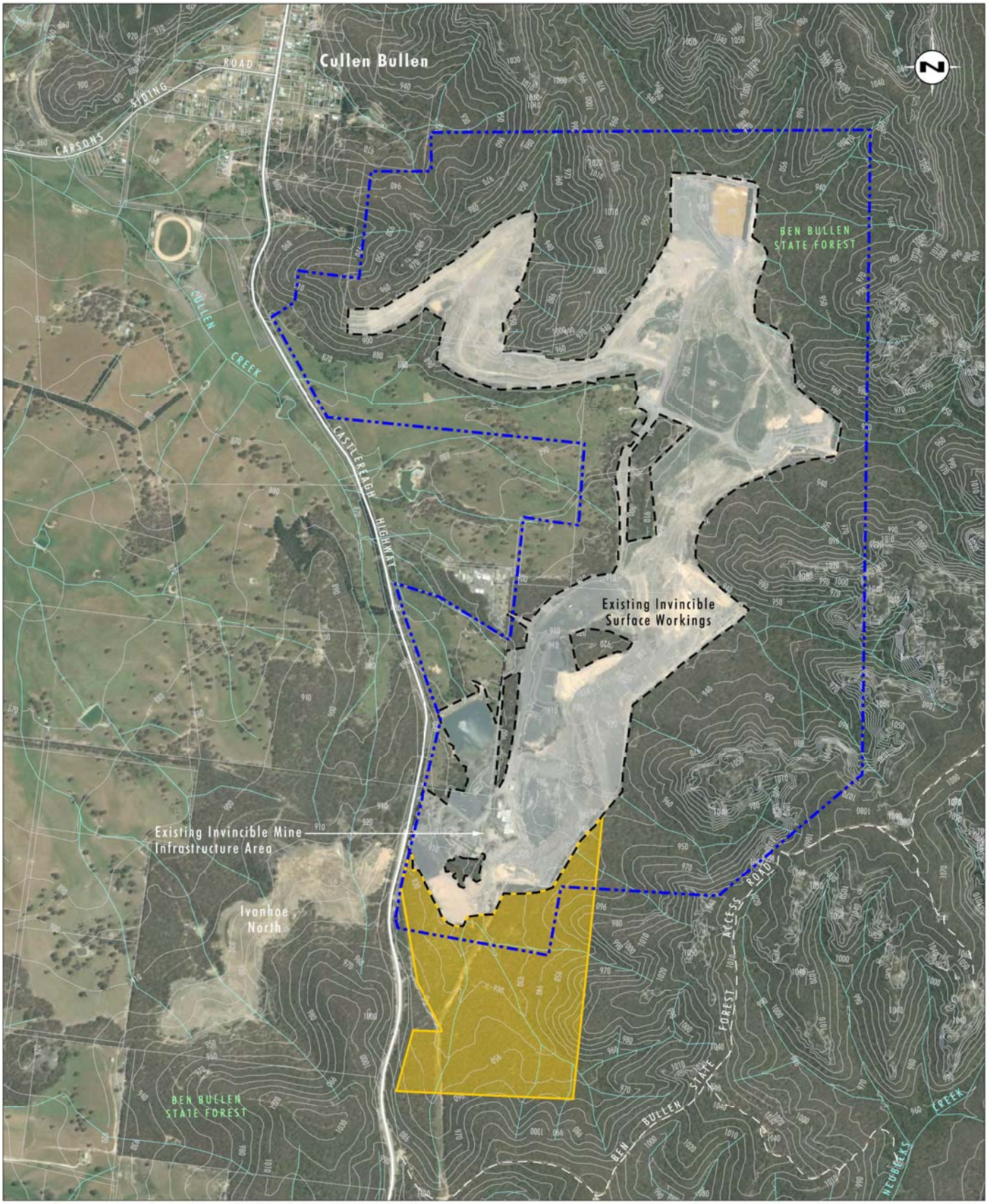


Image Source: Google Earth - CNES/Astrium (Nov 2014)
Data Source: LPI (2016), Forest Corporation of NSW (2015)
Note: Contour Interval 10m

0 0.25 0.5 1.0km

Legend

- Existing Approved Mining Disturbance Area
- Proposed Southern Extension Area
- Invincible Project Approval Boundary (PA07/0127)

FIGURE 1.2

Invincible Southern Extension Project

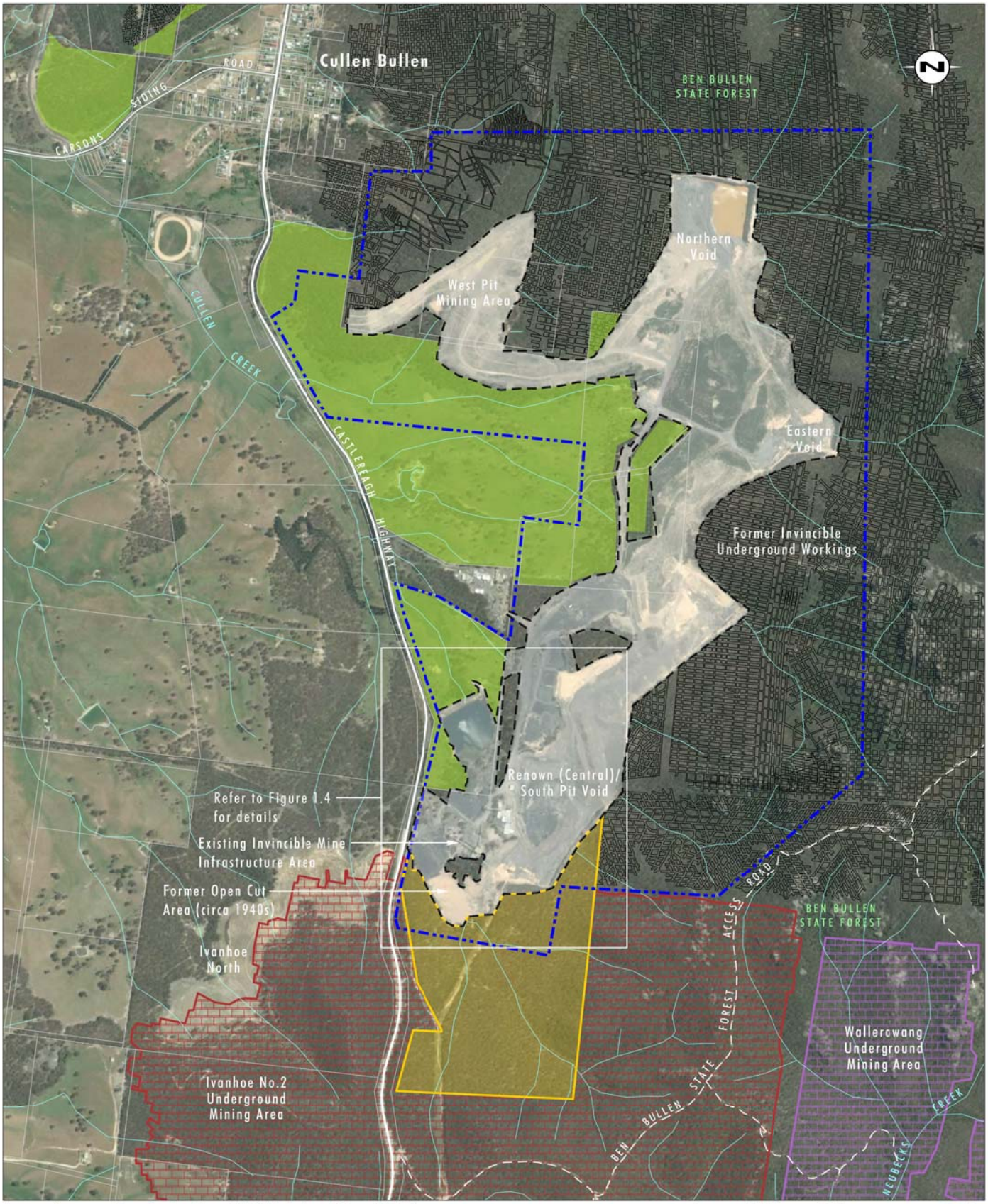


Image Source: Google Earth - CNES/Astrium (Nov 2014)
Data Source: LPI (2016), Sedgman (2014)

0 0.25 0.5 1.0km

Legend

- Existing Approved Mining Disturbance Area
- Proposed Southern Extension Area
- Former Invincible Underground Workings
- Invincible Project Approval Boundary
- Ivanhoe No.2 Underground Mining Area
- Wallerawang Underground Mining Area
- Existing Conservation and Offset Areas

FIGURE 1.3

Invincible Existing Approved Operations

File Name (A4): R07/3622_111.dgn
20160915 15.14

Image Source: Google Earth - Digitalglobe (Mar 2015)
Data Source: LPI (2016)

0 50 100 200m

Legend

Existing Approved Mining Disturbance Area
Proposed Southern Extension Area

FIGURE 1.4

Invincible Existing Mining Infrastructure

Table 1.1 Comparison of Existing Approved Operations at Invincible and the Southern Extension Project.

	Existing Approved Operations	Southern Extension Project
Resource Tonnes	Defined by existing footprint. Approved reserves have been mined.	Approximately 2.7 Mt ROM coal
Mining Methods	Highwall and Open Cut	Open Cut only
Target Seams	All seams down to Lithgow Seam (Irondale, Lidsdale and Lithgow)	All seams down to Lithgow Seam (Irondale, Lidsdale and Lithgow)
Mining Rate	Up to 1.2 Mtpa ROM Coal	Up to 1.2 Mtpa ROM Coal
Production Rate	Up to 1.2 Mtpa Product Coal	Up to 1.2 Mtpa Product Coal
Mining Life	To December 2016 (8 years from date of approval)	Up to 8 years from date of approval
Open Cut Mining Area	152 hectares (ha). 167 ha for total approved disturbance area	Approximately 50 ha of additional disturbance
Operational Workforce	35 full time personnel	Approximately 35 full time personnel.
Hours of operations	7.00 am to 10.00 pm Monday to Saturday (excl. public holidays). Mining in south pits not permitted between 6.00 pm and 10.00 pm.	7:00 am to 10.00 pm Monday to Saturday (excl. public holidays). Mining and coal washery operations will not occur between 6.00 pm and 10.00 pm (operations limited to truck loading and maintenance activities only during this period).
Blasting	Blasting between 9:00 am and 5:00 pm Monday to Saturday, inclusive. No more than: • 2 blasts per day; or • 5 blasts per week averaged over a 12 month period.	Blasting between 9:00 am and 5:00 pm Monday to Saturday, inclusive. No more than: • 2 blasts per day; or • 5 blasts per week averaged over a 12 month period. Blasts sizes limited to manage potential risks to private residences, pagoda and cliff line formations, historical sites and other infrastructure.

	Existing Approved Operations	Southern Extension Project
Transport	Road Transport 7.00 am to 9:30 pm Monday to Saturday, excluding Sundays and public holidays. No more than 146 laden coal truck movements from the site per day (averaged over a week). No more than 16 laden coal truck movements per hour.	Road Transport 7.00 am to 9:30 pm Monday to Saturday, excluding Sundays and public holidays. No more than 146 laden coal truck movements from the site per day (averaged over a week). No more than 16 laden coal truck movements per hour.
Tailings Management	Coarse tailings are co-disposed with overburden. Fine tailings are dried in drying ponds; dry tailings are then either mixed with product coal or co-disposed with overburden.	Coarse tailings are co-disposed with overburden. Fine tailings are dried in drying ponds; dry tailings are then either mixed with product coal or co-disposed with overburden.

1.2 Potential Surface Water Impacts

The following are the key aspects of the Southern Extension Project that have the potential to impact on surface water resources:

- landform changes as a result of the operations, including:
  - open cut mining
  - overburden emplacement areas.
- changes to the water balance associated with the Southern Extension Project
- ongoing rehabilitation of mine areas.

The location of these proposed changes and the associated conceptual surface water management system are discussed in **Section 4.0**.

The key aspects listed above have the potential to impact on the following surface water characteristics:

- catchment areas and flow volumes in downstream watercourses
- flooding, including flow rates, velocities and depths
- water quality in downstream watercourses
- geomorphological and hydrological values of watercourses, including environmental flows
- riparian and ecological values of watercourses
- water users, both in the vicinity and downstream of Invincible.

An assessment of these potential impacts has been undertaken for the Southern Extension Project (refer to **Section 6.0**).

1.3 Report Structure

The key components of the Surface Water Impact Assessment for the Southern Extension Project are included in the following sections:

- Surface water context, including existing watercourses, catchment context and water quality: **Section 2.0**
- Existing Water Management System: **Section 3.0**
- Proposed Water Management System: **Section 4.0**
- Water balance: **Section 5.0**
- Potential impacts of the Southern Extension Project, including consideration of cumulative impacts: **Section 6.0**
- Summary of mitigation and Management Measures: **Section 7.0**
- Monitoring, licensing and reporting: **Section 8.0**.

2.0 Surface Water Context

Invincible and the surrounding areas have been subject to open cut and underground mining operations for over 100 years. Recent and existing mining at the site include the Invincible open cut and underground operations and Ivanhoe No.2 underground operations. In the local region other mining operations include Cullen Valley, Baal Bone, Angus Place, Pine Dale, Ivanhoe and Springvale. With the exception of Springvale Colliery, all other operations are currently in 'care and maintenance' or in the process of being closed.

The Southern Extension Project involves an extension of mining activities to the south of the existing approved Invincible mining area. Due to the history of mining activity at Invincible, there are existing water management systems and structures in place at Invincible. The following sections describe the nature of the catchment areas and associated watercourses, existing water quality and licensing provisions.

2.1 Regulatory Framework

Both Invincible and the Southern Extension Project exist within a regulated system that has been designed to provide for the sustainable management of the State's water resources. This includes licensing of allowable water take with consideration of environmental flow requirements of watercourses and the needs of other water users; control of water pollution; and guidelines that govern the appropriate design of water management systems for mines to manage water quality in accordance with Environment Protection Licence (EPL) requirements.

2.1.1 Water Extraction

Extraction of water in NSW is managed under two legislative acts: *Water Act 1912* and *Water Management Act 2000*.

The objective of the *Water Management Act 2000* is the sustainable and integrated management of water in NSW and is based on the concept of ecologically sustainable development by defining water access and water sharing strategies within NSW. The *Water Management Act 2000* supersedes the provisions of the *Water Act 1912* in regard to water take when a Water Sharing Plan (WSP) is in place and in regards to works adjacent to or within watercourses. Where WSPs have not commenced the provisions of the *Water Act 1912* continue to apply.

WSPs have been developed across NSW to protect the fundamental environmental health of water sources, whilst at the same time securing sustainable access to water for all users in the long-term. The WSPs specify maximum water extractions and allocations and provide water users with a clear picture of when and how water will be available for extraction.

Invincible lies within the area regulated by the WSP for the Macquarie Bogan Unregulated and Alluvial Water Sources 2012 and is located in the Turon Crudine River water source. Water use from surface and alluvial waters in and adjacent to the Invincible (including the Southern Extension Area) is therefore governed by the *Water Management Act 2000*.

Land uses in the vicinity include state forest, mining, electricity generation, and rural and residential landholdings. Much of the invincible open cut workings and all of the Southern Extension Area are located within Ben Bullen State Forest which also extends to the east and north of the site. The Mt Piper Power Station lies approximately 3 kilometres south, and Baal Bone Colliery approximately 4 kilometres north. The town of Cullen Bullen is located approximately 3 kilometres north-west of the Invincible mine infrastructure area. The Castlereagh Highway runs in a north-south alignment to the west of Invincible. A number of rural landholdings are located on the western side of the Castlereagh Highway.

2.1.1.1 Licensing of Extraction

All water extraction in NSW, apart from some exemptions for government authorities and basic landholder rights extractions, must be authorised by a water licence. Harvestable rights, which are a basic landholder right under the *Water Management Act 2000,* allow a landholder to capture and use up to 10 per cent of the average regional runoff from a landholding. Basic landholder rights are exempt from volumetric licensing requirements however water extracted under basic landholder rights must be taken into consideration when assessing licensing requirements.

Each water licence, referred to under the WSP system as a Water Access Licence (WAL), specifies a share component. The share components of specific purpose licences such as local water utility, major utility and domestic and stock are expressed as a number in megalitres per year. The share components of high security, general security and supplementary WALs are expressed as a number of unit shares for the water source. The value of each unit share is subject to Available Water Determinations (AWDs) as specified by Department of Primary Industries – Water (DPI Water).

There are currently no WALs related to surface or alluvial water held by Castlereagh Coal for Invincible.

2.1.2 EPLs and Discharges

The *Protection of the Environment Operations Act 1997* (POEO Act) is the key piece of environment protection legislation in NSW. Scheduled activities or other activities that do or may lead to pollution of waters in NSW are required to be licensed under the POEO Act and are regulated by the NSW Environment Protection Authority EPA. Where discharge of waters is permitted, it is strictly controlled by licence conditions such that discharges do not result in significant impacts on water resources.

Under Section 120 of the POEO Act, it is an offence to pollute waters or cause harm unless licensed to do so. Pollution in NSW is regulated by the POEO Act with discharges from mine water management systems requiring licensing by an Environment Protection Licence (EPL) if the discharge would otherwise constitute a pollution of waters (Section 120 of the POEO Act).

Coal mining and coal works are scheduled activities and Castlereagh Coal holds an EPL which licenses these activities at Invincible, including an existing water discharge point. Further details regarding the Invincible EPL are included in **Section 3.3**.

2.2 Catchment Context

Invincible is located within the catchment of Cullen Creek, a tributary in the upper reaches of the Turon River. The Cullen Creek catchment is approximately 1725 hectares in area. The existing Invincible Water Management System (WMS) encompasses an area of approximately 37 per cent of the pre mining catchment area of Cullen Creek. The Southern Extension Area is located entirely within the existing Invincible WMS catchment area (refer to **Figure 2.1**).

The Turon River and its catchments are managed under a Water Sharing Plan which is administered by the DPI Water, formerly the NSW Office of Water (NOW).

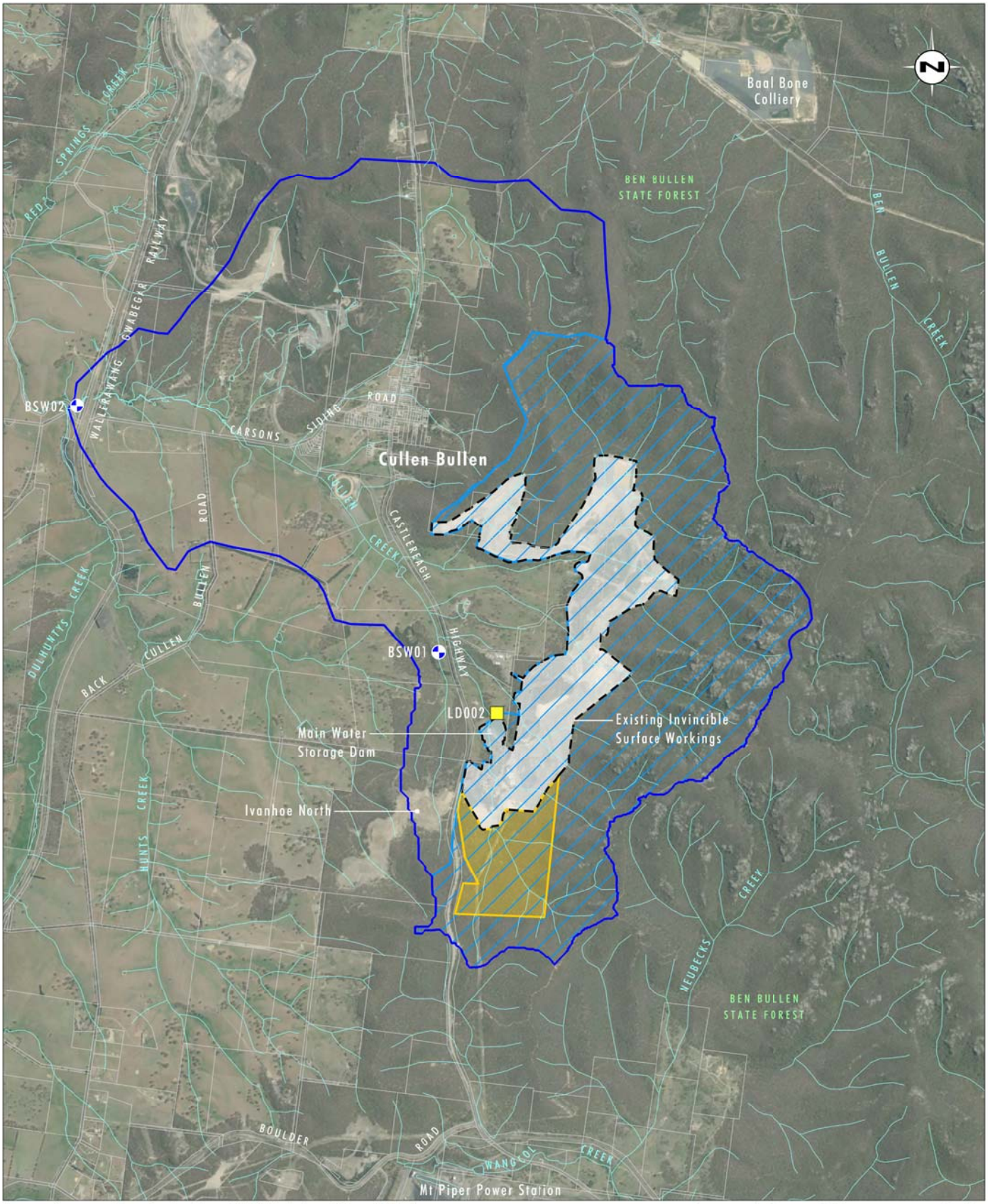


Image Source: Google Earth - CNES/Astrium (Nov 2014)
Data Source: LPI (2016)

0 0.5 1.0 2.0km

Legend

- Existing Mining Disturbance Area
- Proposed Southern Extension Area
- Catchment Area
- Existing Water Management System Area
- Licensed Discharge Point
- Water Monitoring Location

FIGURE 2.1

Surface Water Context

File Name (A4): R07/3622_027.dgn
20160916 8.32

2.2.1 Topography and Drainage

The Invincible open cut workings, existing mine infrastructure area and Southern Extension Area are located on the western fall of the Great Dividing Range within the Murray Darling Basin (refer to **Figure 1.1**). The topography of the land surrounding the Southern Extension Area mainly consists of high Blue Mountains plateau terrain, with the western boundary running roughly parallel to, and west of, the outcrop of the Lithgow seam. The Southern Extension Area is located just within the outcrop of the seam and is characterised by flat undulating land adjacent to the outcrop rising to steeper land in the east.

On a regional scale, Invincible open cut and Southern Extension Area are located in the headwaters of the Turon River catchment within the broader Burrendong Catchment Area. This catchment drains to the west and is not in Sydney's drinking water catchment. Burrendong Dam is located near Wellington, approximately 100 kilometres north-west of Invincible. Regional drainage flows in a northerly direction along the Turon River, then westerly into the Macquarie River (and Burrendong Dam).

On a local scale, both the existing Invincible open cut and the Southern Extension Area lie entirely within the upper catchment of Cullen Creek. Cullen Creek, and its tributaries are ephemeral watercourses (refer to **Figure 2.1**). Cullen Creek is a fourth order (Schedule 3) watercourse (based on the Strahler stream ordering system). Cullen Creek flows in a north-westerly direction before joining Delhuntys Creek approximately 4 kilometres downstream of Invincible, which in turn joins Williwa Creek before flowing into the Turon River. Williwa Creek's confluence with the Turon River is approximately 25 kilometres downstream of Invincible. The nearest downstream flow gauging station is NSW Office of Water's site number 421026 that records flow data for the Turon River at Sofala.

Under the existing Invincible EPL, the site is authorised for wet weather discharges into the tributary of Cullen Creek from the Main Water Storage Dam. This discharge point is referred to as LD002.

The former Invincible underground workings in the Lithgow Seam extend to the east of the open cut workings below land that is located in the upper reaches of the Coxs Creek catchment, part of the Sydney drinking water catchment. There is no current discharge from these underground workings into the Coxs River catchment. Licensed discharges into Coxs River ceased in 2008 and this discharge point (LD001) was removed from the Invincible EPL in 2012.

The existing Invincible open cut workings intersect a number of 1st, 2nd and 3rd order tributaries of Cullen Creek with runoff from the catchment areas of these tributaries captured within the Invincible Water Management System (WMS). In addition, significant portions of the Southern Extension Area are affected by pre-existing surface cracking from underground bord and pillar mining in the abandoned Ivanhoe No.2 underground workings. Much of the surface water runoff from the Southern Extension Area does not report to downstream surface water management structures, instead entering a large sinkhole and fractures in the drainage lines and reporting directly to the abandoned Ivanhoe underground workings.

Figure 2.1 shows the surface water catchment context of the Southern Extension Project.

Table 2.1 shows the pre-mining and current catchment areas of Cullen Creek, as well as the catchment area with the current approved final landform at Invincible. The existing Invincible Project Approval (PA07_0127) allows for water management dams to be either rehabilitated or left in place, depending on their environmental value at the end of the life of the approved operations. There are no final voids in the approved final landform.

Table 2.1 Cullen Creek Catchment Summary

Scenario	Area (ha)
Pre-mining	1,725
Current	1,020
Currently Approved Final Landform	1,725

2.2.2 Geology and Geochemistry

Invincible is located within the Western Coalfield of NSW on the western edge of the Sydney Basin. The Sydney Basin consists of a series of gently dipping sedimentary beds of shale and sandstone of Permo-Carboniferous age capped by massive sandstones of Triassic Age (Yoo *et al* 2001). Directly beneath the Triassic sandstone these beds contain coal seams and form the Upper Coal Measures. The measures extend from the western boundary of the Western Coalfield in an easterly direction, dipping generally at an angle of 1 degree to 3 degrees to the north-east, towards the coast, and extending out to sea (Yoo *et al* 2001).

The Western Coalfield is characterised by the prominent cliffs and eroding plateaus of the Triassic age sandstone and shale Narrabeen Group which overlies the shale, sandstone, conglomerate and coal of the Permian aged Illawarra Coal Measures. These form the slopes which fall away from the sandstone and shale cliffs (Yoo *et al* 2001).

A geochemical assessment was undertaken for the Coalpac Consolidation Project (RGS Environmental 2011) and considered the geochemical properties and constraints associated with overburden and coal reject material at Invincible. The key findings of the report are summarised below:

Overburden

- Overburden materials are likely to be non-acid forming (NAF) and have a high factor of safety with respect to potential acid generation. Most overburden samples tested had negligible total sulphur content and a low-moderate acid neutralising capacity (ANC).
- The concentration of total metals in overburden solids is well below applied guideline criteria for soils and is unlikely to present any environmental issues associated with revegetation and rehabilitation.
- Most overburden material will generate pH neutral, low salinity run-off and seepage following surface exposure. The major ion chemistry of initial surface run-off and seepage from overburden materials is likely to be dominated by sodium and sulphate with lesser amounts of bicarbonate and chloride.
- The concentration of dissolved trace metals in initial and ongoing run-off and seepage from overburden materials is unlikely to present any significant environmental issues associated with surface and ground water quality as a result of the Project.
- Overburden materials below 10 metres depth are likely to be non-sodic and may be suitable for revegetation and rehabilitation activities (in final surfaces or as a growth medium).

Coal Reject

- Most coal reject materials are likely to be NAF and have an elevated factor of safety with respect to potential acid generation.
- Some coal reject materials have uncertain geochemical characteristic or are potentially acid forming (PAF). The few PAF coal reject materials appear to be associated with the Lithgow Seam and particularly coarse reject materials. In contrast, tailings materials generated from processing the Lithgow Seam appear to be NAF.
- The concentration of total metals in potential coal reject solids is well below applied guideline criteria for soils and is unlikely to present any environmental issues.
- Most NAF potential coal reject materials will generate pH neutral and relatively low-salinity run-off and seepage following surface exposure. However, PAF coarse reject materials from the Lithgow Seam may generate acidic and more saline run-off and seepage if exposed to oxidising conditions.
- The major ion chemistry of initial surface run-off and seepage from NAF coal reject materials is likely to be dominated by sodium and sulphate, with lesser amounts of bicarbonate and chloride.
- For PAF coarse reject materials, the initial concentration of soluble sulphate in surface run-off and seepage is expected to be relatively low, although further exposure to oxidising conditions may lead to increased sulphate conditions.
- Castlereagh Coal have established management processes in place for the management of PAF coal reject at Invincible.

2.2.3 Soils

Three soil units have been mapped within the Southern Extension Area, deep orange clay loam, shallow brown sandy loam and skeletal sandy loam (Ecobiological, 2011). The location of these soil units in the Southern Extension Area is mapped on **Figure 2.2**. The following sections describe the soil units in the Southern Extension Area.

2.2.3.1 Deep orange clay loam

This soil type occurs in a residual soil landscape and primarily on lower gradual slopes. The topsoil associated with the soil is approximately 20 centimetres in depth, and is non-saline, slightly dispersive and slightly acidic (pH 5.0 to 5.5). The subsoil extends to a depth of up to 240 centimetres and is non-saline, moderately dispersive and acidic (pH 4.9 to 6.1).

The deep orange clay loam covers approximately 42 hectares (85 per cent) of the Southern Extension Area (refer to **Figure 2.2**).

2.2.3.2 Shallow brown sandy loam

This soil type occurs in residual soil landscapes located primarily on the upper gradual slopes.

The topsoil associated with the soil is approximately 15 centimetres in depth and is non-saline, slightly dispersive and slightly acidic (pH 4.6 to 6.1). The subsoil extends to a depth of up to 114 centimetres and is non-saline, moderately dispersive and acidic (pH 4.6 to 6.2).

The salinity levels and acidity of the soil material is not suitable for supporting vegetation growth (Ecobiological, 2011).

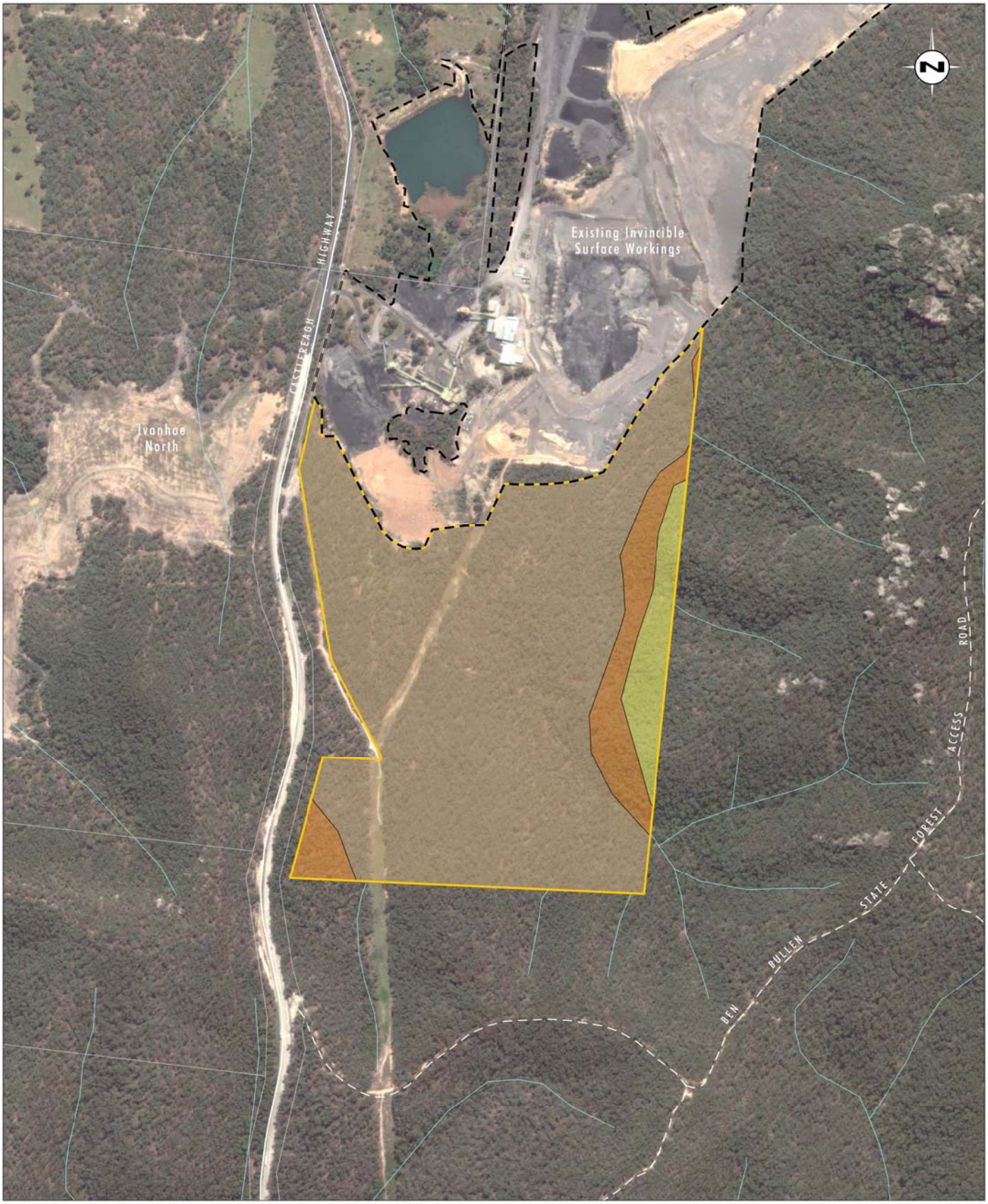


Image Source: Google Earth - CNES/Astrium (March 2015)
Data Source: LPI (2016), EcoBiological (2011)

0 100 250 500m

Legend

- Existing Approved Mining Disturbance Area
- Proposed Southern Extension Area
- Deep Orange Clay Loam
- Shallow Brown Sandy Loam
- Skeletal Sandy Loam

FIGURE 2.2

Soil Types within Southern Extension Area

The shallow brown sandy loam is found on mid slope areas in the east of the Southern Extension area and covers approximately 5 hectares (10 per cent) of the Southern Extension Area (refer to **Figure 2.2**).

2.2.3.3 Skeletal sandy loam

This soil type occurs in a residual soil landscapes located primarily on crests and upper steep slopes. The occurrence of this soil landscape in the Southern Extension Area is limited to the upper crests of the in the east of the Southern Extension Area (refer to **Figure 2.2**)

The topsoil associated with the soil is approximately 2 centimetres in depth and is non-saline, slightly dispersive and slightly acidic (pH 5.1). The subsoil is limited to a depth of only 2 centimetres and is non-saline, moderately dispersive and generally slightly acidic (pH 5.1).

The skeletal sandy loam covers approximately 3 hectares (6 per cent) of the Southern Extension Area.

2.2.4 Existing Water Quality

Surface water quality monitoring is undertaken at two locations downstream of Invincible on Cullen Creek. BSW01 is located immediately downstream of the southern portion of Invincible and BSW02 is located approximately 3 kilometres further downstream (refer to **Figure 2.1**). The surface water quality monitoring program commenced in October 2011.

There is limited surface water quality data available due to the ephemeral nature of Cullen Creek. Surface water was monitored every two to three months for pH, total suspended solids (TSS) and oil and grease between October 2011 and April 2012 at both BWS01 and BWS02. After this period the monitoring was undertaken on a quarterly basis. During 2013 and 2014 the monitoring results presented in the Annual Environmental Management Reports (AEMRs) include Electrical Conductivity (EC) as well as pH, and oil and grease. No results for TSS were presented for 2013 or 2014. pH, TSS and oil and grease were monitored during 2015.

Average annual surface water quality monitoring results, as reported in the AEMRs for the two monitoring locations is presented in **Tables 2.2** and **2.3**.

Table 2.2 Average Annual Surface Water Quality Monitoring Results – BWS01

Year	pH	TSS (mg/L)	Oil & Grease (mg/L)	Electrical Conductivity (µS/cm)
2011	6.6	21	<2	
2012	6.5	16.8	<5	
2013	6.8		<5	660
2014	4.6		<5	432
2015	7.0	18.9	<2	

Source: Coalpac AEMRs

Table 2.3 Average Annual Surface Water Quality Monitoring Results – BWS02

Year	pH	TSS (mg/L)	Oil & Grease (mg/L)	Electrical Conductivity (µS/cm)
2011	7.3	4	<2	
2012	7.3	6.5	<5	
2013	7.6		<5	1080
2014	7.6		<5	975
2015	7.9	7.8	<2	

Source: Coalpac AEMRs

The water quality monitoring data indicates that the water quality downstream in Cullen Creek is typically neutral with low TSS and no trace of oil or grease present.

The NSW Water Quality and River Flow Objectives (NSW Office of Environment and Heritage (OEH), 2006) are the agreed environmental values and long-term goals for NSW's surface waters. The objectives are consistent with the agreed national framework for assessing water quality as set out in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality Guidelines (2000) (ANZECC Guidelines).

The ANZECC Guidelines provide default trigger values and methods to determine site specific trigger values. The ANZECC Guidelines indicate the preferred use of site specific trigger values. Trigger values can be used to characterise the water quality and estimate the ecological integrity of a water resource. The default trigger values for NSW upland rivers and NSW lowland rivers as presented in the ANZECC guidelines are shown in **Table 2.4**. It is considered that, based on the water quality recorded for Cullen Creek, that the water quality in Cullen Creek is typical of the ANZECC default trigger values for NSW lowland rivers.

Table 2.4 Default Water Quality Triggers

Analyte	NSW Upland Rivers (>150 mAHD)[1]	NSW Lowland Rivers (<150 mAHD)[1]	EPL 1095
pH	6.5 to 8.0	6.5 to 8.5	6.5 to 8.5
EC (µS/cm)	30 to 350	125 to 2200	
TSS (mg/L)[2]			30

Note 1: ANZECC Guidelines (2000)

Note 2: Not specified in the ANZECC Guidelines

Invincible also undertakes surface water monitoring to meet the requirements of EPL 1095 (refer to **Section 3.0**) and to assist in on-site water management within the water management dams.

The EPL identifies only one discharge/monitoring point for Invincible, LD002 (identified as Point 2 in the EPL), and located at the overflow point of the Main Water Storage Dam below the Invincible Coal Preparation Plant (CPP) (refer to **Figure 2.1** and **Section 3.0**). This point is a wet weather discharge point and, in line with Condition M2.3 of EPL 1095, is monitored monthly at times when there is a discharge. At present, the Invincible EPL only requires the monitoring of pH, TSS and oil and grease at LD002. The water quality monitoring results are compiled and reported on an annual basis in the EPL Annual Report and AEMRs. There have been no recorded instances of discharge water exceeding the EPL limits in the 2011 to 2015 AEMRs, or in the period subsequent to the 2015 AEMR reporting period.

3.0 Existing Water Management

3.1 Context

The approved Water Management Plan (Coalpac, 2009) describes the current water management systems for Invincible. The water management strategy at Invincible is focused, where possible, on the separation of clean and dirty water streams by interception and diversion of stormwater runoff from operational and non-operational areas. In this context clean water comprises runoff from undisturbed parts of the WMS, while dirty water comprises stormwater runoff from disturbed areas of the site (including stockpiles, reject storage areas, coal handling and processing areas, mine infrastructure and overburden emplacement areas). This water has the potential for contamination from coal fines and/or oil and grease.

The water management system was been designed (as far as possible) as a closed loop system, with all water which enters the site via rainfall or runoff being managed in a series of dams within the WMS. A number of pit sumps (voids) located in the open cut areas collect dirty runoff from the active mining areas and overburden emplacement areas. However, clean runoff from undisturbed catchment areas upstream of the active mining area also drains into these sumps as it is not practical to divert runoff from the upstream catchments due to the steep nature of the topography to the north and east of the existing Invincible mining area.

The Northern Void (refer to **Figure 3.1**) is hydraulically connected to the former Invincible underground workings. The floor of the Invincible open cut workings slopes down toward the north-east. Water collected in the Eastern and Renown/South Pit Voids (refer to **Figure 3.1**) seeps through the spoil in a north-easterly direction to the Northern Void where it drains into the former Invincible underground workings or is reused for dust suppression or other operational purposes. Stored water in the former Invincible underground workings seeps into the Lithgow seam and this seepage is estimated to range between 111 ML per year to 317 ML per year (AGE 2016).

As discussed in **Section 2.2.4**, the licensed discharge point for Invincible is the Invincible Main Water Storage Dam (LD002) (refer to **Figure 3.1** and **Section 3.3**).

Key components of the existing WMS are shown on **Figure 3.1**.

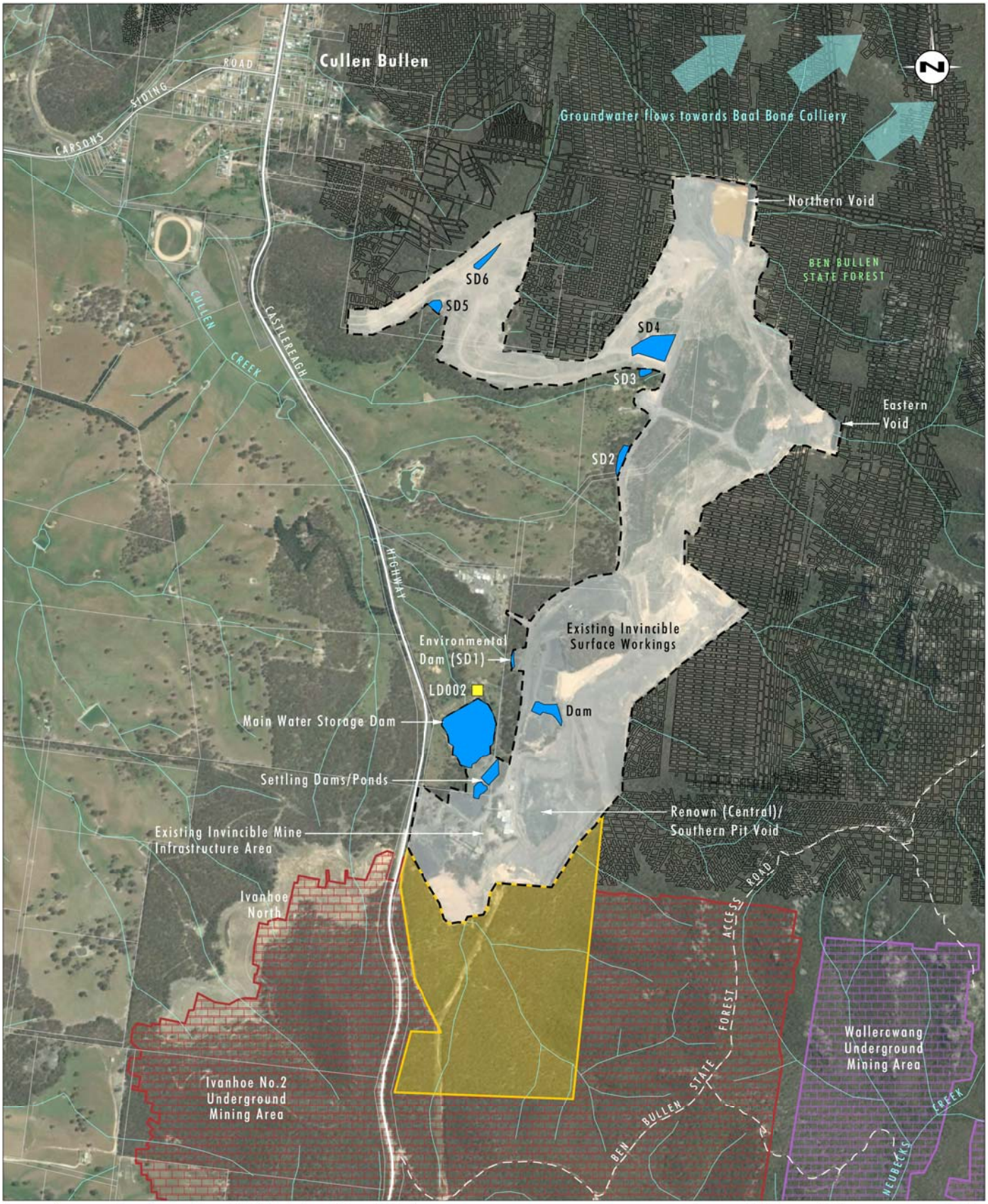


Image Source: Google Earth - CNES/Astrium (Nov 2014)
Data Source: LPI (2016)

0 0.25 0.5 1.0km

Legend

- Existing Mining Disturbance Area
- Proposed Southern Extension Area
- Licensed Discharge Point
- Former Invincible Underground Workings
- Ivanhoe No.2 Underground Mining Area
- Wallerawang Underground Mining Area

FIGURE 3.1

Existing Invincible Water Management System

File Name (A4): R07/3622_028.dgn
20160916 10.59

3.2 Water Management System Overview

Runoff from rehabilitated landforms, including overburden emplacement areas, is collected in a series of sediment dams (refer to **Figure 3.1**). There remain areas where vegetation has not been established, and consequently runoff from these catchments is treated as dirty water. Similarly to the pit sumps (refer to **Section 3.1**), the sediment dams also collect clean runoff from upstream undisturbed catchments. Water collected in sediment dams is either pumped to the Northern Void, the Main Water Storage Dam or infiltrates through spoil towards the Northern Void and the former Invincible underground workings. Dirty runoff from haul roads is directed into roadside sediment dams and is periodically pumped to the Northern Void or Main Water Storage Dam. During heavy or prolonged rainfall periods, where the rainfall exceeds the design criteria of sediment dams, sediment dams overflow either to other downstream dams within the WMS or to downstream drainage lines and Cullen Creek.

The Environmental Dam is located on the western side of the haul road downstream of the fine reject storage dams and coal stockpile area (refer to **Section 3.1**). The Environmental Dam collects seepage from the fine rejects storage dams and runoff from a minor undisturbed catchment. Water stored in the Environmental Dam is pumped to the Main Water Storage Dam. It is understood that seepage water from the fine reject storage dams is generally acidic and of poor quality.

Dirty runoff from the mine infrastructure area and upstream undisturbed catchment drains by gravity to the Main Water Storage Dam. Significant portions of the catchments draining the Invincible site are affected by pre-existing subsidence from underground bord and pillar mining in the abandoned underground Ivanhoe Colliery workings. Large sinkholes are evident along drainage lines in these portions of the catchment and it is expected that a substantial portion of surface water runoff which drains through these subsidence affected areas does not report to downstream surface water management structures, and instead enters the sinkholes and reports directly to the abandoned underground workings.

Water stored in the Main Water Storage Dam is used in the Invincible CPP and for dust suppression. Water can also be transferred from the Northern Void to the Main Water Storage Dam for use at the Invincible CPP or can be used for dust suppression.

Due to the permeable nature of the underlying geology and proximity to abandoned underground workings, the majority of surface water runoff collected in pit sumps, fine reject dams and coal stockpile areas seeps into the abandoned underground workings shortly after a runoff event occurs. This is supported by groundwater modelling undertaken by AGE Consulting on behalf of Coalpac (AGE, 2011), which indicates significant volumes of water are held in the former Invincible underground workings beneath the surface operations area. Further, the AGE study suggests that water stored in the former Invincible underground workings is passing through the Lithgow Coal Seam into the Baal Bone Colliery underground workings, located to the north-east of Invincible. Evidence suggests that little or no groundwater seeps into the pits or storages at the site.

The key surface water storage structures are shown on **Figure 3.1**.

3.3 Environment Protection Licence

Castlereagh Coal holds an EPL 1095, issued and administered by the EPA. The EPL identifies one water quality monitoring/wet weather discharge point (LDP 002), located at the overflow point of the Main Water Storage Dam (refer to **Figure 3.1**). Concentration limits for this discharge point (expressed as 100 percentile concentration limits) are as follows:

- Oil and grease; 10 mg/L
- pH; within the range 6.5 to 8.5
- Total suspended solids; 30 mg/L

Castlereagh Coal is required to monitor the concentrations of each of the above on a monthly basis (during discharge).

4.0 Proposed Water Management

4.1 Water Management Strategy

The water management strategy for the Southern Extension Project has been designed to integrate water management of the Project with the existing water management system, to the extent practical. The strategy includes the separation of clean and dirty water where practicable, seeking to prevent the contamination of clean water by mining activities and managing compliance with statutory obligations.

The existing Water Management System allows for two categories of water: clean, comprising runoff from undisturbed and fully rehabilitated areas; and dirty, comprising runoff from any area disturbed by mining operations.

For the Southern Extension Project, three categories of water will be managed, each with different potential for water quality impacts, namely:

- Clean water - Runoff from undisturbed areas or rehabilitated areas where vegetation is fully established, and where the water quality is suitable for release/discharge.
- Dirty water - Runoff from disturbed areas, such as active overburden emplacement areas or overburden emplacement areas where vegetation is not fully established. These areas have the potential for elevated TSS.
- Mine water - Mine water, being water exposed to coal or used in coal processing and runoff within mining areas. This water quality typically displays a higher level of salinity.

The target design criteria for the three categories of water are summarised in **Table 4.1**.

Table 4.1 Design Criteria for Components of the WMS

Water Category	Water Description	Target Design Criteria
Clean	Runoff from undisturbed or established rehabilitated areas	Intercept, convey and/or release, where practicable, to downstream environment.
Dirty	Runoff from disturbed areas	Managed in line with the Blue Book (Managing Urban Stormwater: Soils and Construction Volumes 1 and 2E).
Mine	Runoff from areas exposed to coal, or water used in coal processing or from coal stockpile areas	Sumps and associated systems located within the CPP area are sufficient to manage runoff for events up to and including the 1 per cent 24 hour AEP (Annual Exceedance Probability) storm event.

Dirty water and mine water will be utilised preferentially to meet the water needs for the Southern Extension Project – i.e. for coal processing and dust suppression. This will minimise the demand for importing raw/clean water into the site. In addition, excess water that cannot be utilised will be discharged in accordance with the EPL.

Potable water supply and wastewater treatment and disposal practices for the Southern Extension Project will be the same as for the existing operations. Potable water is currently sourced from the Fish River Dam Water Supply main pipeline system. Wastewater is managed on site using a septic tank system which is periodically maintained by licensed contractors.

The WMS for the Southern Extension Project will make provision for ongoing evaluation of all existing and proposed components of the WMS using additional data obtained through ongoing water quality sampling together with risk assessments where required so that the objectives (refer to **Section 3.1**) of the WMS are achieved.

4.1.1 Clean Water Management

As discussed in **Section 2.1**, Invincible currently intersects several remnant drainage lines and is situated within an extremely steep catchment. Clean water runoff from the area upslope of the Southern Extension Area is currently piped under the mining infrastructure area to the Main Water Storage Dam and as such to the existing WMS. Due to the nature of the topography in this area and the proposed Southern Extension Project it is impractical to divert the upslope runoff around the WMS. As such runoff from upslope of the Southern Extension Area will continue, during the Southern Extension Project, to be managed within the WMS.

4.1.2 Dirty Water Management

The existing WMS makes no separation between mine and dirty water. The existing system includes a series of catch drains and sediment dams located to capture and manage runoff from disturbed areas. The separation of mine water is discussed in **Section 4.1.3**.

The concept dirty water management system for the Southern Extension Project has been designed in accordance with *Managing Urban Stormwater: Soils and Construction* (the Blue Book)*, Volumes 1 and 2E - Mines and Quarries* (Landcom 2004 and DECC 2008) to manage runoff from the 5 day, 95th percentile rainfall event.

As mining progresses, runoff from disturbed areas will be managed within the water management system and reused, or if water quality meets required guidelines, will be released to downstream waterways. The sediment dams will be emptied into the mine water system using a pump and pipe or gravity systems after rainfall events so that the required capacity is retained. In extreme events, the dirty water dams would discharge to the natural drainage system.

Dirty water drains will be sized to safely convey the 5 per cent AEP storm event. All drains will be constructed with non-scouring flow velocities. Rock protection and energy dissipation structures will be installed at the downstream outlets, where required, to prevent runoff causing scour or erosion in downstream drainage systems.

Erosion and sediment controls will be implemented to mitigate the impacts of construction and mining operations on nearby watercourses and the surrounding environment. Standard erosion and sediment control techniques will be used in accordance with the requirements of the Blue Book (Landcom 2004 and DECC 2008) and are detailed in **Section 7.1**.

4.1.3 Mine Water Management

Mine water consists of water that has the potential to be in contact with coal or carbonaceous material, and therefore has the potential to be saline. Mine water also includes runoff from the mine infrastructure areas. The existing WMS does not delineate between mine water and dirty water.

The concept WMS for mine water management areas has been designed to manage runoff from the 1 per cent 24 hour AEP storm event within the mine water storage dams/sumps and to provide systems to manage that runoff. The water management system within the mine water management areas has been designed to minimise the risk of discharges of contaminated water to downstream watercourses.

Surplus mine water will continue to be contained and where needed diverted to the existing Main Water Storage Dam, where is it diluted, by a series of bunds, culverts, and diversion drains prior to reuse in the WMS.

4.1.4 Water Abstraction and Discharges

Water discharges occur via the Main Water Storage Dam to Cullen Creek in accordance with the EPL (refer to **Section 3.0**).

There are no proposed changes to the discharge infrastructure. A variation in the EPL may be required in relation to volume and quality of discharge (refer to **Section 8.3**).

Castlereagh Coal does not propose to modify the current import of potable water for the Southern Extension Project (refer to **Section 3.0**).

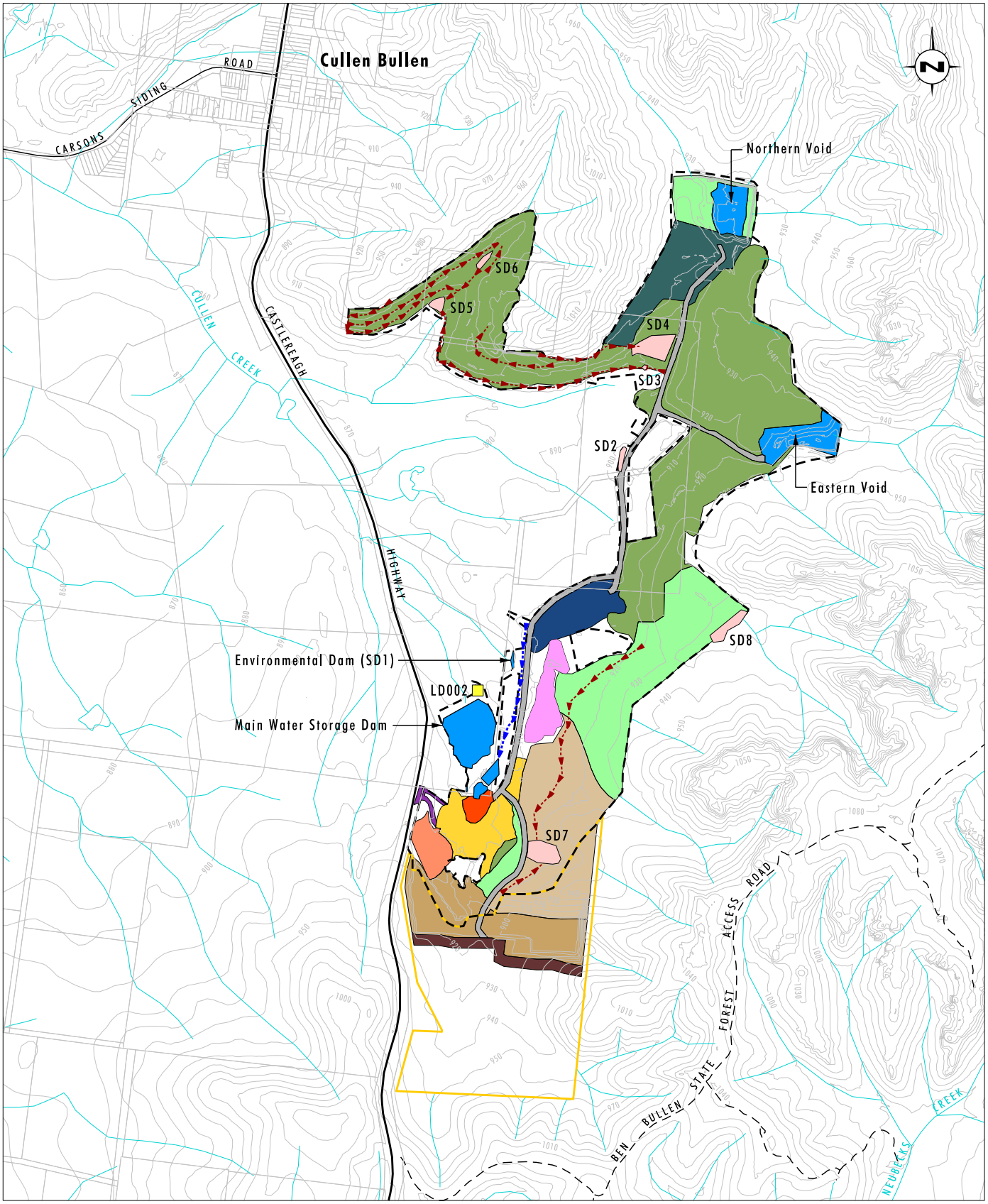
4.2 Overview of Proposed Water Management System

As discussed in **Section 4.1**, the WMS for the Southern Extension Project will manage water of three distinct types: clean, dirty and mine water. Each type of water requires different management measures to minimise the risk of water quality impacts on downstream drainage systems by mining activities.

The conceptual layout of the key components of the WMS for Stage 1 and Stage 2 of the Southern Extension Project are shown on **Figures 4.1** and **4.2**. **Figure 4.3** shows the proposed drainage systems for the proposed conceptual final landform. A schematic showing the proposed WMS components is included as **Figure 4.4**.

It is important to note that the stage plans presented in **Figures 4.1** and **4.2** are conceptual, being determined by current mining schedules and in consideration of the maximum disturbance area. The WMS will be constructed and modified as and when required so as to support the infrastructure and mine development. Further, the stage plan indicates only the components of the WMS which are required for that particular stage of the mine, and does not preclude the construction of some components earlier in the Southern Extension Project.

Similarly, the conceptual storage capacities required for the various water management dams are provided to indicate the quantum of the proposed dams. Refinement of the design criteria and capacities will be undertaken during detailed design stages of the Southern Extension Project, as well as the ongoing operational stages.



Data Source: LPI (2016)
Note: Contour Interval 10m

0 0.25 0.5 1.0km

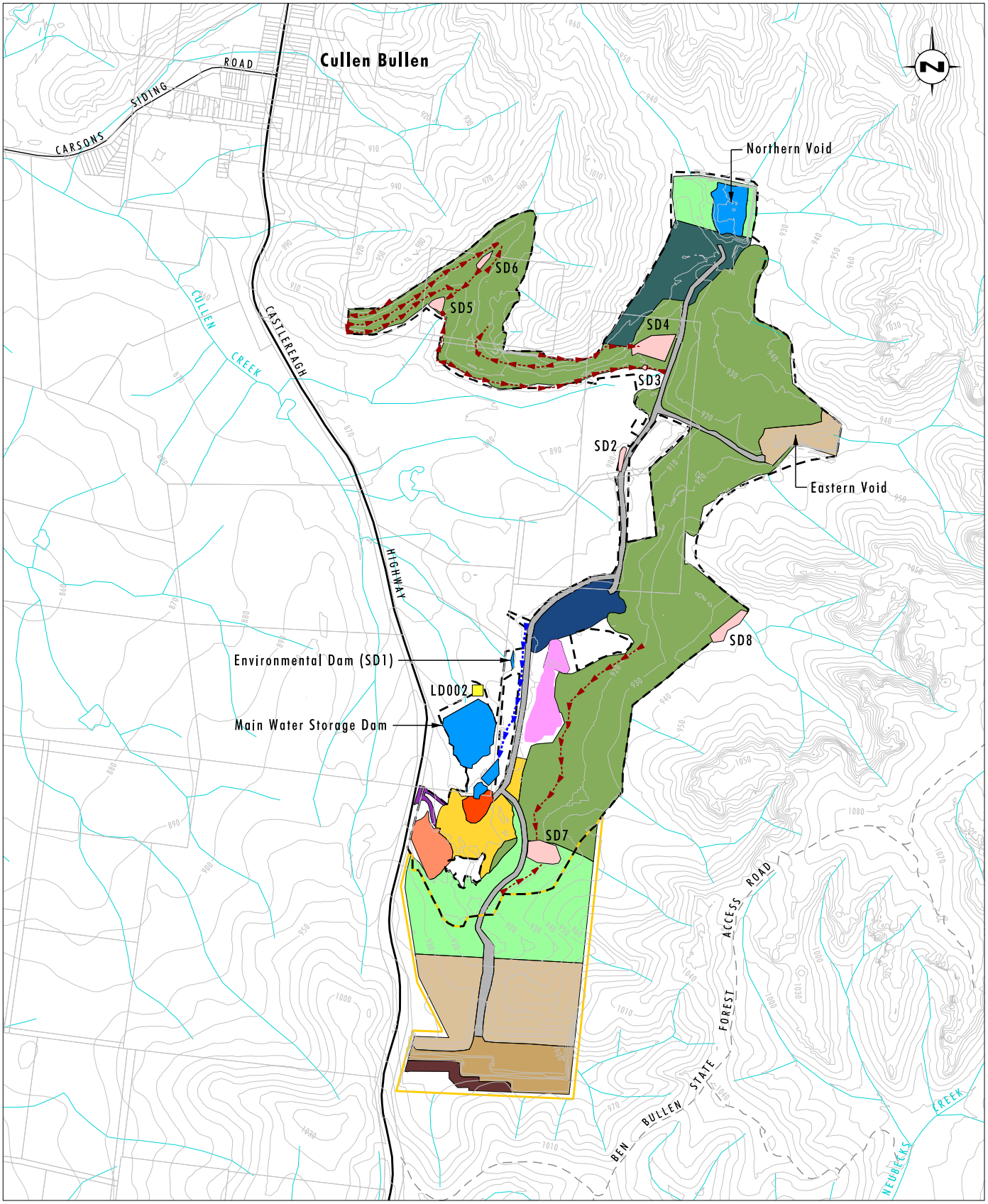
Legend

- Existing Approved Mining Disturbance Area
- Proposed Southern Extension Area
- Active Mining
- Active Overburden Emplacement Area
- Pre Strip
- Rehabilitation - Vegetated
- Shaped Not Seeded
- Coal Stockpile - Product
- Coal Stockpile - ROM
- Haul Road / Access Road
- Sealed Access Road
- Infrastructure / Laydown Area
- MIA / Administration
- Water Management Area
- Tailings Drying Area
- Temporary Stabilisation Area
- Sediment Dam
- Mine Water Drain
- Dirty Water Drain
- Licensed Discharge Point

FIGURE 4.1

Conceptual Water Management System Stage 1

File Name (A4): R07/3622_029.dgn
20160916 10.06



Data Source: LPI (2016)
Note: Contour Interval 10m

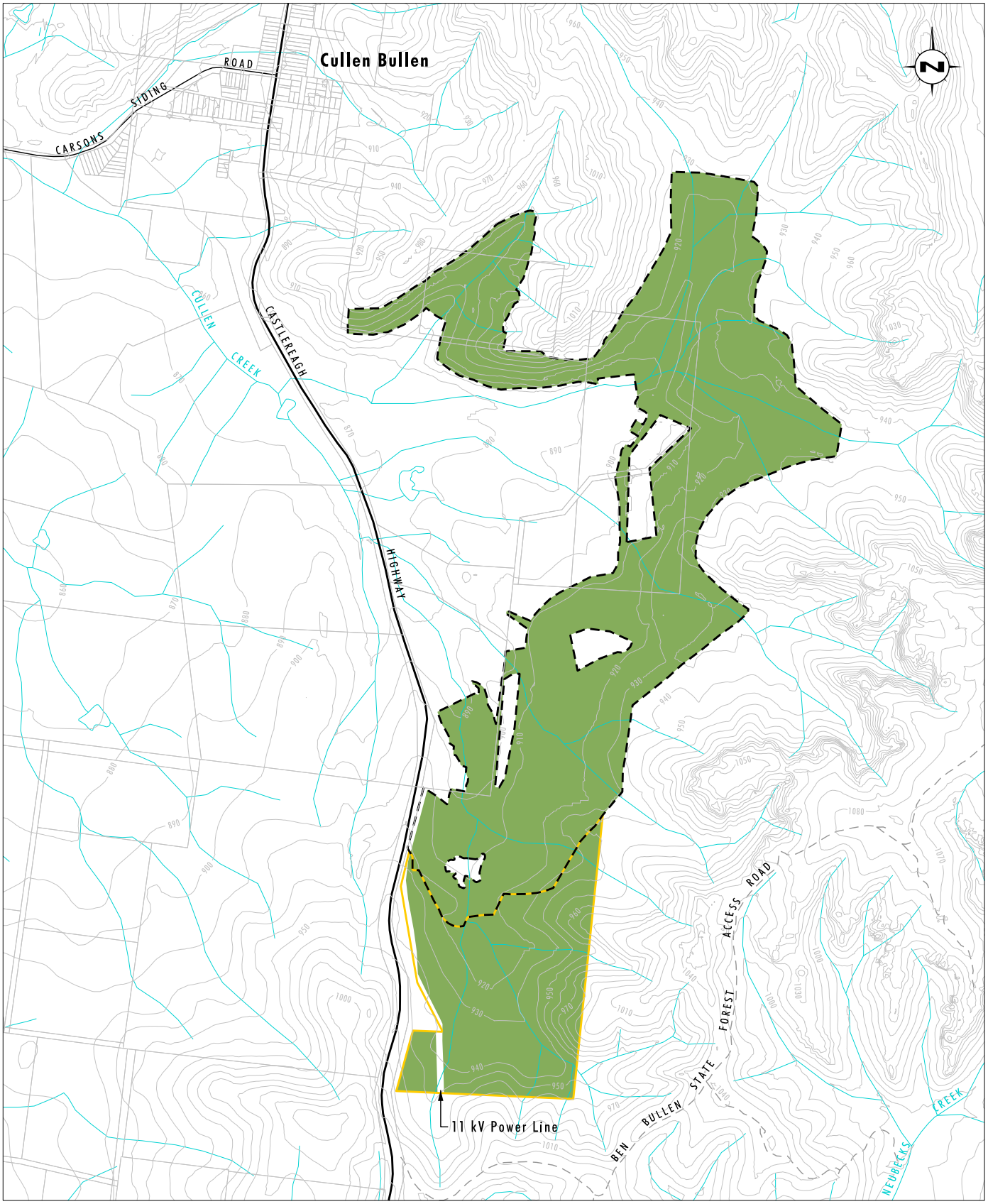
Legend

- Existing Approved Mining Disturbance Area
- Proposed Southern Extension Area
- Active Mining
- Active Overburden Emplacement Area
- Pre Strip
- Rehabilitation - Vegetated
- Shaped Not Seeded
- Coal Stockpile - Product
- Coal Stockpile - ROM
- Haul Road / Access Road
- Sealed Access Road
- Infrastructure / Laydown Area
- MIA / Administration
- Water Management Area
- Tailings Drying Area
- Temporary Stabilisation Area
- Sediment Dam
- Mine Water Drain
- Dirty Water Drain
- Licensed Discharge Point

FIGURE 4.2

Conceptual Water Management System Stage 2

File Name (A4): R07/3622_030.dgn
20160916 10.08



Data Source: LPI (2016)
Note: Contour Interval 10m

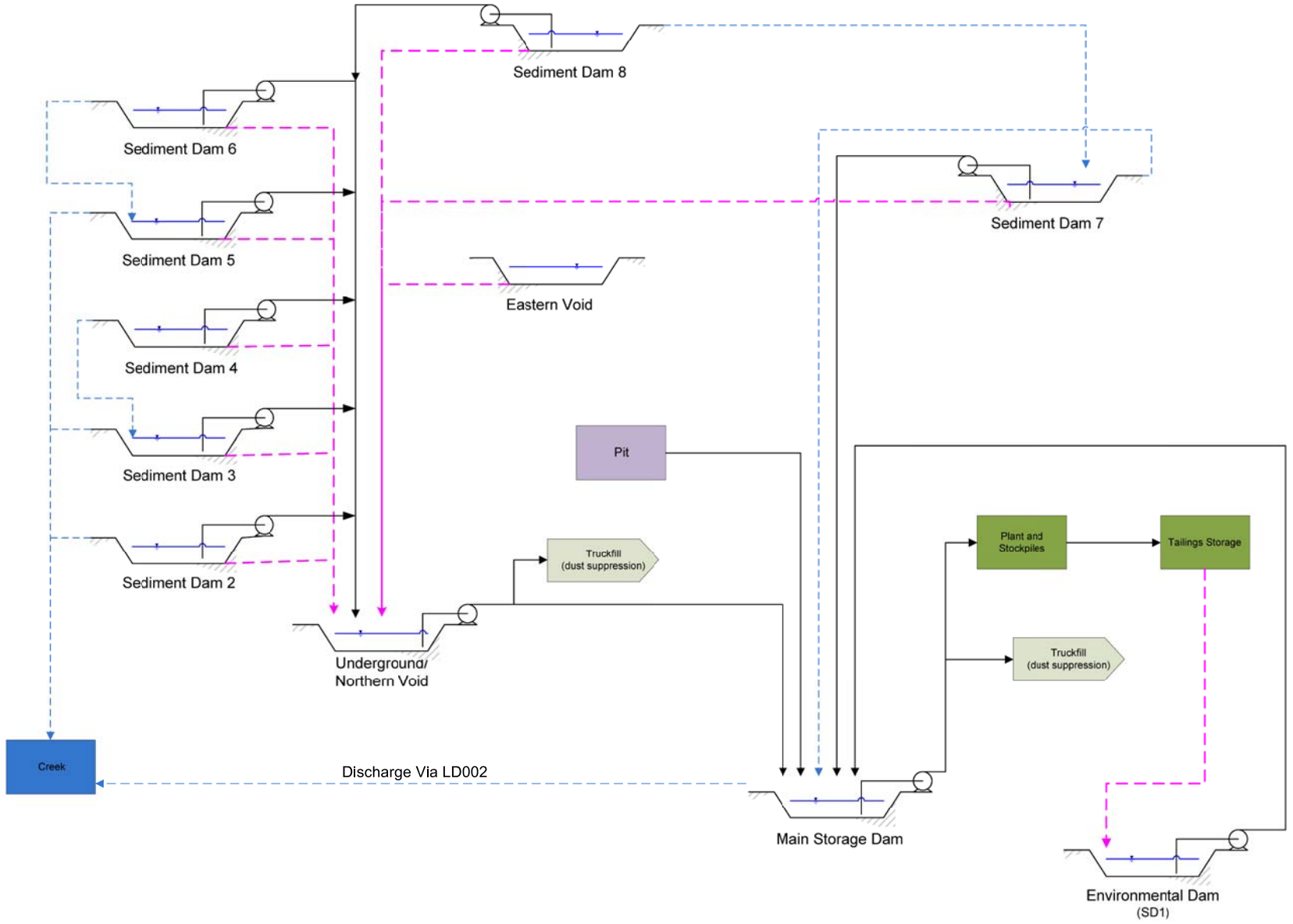
0 0.25 0.5 1.0km

Legend

- Existing Approved Mining Disturbance Area
- Proposed Southern Extension Area
- Rehabilitation - Vegetated

FIGURE 4.3

Conceptual Drainage Systems in Final Landform



Legend

- Pumped Flow
- Overflow
- Gravity Transfer
- Seepage

FIGURE 4.4

Schematic of Proposed Water Management System

4.2.1 Stage 1

At Stage 1 of the Southern Extension Project (refer to **Figure 4.1**), the Southern Extension Area will be active. Mining will progress to the south, and overburden material will be used to progressively backfill the existing Invincible south pit. Runoff from these locations will be contained within the WMS.

Diversion of runoff from undisturbed and rehabilitated catchments to the north and east of the active mining area and overburden infill areas is not practicable; runoff from these areas will continue be managed, as per the existing WMS, within the WMS.

Progressive rehabilitation has already commenced at the site and will continue as the Southern Extension Project advances. However, only runoff from areas of existing rehabilitation (rehabilitation that has occurred several years prior to commencement of the Southern Extension Project) will be sufficiently established to be released to the environment. Runoff from these areas with existing rehabilitation will be released to the environment where runoff can be practically separated from runoff from mine and dirty water catchments.

4.2.2 Stage 2

At Stage 2 of the Southern Extension Project (refer to **Figure 4.2**) mining will continue in the Southern Extension Area. As the mining progresses further to the south, overburden material will continue to be progressively placed within the existing pit and behind the advancing highwall of the Southern Extension Project. Runoff from the mining pit and overburden emplacement area will be managed within the WMS.

Similarly to Stage 1, rehabilitation will continue to be established over the site where then final landform has been achieved.

4.2.3 Final Landform

When final landform is achieved (refer to **Figure 4.3**), all operations will be complete and disturbed areas will be completely rehabilitated. No final voids will remain in the rehabilitated landform and the site will be free-draining.

4.2.4 Proposed Dams for the Southern Extension Project

The proposed clean water and dirty water dams required to manage dirty and clean runoff from disturbance areas and rehabilitated areas for the Southern Extension Project are listed in **Table 4.2**.

Table 4.2 Additional WMS Dams associated with the Southern Extension Project

Dam	Approximate minimum operating volume (ML)	Year 2 Quality	Year 4 Quality	Final Landform
SD7	25	Dirty	Dirty	-
SD8	32	Dirty	Dirty	-

Rehabilitation of the existing pit and the active mining area will be undertaken as mining progresses. Runoff from final, stable rehabilitated areas will, where practicable, be conveyed to the downstream catchment areas once the required runoff water quality criteria are achieved.

4.3 Proposed Discharges

Invincible currently has a licence to discharge during wet weather as specified in the EPL (refer to **Section 3.3**). It is proposed to continue to discharge surplus water from the operations via the existing licensed discharge point (LD002) at the Main Water Storage Dam (refer to **Figure 3.1**). Further details on the predicted discharge volumes, including those associated with dewatering of the Ivanhoe No.2 underground workings, is included in **Section 5.4**.

5.0 Water Balance

The WMS for the Southern Extension Project will be integrated with the existing Invincible WMS (refer to **Section 4.0**). As such, the water balance for the Southern Extension Project has been modelled as an integrated system including both the Southern Extension Area and the existing Invincible WMS.

5.1 Model Overview

A water balance model was developed for the Southern Extension Project using the Goldsim modelling package. The model is a daily time step model. The model uses the historical meteorological records from 1960 to 2015 from the Bureau of Meteorology's Lidsdale monitoring station (Station ID 63132) with infill from the Lithgow climate monitoring station (Station ID 63226) in years with inadequate data.

Inflows to the water balance include runoff and rainfall. Where possible, dirty and mine water is reused in the Invincible CPP and for haul road dust suppression. The water balance also considers seepage from existing mining areas / voids to the underground workings and associated seepage out of the underground workings to the north-east into Baal Bone workings.

5.2 Rainfall and Climate

Invincible lies within a cool-temperate climatic zone and is characterised by mild summers and cold winters. The local climate is largely influenced by factors such as topography, altitude, aspect and exposure.

Three Bureau of Meteorology (BoM) rainfall stations lie within close proximity to Invincible: Station 63132 Lidsale (9 kilometres south-east); Station 63071 Portland (6 kilometres south); and Station 63226 Lithgow (21 kilometres south-east). Of these three BoM rainfall stations Lidsdale is considered most representative of rainfall conditions at Invincible due to its topographical location and also the completeness of the data set.

Daily rainfall has been recorded at Lidsdale (Station 63132) since 1960. Rainfall is generally spread evenly across the year, with slightly higher falls in late spring and summer and lower falls in autumn. For use in the water balance, periods of incomplete rainfall data at the Lidsdale gauge have been infilled with data sourced from Lithgow (Station 63226). **Table 5.1** presents the rainfall statistics for the data set used in the water balance (Lidsdale data with infilled Lithgow data).

Table 5.1 Water Balance Rainfall Data

Statistic	Rainfall (mm)
Minimum	329.8
10th %ile	505.5
50th %ile	758.6
90th %ile	927.9
Maximum	1171.0

Source: Bureau of Meteorology, 2016

Castlereagh Coal operates a meteorological monitoring station at Invincible (refer to **Figure 2.1**). In 2014, the site received 695 millimetres of rainfall over 141 rainfall days, which is consistent with a slightly below average rainfall year for the Lidsdale station.

Evaporation of about 1,351 mm/year exceeds rainfall throughout most of the year except for the winter months of June, July, and August (BOM Station No. 063005 – Bathurst agricultural station).

5.3 Predicted Water Balance

On average, the modelling predicts that the operation will have a positive gross site water balance. The water make associated with the water balance will either be stored in the former Invincible Underground Workings or discharged off site in accordance will the EPL.

An analysis of the modelled discharges assuming no additional storage volume within the former Invincible underground workings (i.e. the worst case scenario) is included in **Table 5.2**.

Table 5.2 Main Water Storage Dam Modelled Discharges

Percentile	Discharge (ML)
10th %ile	21
50th %ile	206
90th %ile	785

The modelled maximum number of days that discharges would occur from the Main Water Storage Dam is 78 days based on historical climate data and predicted site water demands.

As discussed in **Section 3.0** Castlereagh Coal is able to either discharge surplus water during wet weather to Cullen Creek (via EPL 1095) or pump surplus water to the underground voids. The modelled average daily discharge volume from the Main Water Storage Dam for the climatic period modelled is 0.94 ML per day.

Sediment dams for the Southern Extension Project are proposed to be designed in accordance with Blue Book requirements to contain the 95th percentile 5 day runoff. Consistent with the design criteria, the water balance model predicts that on average the Southern Extension Project sediment dams will spill during prolonged or unusually intense periods of rainfall. The average number of spills from sediment dams that spill off site for the climatic period modelled is estimated to be less than one spill per year.

5.4 Management of Dewatering of the Old Ivanhoe Underground Workings

The Ivanhoe No. 2 underground workings within the Southern Extension Area will need to be dewatered prior to open cut mining in the Lithgow seam. The Groundwater Assessment (AGE, 2016) has determined that up to approximately 2,121 ML of water contained in the Ivanhoe No.2 underground workings may need to be removed to enable the mining of the Lithgow seam in the Southern Extension Area. As noted in the Groundwater Assessment this volume is based on an inferred maximum storage within these workings in absence of water monitoring confirming current water levels within these former workings. Castlereagh Coal has committed to the establishment of monitoring bores within the former Ivanhoe workings to confirm the volume of water in these workings that will require management.

This water is expected to be of similar or better water quality to that in the Baal Bone Colliery to the north-east due to being sourced almost entirely from surface flow through subsidence cracking and not from groundwater inflow from the coal seam. The groundwater discharged at Baal Bone Colliery typically has the following concentrations of key analytes dissolved iron of 0.07 mg/L, pH between 6.5 to 8.5, TSS of 5 mg/L, EC of 1,125 µS/cm and Sulphate of 288 mg/L (based on 12 month rolling average data published 2016).

Studies have indicated that the former Invincible Underground workings (i.e. those hydraulically connect to the Northern Void) have current free volume of approximately 1,585 ML with outflows to Baal Bone workings of between 111 ML per year and 317 ML per year (refer to **Section 5.3**). As noted in the Groundwater Assessment, this volume is based on previously provided observations of water level within the Invincible Underground workings, which provides an inferred calculation of available storage. Castlereagh Coal has committed to the establishment of monitoring bores within the former Invincible underground workings to confirm the storage available in the former underground workings.

Castlereagh Coal proposes to discharge surplus water, both during the operational mine stages and to dewater the Ivanhoe No.2 underground workings, in accordance with the EPL conditions. It is proposed to dewater the Ivanhoe No.2 underground workings prior to mining accessing the potential flooded extent of the former Ivanhoe workings in the Southern Extension Area. Mining within the Southern Extension Area will commence outside of the flooded extent of former Ivanhoe underground workings.

Whilst there are a range of potential management options available, including pumping and storage of water from Ivanhoe in the former Invincible underground workings, this assessment has been based on the option of discharging all water from Ivanhoe from the site. An assessment of the receiving watercourses, i.e. Cullen Creek and its tributaries, indicates that the flow capacity of the channel immediately downstream of the Main Water Storage Dam is approximately 1.0 m^3 per second (i.e. 86.4 ML per day) which increases to a capacity of approximately 15 m^3 per second (i.e. 1,296 ML per day) immediately downstream of the Castlereagh Highway. The abovementioned flow rates have been determined for the bank full conditions using the XP-Storm model used to assess potential flood impacts associated with the Southern Extension Project (refer to **Section 6.2**).

The likelihood of wet weather discharge is limited by the number of rain days (i.e. wet weather). Based on the Lidsdale rainfall data (refer to **Table 5.1**) the number of rain days per year and associated likely wet weather discharge rates are shown in **Table 5.2**. Given the conservative nature of the assessment of volumes in both the Ivanhoe and Invincible underground workings, the assessment below is based on the worst case scenario, that is, none of the water in the Ivanhoe No.2 underground workings is stored in the former Invincible underground workings, instead all of the water from these workings is discharged in accordance with the EPL.

Table 5.2 Wet Weather Discharge Rate (Dewatering of Old Ivanhoe Underground Workings)

Percentile	Rain Days (per year)	Volume to be Dewatered (ML)	Wet Weather Discharge Rate (ML/d)	Wet Weather Discharge Rate (m^3/s)	Percentage of Bank Full (d/s of Main Water Storage Dam)
10%	93	2,121	22.8	0.26	26%
50%	117	2,121	18.1	0.21	21%
90%	137	2,121	15.4	0.18	18%

Note: Data is based on Dewatering over the course of 1 year

Based on the above data, maintaining the existing EPL discharge limits and restricting discharges to wet weather days only and taking account of existing flows in the receiving catchment, in excess of 2121 ML could be discharged from via the overflow in the Main Water Storage Dam in the first year of operations without exceeding the downstream channel capacity. Based on an analysis of climatic data and channel capacity, discharges from the site associated with dewatering activities would be limited to 260 l/s (22.8ML/day) on wet weather days only. This volume represents 26% of bank full flows.

In order to progressively dewater the Ivanhoe No. 2 workings, it may be necessary to temporarily store some of the Ivanhoe No. 2 water in the Invincible underground workings, pending suitable days for discharge. This can be managed through pumping from the Ivanhoe No 2 workings to the Eastern or Northern Voids or by direct drainage from the Ivanhoe No.2 workings into the Southern/Renown Pit void and allowing for percolation through spoil into the former Invincible Underground Workings. Water levels in the spoil of the former Invincible open cut workings would be monitored to ensure the volume stored does not exceed storage capacity.

Should groundwater monitoring indicate additional storage available within the former Invincible underground workings is available and/or the volume of water in the Ivanhoe No. 2 underground workings is less than assumed, some or all of the water from Ivanhoe No. 2 underground workings may be transferred to these workings. Should this additional storage be confirmed through monitoring, the volumes of water requiring to be discharged would be reduced. The period over which discharges associated with the dewatering would occur would also be reduced if there is less water than assumed in the Ivanhoe No. 2 workings or there is additional storage available in the Invincible underground workings.

Discharge rates may be increased to meet operational requirements and any increase in discharges would be assessed as part of an application, if required, to vary the EPL. The EPL will also need to be varied to cover limits on EC, iron and sulfate levels similar to those applying to discharges for other mining operations in the area. It is noted that any discharges associated with the dewatering of the former Ivanhoe underground workings will only be required in the short term. Ongoing discharges during the operation of the Southern Extension Project to manage operational water surpluses will be in accordance with relevant EPL requirements.

6.0 Surface Water Impacts

The Southern Extension Project and the associated WMS has the potential to impact on surface water systems including:

- Impacts to catchment areas and downstream watercourses
- Impacts to flooding, including flow rates, velocities and depths
- Impacts to water quality in downstream watercourses.

6.1 Catchment Areas and Annual Flow Volumes

Invincible with the Southern Extension Project will continue to capture runoff from upslope of the operational mining areas and manage runoff from disturbed areas during the operational and rehabilitation phases of the Southern Extension Project. Changes to catchment areas resulting from the Southern Extension Project provide an indicator of the potential relative changes in flow volumes that might occur. As such, changes in catchment areas have been used to predict the potential impacts on annual flow volumes in the downstream ephemeral watercourse systems for which long-term flow gauging data is not available.

The existing approved mining operations include capture of runoff from upslope of the operational areas and management of runoff from disturbed areas. The overburden emplacement areas will be rehabilitated as soon as practicable when final landform is achieved. By implication, some areas will be rehabilitated concurrently with overburden placement in others. The strategy of progressive rehabilitation will minimise the duration for which catchment is lost during the operational phase. Where practical, once rehabilitation is established, areas will be designed to externally drain to return water to the surrounding environment.

Table 6.1 summarises the predicted impacts on the catchment areas of Cullen Creek for the following scenarios:

- Prior to any mining
- Current landform
- Currently Approved Final Landform
- Maximum extent of mining under Southern Extension Project
- Proposed conceptual final landform.

For the assessment, the Southern Extension Project conceptual final landform has been compared to the currently approved final landform (refer to **Table 6.1**) unless stated otherwise.

Table 6.1 Cullen Creek Catchment Summary

Scenario	Area (ha)
Pre-mining	1,725
Current	1,020
Currently Approved Final Landform	1,725
End of Mining	1,020
Proposed Conceptual Final Landform	1,725

As shown in **Table 6.1**, substantial changes have occurred to date to the catchment area of Cullen Creek (i.e. when comparing pre-mining to the current area) as a result of approved mining operations within this catchment area.

During the life of the Southern Extension Project there will be no changes to the catchment area of Cullen Creek compared to the current impacts with the existing WMS. The Southern Extension Project will return by rehabilitation, existing catchment area as soon as possible to the downstream catchments. The Southern Extension Project final landform will not result in any final voids or changes to catchment boundaries as such there is no impact on the final catchment area compared to pre mining or the currently approved final landform.

As the Southern Extension Project will not result in changes to the current catchment area of Cullen Creek relative to the existing WMS or with the Southern Extension Project Final Landform compared to the currently approved Final Landform it is considered that there will be no reduction in annual flow volumes, relative to the currently approved impacts, in Cullen Creek. If required, the discharge of water from the site will increase flows in the Cullen Creek catchment relative to the current approved operations. As outlined in **Section 5.4**, this discharge would be managed in accordance with the relevant EPL requirements and in consultation with the EPA.

6.2 Flooding

Dynamic flood modelling of Cullen Creek was undertaken using XPStorm®. Flood modelling was undertaken for the pre mining landform, the existing site, and the Southern Extension Project final landform. Flood events that were simulated included the 100 per cent, 5 per cent, 2 per cent and 1 per cent AEP flood events.

For the assessment, flood modelling results for the Southern Extension Project final landform have been compared to the pre mining landform. As no change occurs to the current catchment area during the operational life of the Southern Extension Project it is considered that there will be no impacts on downstream flooding during the life of the Southern Extension Project.

The key potential changes to flood behaviour in Cullen Creek associated with the Southern Extension Project final landform include:

- changes of flood hazard category and as such associated access during flooding along the Castlereagh Highway
- changes to flood depths and inundation extents

- changes to maximum flow velocities and as such potential impacts on erosion/scour.

6.2.1.1 Results

The results of the modelling for Cullen Creek, including peak flows, flood depths, velocities, and flood downstream of the Castlereagh Highway are shown in **Table 6.2**.

Table 6.2 Peak Flood Model Results for Cullen Creek downstream of the Castlereagh Highway

Flood Event	Parameter	Scenario	
		Pre-mining	Southern Extension Project Final Landform
100% AEP event	Depth (m)	1.14	1.01
	Velocity (m/s)	0.63	0.60
	Flow (m^3/s)	14.6	13.0
5% AEP event	Depth (m)	1.61	1.54
	Velocity (m/s)	0.88	0.84
	Flow (m^3/s)	38.3	33.3
2% AEP event	Depth (m)	1.74	1.65
	Velocity (m/s)	0.95	0.91
	Flow (m^3/s)	47.0	40.8
1% AEP event	Depth (m)	1.82	1.75
	Velocity (m/s)	1.00	0.95
	Flow (m^3/s)	53.5	46.0

There are four road crossings located over tributaries of Cullen Creek downstream of Invincible that have the potential to be impacted upon by changes to flooding associated with the Southern Extension Project final landform (refer to **Figure 4.3**). The calculated flood hazard category, as determined in accordance with the methods outlined in Appendix H of the NSW Floodplain Development Manual (NSW DIPNR, 2005) for the pre-mining and Southern Extension Project final landform are shown in **Table 6.3**.

Table 6.3 Peak Modelled Flood Hazard Categories at the Castlereagh Highway

Flood Event	Culvert ID	Scenario	
		Pre-Mining	Southern Extension Project Final Landform
100% AEP event	1	Walking and Vehicle Access	Walking and Vehicle Access
	2	Walking and Vehicle Access	Walking and Vehicle Access
	3	Walking and Vehicle Access	Walking and Vehicle Access
	4	Vehicle Unstable	Vehicle Unstable
5% AEP event	1	Wading Unsafe	Wading Unsafe
	2	Walking and Vehicle Access	Vehicle Unstable
	3	Vehicle Unstable	Vehicle Unstable
	4	Wading Unsafe	Wading Unsafe
2% AEP event	1	Wading Unsafe	Wading Unsafe
	2	Walking and Vehicle Access	Vehicle Unstable
	3	Vehicle Unstable	Vehicle Unstable
	4	Damage to Light Structures	Wading Unsafe
1% AEP event	1	Wading Unsafe	Wading Unsafe
	2	Walking and Vehicle Access	Vehicle Unstable
	3	Wading Unsafe	Vehicle Unstable
	4	Damage to Light Structures	Wading Unsafe
100% AEP event	1	Walking and Vehicle Access	Walking and Vehicle Access
	2	Walking and Vehicle Access	Vehicle Unstable
	3	Wading Unsafe	Vehicle Unstable
	4	Damage to Light Structures	Wading Unsafe

Note: Flood hazard category is determined accordance with the methods outlined in Appendix H of the *NSW Floodplain Development Manual* (NSW DIPNR, 2005).

Note 2: Flood Hazard Categories increasing in order are: Walking and vehicle access (1), Vehicles unstable (2), Wading unsafe (3), Damage to light structures (4). (i.e. accessibility decreases with increasing flood hazard category)

The modelling indicates that the Southern Extension Project results in decreases to peak flood depths, flows and velocities downstream in Cullen Creek.

The modelling indicates that the Southern Extension Project will range between negligible to improved flood access at the three of the culvert creek crossings over the Castlereagh Highway with the Southern Extension Project final landform. There is one culvert crossing, Culvert ID 2 that increases in flood hazard category between the pre-mining and Southern Extension Project final landform scenarios. However, it is considered that although the modelling predicts an increase this will not impact on the accessibility of the Castlereagh Highway at this location as the flood hazard categories are the same as the northern adjacent culvert (ID 3) and less than at the most northerly culvert (ID 4). Overall the flood accessibility of the Castlereagh Highway is improved with a reduction of the maximum flood hazard category from Damage to Light Structures to Wading Unsafe.

The changes in flood characteristics between the pre-mining and final landform scenarios are considered minor and would not be expected to impact on erosion/scour or sediment deposition within Cullen Creek.

6.3 Geomorphological and Hydrological Values

The Southern Extension Project is not expected to result in impacts to the geomorphological or hydrological values of local surface water systems. Potential impacts on geomorphological stability and changes to potential erodibility and scour as a result of the Southern Extension Project are discussed below.

The bed and banks of Cullen Creek have undergone little modification from existing operations. Upstream of the crossing with the Castlereagh Highway, Cullen Creek has a generally poorly defined channel and a sparsely vegetated riparian zone. The lower reaches of Cullen Creek prior to joining Delhuntys Creek are better defined, but remain sparsely vegetated.

The Southern Extension Project will not influence the contributing catchment of Cullen Creek over its life.

The Southern Extension Project final landform will result in a slight decrease in modelled flood flows and velocities compared to the pre-mining case. This slight decrease would likely be associated a reduction in potential impacts on stability, such as scour, are therefore predicted to be reduced in comparison with the pre-mining case.

6.4 Water Users

The Macquarie Bogan Unregulated and Alluvial Water Sources WSP applies to all land affected by surface operations at Invincible. The WSP includes rules for protecting the environment, water extractions, managing licence holders' water accounts and water trading in the plan area.

The majority of land adjacent to Cullen Creek immediately downstream of Invincible is owned by private landholders that retain basic landholder rights for domestic and stock use. There are no known licensed water users on waterways directly downstream of Invincible along Cullen Creek.

While the Southern Extension Project does not extract water from Cullen Creek directly, the WMS does intercept runoff from part of the upstream catchment area. Capture of water from Cullen Creek is managed under *Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources (Turon Crudine River Water Source)* and is discussed in **Section 2**. Capture of quantities beyond those allowed under basic landholder rights (10 per cent of the average regional runoff from a landholding) require a WAL which Invincible will obtain as part of its permitting process.

Following rehabilitation, the Southern Extension Project will have minimal impact on annual flow volumes in Cullen Creek compared to the pre-mining conditions. During the life of the Southern Extension Project, impacts will be commensurate with those associated with the currently approved existing site. Water take associated with any dams remaining in the Southern Extension Project final landform will be managed within the harvestable rights provisions for the final landholdings (refer to **Section 9**).

The predicted impacts on flows in the downstream receiving waters, including Cullen Creek and it is considered there will be no negative impacts on downstream water users in the Turon River system.

6.5 Water Quality

To manage potential water quality impacts throughout the life of the Southern Extension Project, it is proposed to integrate water management for the Southern Extension Project within the existing WMS. The concept WMS is described in **Section 4.0**. In conjunction with the proposed WMS, a series of erosion and sediment control measures will be utilised during the construction, operation and rehabilitation phases of the Southern Extension Project to manage water quality (refer to **Section 7.1**).

As set out in **Section 4.0**, it is proposed to integrate water management for the Southern Extension Project with the existing WMS to limit the potential impacts of the Southern Extension Project on downstream water quality by managing water that has the potential to cause environmental harm. In conjunction with the proposed WMS, a series of erosion and sediment control measures will be utilised during construction, operation and rehabilitation phases of the Southern Extension Project to manage water quality (refer to **Section 7.1**).

Through management of dirty water and mine water within the WMS over the life of the Southern Extension Project, and based on the outcomes of the assessment of changes to flood behaviour and flows in downstream watercourses, it is not anticipated that water quality in downstream watercourses will be adversely impacted by the Southern Extension Project. As such the Southern Extension Project is considered to have a low potential for adverse cumulative impacts to water quality on downstream watercourses.

Water discharges from Invincible will continue to be managed in accordance with EPL requirements.

6.5.1 Likely Risks to Downstream Water Quality

The surface water monitoring programs have been in place at Invincible for a number of years and were developed based on the management of risk to downstream water quality posed by the existing operations. It is considered that the Southern Extension Project will not change the specific risks to water quality compared to the existing operations.

The highest risks to downstream surface water quality as a result of the Southern Extension Project are summarised in **Table 6.3**. **Table 6.3** identifies the water management control category which is proposed to manage the risk.

Table 6.4 Preliminary Risk Assessment - Surface Water Quality

Aspect	Water Management Control Category	Risk to Environment	Comment
Discharge of mine water	Mine	Low - Medium	The WMS in the CPP area is designed to manage runoff for events up to and including the 1 per cent 24 hour AEP storm event. Water will overflow to the Main Water Storage Dam where it is considerably diluted. Water quality monitoring results indicate negligible impact on downstream systems.
Overflow/failure of sediment pond (dirty water)	Dirty	Low - Medium	Sediment dams are managed in line with the Blue Book and designed to manage runoff from the 5 day, 95th percentile rainfall event. Some sediment dams have secondary containment measures downstream. Elevated TSS is primary risk.
Spillage of tailings	Mine	Low	Tailings are disposed of on site. Risk only arises as a result of tailings storages filling in extreme events and overtopping, however, management procedures are in place which limit water volume making this very unlikely to occur.

The higher risks (low to medium level) outlined in **Table 6.3** are associated with the dirty water management system where the risk is associated with overflow from sediment dams during rainfall events above the design criteria specified in the Blue Book. These design criteria have been established by the NSW Government specifically for sediment control at mining and quarry operations.

Based on the preliminary risk assessment and considering the controls to be implemented as part of the Southern Extension Project design, the primary monitoring parameter for mining impacts in regard to potential impacts on downstream water quality is TSS. Invincible currently monitors pH, EC and oil and grease in downstream watercourse.

Additional management and monitoring measures for the Southern Extension Project are summarised in **Section 7.0** and **8.0**.

6.6 Cumulative Impacts

Both the Southern Extension Area and the surrounding areas have been subject to open cut and underground mining operations for several decades. Recent and existing mining at the site include underground workings and open cut pits. In the local region other mining operations include open cut and underground operations at Cullen Valley, Ivanhoe and Baal Bone Collieries, which are on care and maintenance or in the case of Ivanhoe being rehabilitated.

The surface water assessment indicates that the Southern Extension Project is expected to have negligible impacts on flows, water quality and water users relative to the current approved impacts immediately downstream of Invincible on Cullen Creek and the Turon River system.

7.0 Mitigation and Management Measures

The key management measures for the Southern Extension Project in regard to surface water are the Invincible WMS (refer to **Section 4.0**) and associated erosion and sediment control measures (refer to **Section 7.1**).

In addition, there will be a series of erosion and sediment control measures utilised during the construction and operation phases of the Southern Extension Project. These measures are described in **Section 7.1.**

The existing monitoring programs at the operations will be updated as part of the implementation of the Southern Extension Project, including development of specific triggers around low pH and associated monitoring of metals/metalloids. These programs will be documented in the Invincible Surface Water and Groundwater Monitoring Program.

In addition, the Water Management Plan will be updated to guide the overall management of water as part of the Southern Extension Project (refer to **Section 8.0**).

7.1 Erosion and Sediment Control Measures

Erosion and sediment control measures to be implemented as part of the Southern Extension Project will be described in the Erosion and Sediment Control Plan (ESCP). These measures will be undertaken in accordance with the Blue Book (Volumes 1 and 2). The ESCP will provide a framework for the management of erosion and sedimentation for the Southern Extension Project.

The objective of the ESCP will be to ensure that appropriate structures and programs of work are in place to:

- Identify activities that could cause erosion and generate sediment
- Describe the location, function and capacity of erosion and sediment control structures required to minimise soil erosion and the potential for transport of sediment downstream
- Ensure erosion and sediment control structures are appropriately maintained
- Fulfil the statutory conditions of the project approval
- Meet the requirements of the Blue Book (Landcom 2004) and DECC (2008).

7.1.1 Construction

Erosion and Sediment Control Plans (ESCPs) will be prepared for construction of works associated with the Water Management System. The ESCPs will detail the specific soil and water controls and their inspection and maintenance requirements, along with revegetation requirements for each work area based on the construction program schedule. These control measures will be in accordance with relevant guidelines for erosion and sediment control, including the relevant volumes of the Blue Book, as follows:

- Landcom 2004. Managing Urban Stormwater – *Soils and Construction, Volume 1, 4th Edition.*
- Department of Environment and Climate Change (DECC) 2008. *Managing Urban Stormwater – Soils and Construction, Volume 2E – Mines and Quarries.*

7.1.2 Operations

The operational phase will involve the ongoing management of the WMS, and be consistent with:

- Landcom 2004. Managing Urban Stormwater – *Soils and Construction, Volume 1, 4th Edition*
- Department of Environment and Climate Change (DECC) 2008. *Managing Urban Stormwater – Soils and Construction, Volume 2E – Mines and Quarries*.

Specific erosion and sediment control measures proposed to be implemented for the Southern Extension Project will also include those measures outlined in **Section 4.0** and the Mine Closure and Rehabilitation Assessment.

Periodic maintenance of the water management system is undertaken and includes:

- de-silting and maintenance of sediment dams and drainage lines
- installation of silt fences, hay bales and armouring as appropriate to minimise soil erosion during rainfall events
- construction of additional drainage lines as required
- continuation of the water quality monitoring program.

8.0 Monitoring, Licensing and Reporting

Water systems at and surrounding the Southern Extension Project are currently monitored in accordance with the Invincible Water Management Plan (Coalpac Pty Limited, 2009).

Water monitoring is undertaken to assess compliance against licence and consent conditions and for operational purposes. This includes monitoring of erosion and sediment controls, the site water balance and water quality.

A record of baseline data has been collected for Invincible (refer to **Section 2.2.4**) and will be used to inform the ongoing review of monitoring data, allowing any potential impacts of the Southern Extension Project to be identified and management measures implemented where appropriate.

As part of the implementation of the Southern Extension Project, the water management plan will be updated for the Project. This plan will be used to guide the overall management of water as part of the Project, and will include:

- A water balance including details of water supply, use, management and transfers
- A Erosion and Sediment Control Plan that is consistent with the requirements of Managing Urban Stormwater: Soils and Construction – Volume 1 and Volume 2E Mines and Quarries, or its latest version
- A Surface Water Management Plan, including:
    - relevant baseline data on water quality
    - a description of the water management system on site including design objectives and performance criteria
    - trigger levels for investigating any potentially adverse impacts
    - a surface water monitoring program.
- A Groundwater Management Plan.

8.1 Monitoring

Erosion and sediment controls will be monitored during construction and operation in accordance with the *Blue Book* (Landcom, 2004 and DECC, 2008). Monitoring of the performance of the water management systems and associated erosion and sediment control measures will be set out in the WMP, with monitoring typically undertaken monthly and after major storm events.

8.1.1 Water Balance Monitoring

As part of the water balance monitoring for the water management system, water imported to site, water used on site and water discharged from site will be monitored in accordance with *Water Reporting Requirements for Mines* (NSW Office of Water, undated).

8.1.2 Surface Water Quality Monitoring

Surface water quality monitoring is currently undertaken within the WMS and at two locations downstream of Invincible and at one discharge/monitoring point on site. Water quality parameters monitored in watercourses include sampling of pH; Total Suspended Solids (TSS); iron (Fe); manganese (Mn); and Oil and Grease in the Main Water Storage Dam, and pH and Oil and Grease in the downstream locations. Surface water monitoring will be continued over the life of the Project.

It is proposed to:

- Monitor and document the existing water quality downstream of Invincible using the water quality parameters, frequency of sampling and water quality triggers as for the existing operations (i.e. pH, EC, TSS and oil & grease)
- When water quality data is available for the Ivanhoe No.2 underground workings, the parameters to be monitored during wet weather discharges will be reviewed in relation to the requirements of the EPL
- review and monitor the performance of erosion and sediment controls
- continue the reporting of monitoring results in the Annual Return as required in the EPL.

8.1.3 Flow Monitoring

Flow monitoring will continue to be undertaken by visual observation of the flows during water quality sampling (flow, no-flow). The flow observations will be used to inform the assessment of water quality data.

Visual inspections will also be made of the channel immediately downstream of the Main Water Storage Dam for the extent of the Castlereagh Coal land holdings to monitor for any erosion and/or scour associated with wet weather discharges.

8.1.4 Contingency Measures

The process of detailed design, construction and monitoring/maintenance of the proposed WMS during the operational phase is intended to reduce the risks associated with unplanned spillages or other unforeseen circumstances with potential to result in unexpected environmental impacts. That is, the system has been designed considering the range of potentially relevant environmental factors and variables, reducing the risk of the implemented system not performing as planned.

As outlined in **Section 8.0,** the Water Management Plan will include plans to respond to any exceedances of the performance criteria, and mitigate and/or offset any adverse surface water impacts of the development. This will include, for the operational phase of the Project, the hazards to be managed, incident management processes, notification procedures, and other key information to address incidents.

8.2 Decommissioning of the Water Management System

As part of decommissioning, water management dams will either remain in use for identified and approved future land uses or will be removed. If the dams are to be retained, the capacity of the dams will be reviewed and the size/volume modified as necessary. Areas disturbed by removal or modification of water management structures will be reshaped and revegetated. The measures required to effectively decommission the water management system and the water management controls required in the post mining landform will be considered in further detail as part of the detailed colliery closure planning process.

8.3 Licensing Requirements

8.3.1 Protection of the Environment Operations Act 1997

Operations at Invincible are currently undertaken in accordance with Environment Protection Licence (EPL) 1095 under the *Protection of the Environment Operations Act 1997*. Invincible propose to continue to operate under EPL 1095, which may require variations in relation to the changes wet weather discharge requirements as associated with the dewatering of Ivanhoe workings. This will be confirmed through the completion of monitoring in the former Ivanhoe workings as part of the Southern Extension Project.

8.3.2 Water Management Act 2000

8.3.2.1 Licensing of take during operations

Water licensing for the Southern Extension Project is governed by the *Water Management Act 2000* and applicable WSPs. Whilst technically classified as 'groundwater' for the purposes of the *Water Management Act 2000*, the water in the Ivanhoe No. 2 workings is largely stored surface water which was historically intercepted by subsidence cracks. The historical take of this water has been considered in the development of the WSP applicable to these surface flows and the extraction of this water is not considered to be take for the purposes of the Water Management Act. Surface flows from upstream catchments intercepted by the open cut workings is considered licensable take. The net take from surface flows (i.e. intercepted flow less water returned to the catchment via discharges) over basic landholder rights will need to be licensed.

A detailed site water balance will be developed, based on confirmed water volumes in Ivanhoe No. 2 workings, to confirm net take and outflows into both groundwater and surface water systems. Net take from these systems in excess of basic landholder rights will be licenced in accordance with the rules under the relevant WSP. Licensing of take associated with final landform.

The allowable annual water take under Harvestable Rights provisions is calculated based on the average regional runoff rate (as published by DPI Water on the Farm Dams Calculator website). Castlereagh Coal owns a land area of approximately 146 hectares. Based on the capture of 10 percent of the average regional runoff (http://www.water.nsw.gov.au/water-licensing/basic-water-rights/harvesting-runoff/calculator) this equates to a MHRDC of 11.68 ML per year i.e. the total capacity of dams allowable without a licence under Harvestable Rights provisions. The Project final landform currently does not include provision for retention of farm dams within the landform. Castlereagh Coal may, depending on the final landuse and associated potential lots, retain specific dams within the proposed final landform. The volume of these dams will not exceed the Maximum Harvestable Rights Dam Volume for each land parcel, or if this volume is exceeded, water access licences will be allocated to the land parcel to allow for water take associated with each dam.

Castlereagh Coal has consulted with DPI Water in relation to the relevant licensing requirements for the Southern Extension Project and will continue to engage with DPI Water to confirm the specific water licensing requirements for the Southern Extension Project.

8.3.3 Reporting

A summary of surface water monitoring results will be provided in the Annual Review. As a minimum, the following information will be reported in the Annual Review:

- a summary of monitoring results
- an analysis of monitoring results against impact assessment criteria, historical monitoring results and the predictions in the EIS
- annual site water balance and comparison against predictions in the EIS
- an identification of any trends in the monitoring results
- any non-compliances reported during the year
- actions taken to address any non-compliances.

In addition, any significant findings regarding the implementation of the WMP will be reported in the Annual Review, including:

- the effectiveness of the erosion and sediment controls
- changes to the site water balance
- any identified issues or exceedances of trigger values.

The Annual Review will also document reviews and feedback relating to the maintenance and performance of the water management system. Reporting of monitoring data will also occur in accordance with EPL requirements.

9.0 References

ANZECC/ARMCANZ, 2000. *National Water Quality Management Strategy: Australian Guidelines for Fresh and Marine Water Quality*.

Australian Groundwater Consultants (AGE), 2011. *Coalpac Consolidation Project Groundwater Impact Assessment.*

Australian Groundwater Consultants (AGE), 2016. *Invincible Southern Extension Project – Groundwater Impact Assessment.*

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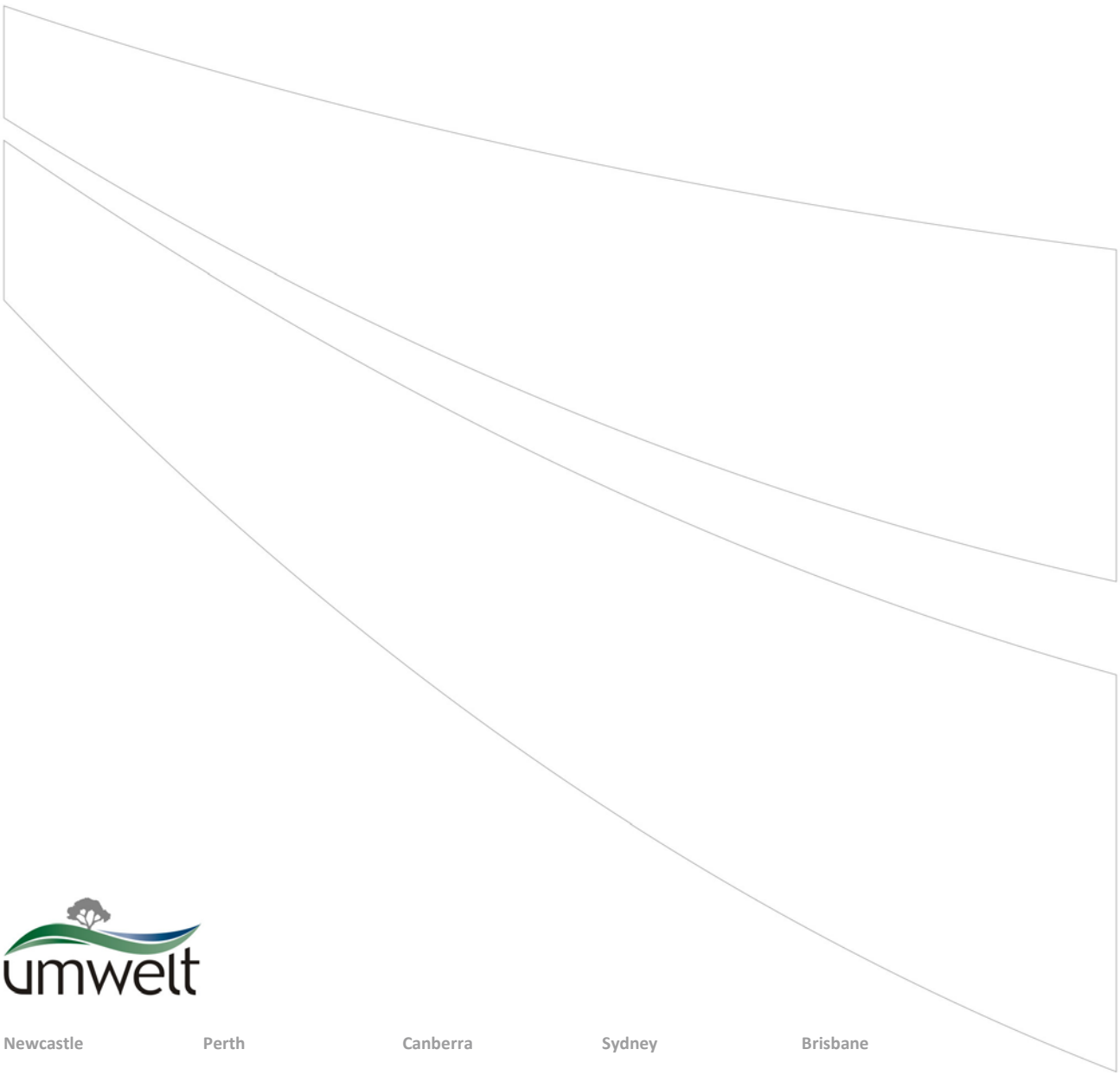

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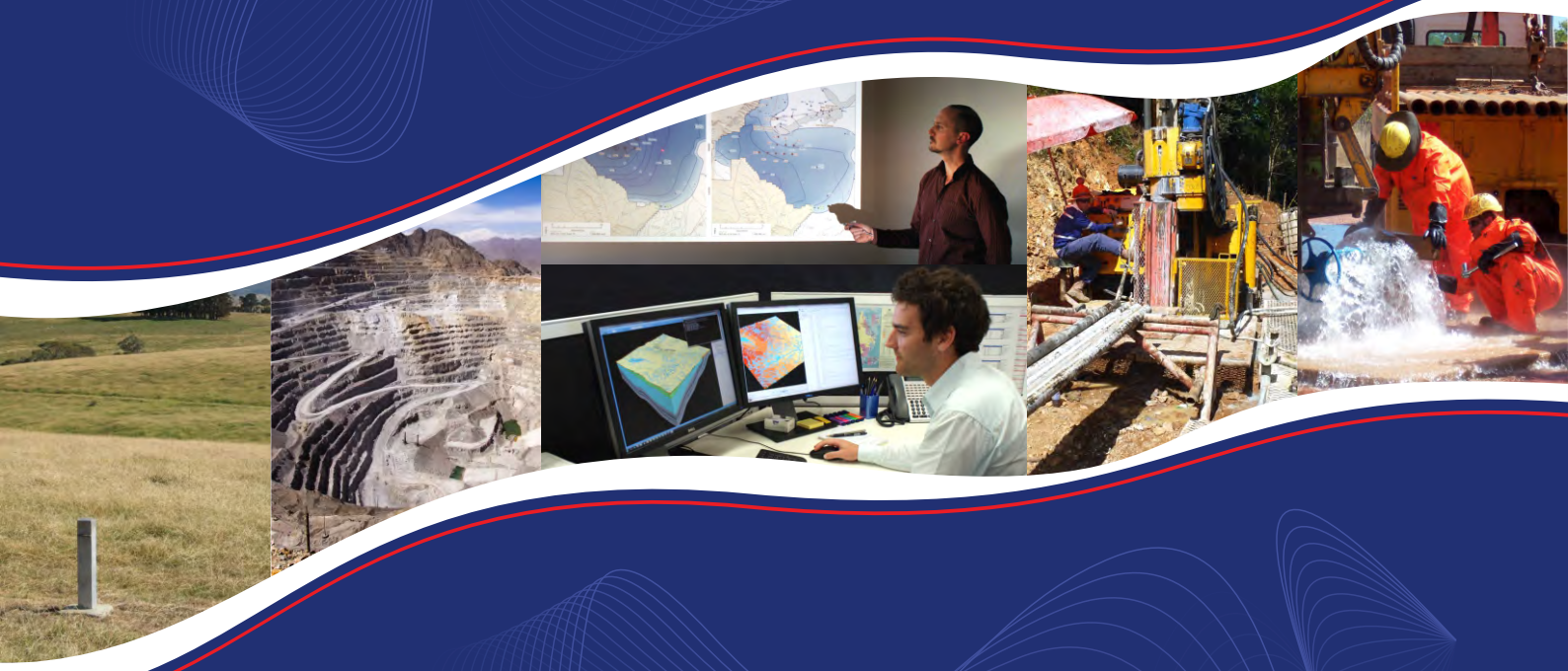
APPENDIX 5

Groundwater Assessment

Australasian
Groundwater
and Environmental
Consultants Pty Ltd
(AGE)



Report on

Invincible Southern Extension Groundwater Impact Assessment

Prepared for
Umwelt Pty Ltd

Project No. G1817 September 2016
www.ageconsultants.com.au ABN 64 080 238 642

Document details and history

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Report on

Invincible Southern Extension Groundwater Impact Assessment

1 Introduction

The Invincible Colliery operation (Invincible) is located adjacent to the Castlereagh Highway, approximately 25 km to the northwest of Lithgow, New South Wales (NSW) – refer Figure 1. Mining operations at Invincible are undertaken in accordance with Project Approval (PA) 07_0127 (approved 4th December 2008) to mine coal at a maximum rate of 1.2 Million tonnes per annum (Mtpa) Run of Mine (ROM).

Shoalhaven Coal Pty Ltd, trading as Castlereagh Coal (Castlereagh Coal), are part of the Manildra group of companies and purchased Invincible and the nearby Cullen Valley Mine for the purposes of providing coal to the Manildra Group's Shoalhaven Starches Plant. Castlereagh Coal commissioned Umwelt Pty Ltd (Umwelt) to manage and prepare an environmental assessment to support a Section 75W *Environmental Planning and Assessment Act 1979* (EP&A Act) modification application for the Invincible Southern Extension Project (hereafter referred to as the Southern Extension Project).

Castlereagh Coal proposes to extend the open cut Invincible workings south of the existing approved mining area into the Southern Extension Project area (refer Figure 2). The Project will extend the life of the mine for a further four years at maximum production rate. However, approval is sought to extend the period of mining in the Southern Extension Project area for up to 8 years to enable flexibility in production and supply of coal to Shoalhaven Starches. The 50 hectare Southern Extension Project area was previously mined by underground bord and pillar methods and approximately 35% of the coal reserves in this area are estimated to remain. These old mine workings are part of the Ivanhoe No. 2 Colliery which extracted the Lithgow coal seam.

Umwelt commissioned Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) to prepare a groundwater impact assessment for the Southern Extension Project.

1.1 Objectives and scope of work

The objective of this groundwater assessment was to appraise the potential impact of the Southern Extension Project on the groundwater system, compared to the approved development, and address the requirements of NSW Government legislation, policies, and guidelines.

Groundwater impact assessments have previously been undertaken at Invincible (and neighbouring Cullen Valley Mine) for other recent mine modification applications lodged by the previous owners of the site, Coalpac Pty Ltd (Coalpac). Although the recent modification applications by Coalpac were not progressed or were not approved by the NSW Government, the previous groundwater impact assessments concluded the risk of impact to surrounding groundwater systems by these modifications was low (AGE, 2012 and 2014). This conclusion was reached because the previously proposed modifications were located along an elevated ridge where much of the target strata were located above the groundwater table and unsaturated.

The Lithgow Coal Seam has been mined extensively in the vicinity of Invincible by historic underground and open cut workings in addition to current approved operations. This past mining has largely removed the coal seam aquifer (being the main aquifer within the Southern Extension Project area), and depressurised the remaining un-mined coal. The former underground workings are possibly wholly or partly flooded. However, this partial recharge of the aquifer does not represent a repressurisation of the aquifer to pre-mining conditions. Hence, as the coal seam aquifer has been largely replaced by underground open voids that are wholly or partly flooded, the key water related issue for the Southern Extension Project is managing the water stored within flooded former underground workings.

The proposed Southern Extension Project is proposed to mine into the former underground workings of the Ivanhoe No. 2 Colliery, and these workings are possibly flooded. The total volume of water in the Ivanhoe No. 2 Colliery has not been monitored with the volumes of water quantity being estimated as part of this groundwater assessment.

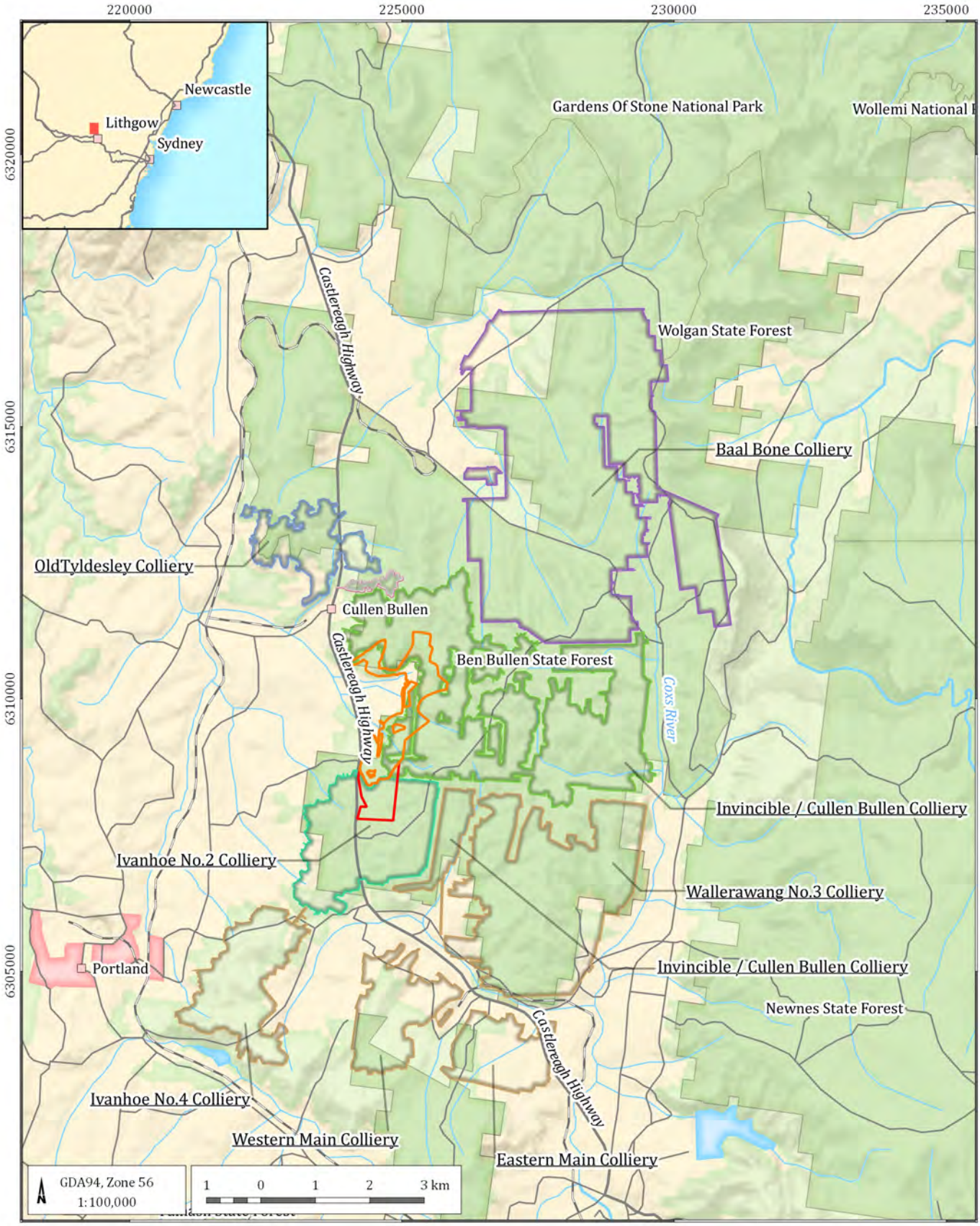
Water in the Ivanhoe No. 2 Colliery will have largely (if not totally) come from surface inflows from subsidence cracking. A large percentage of the runoff from the Southern Extension Project area and upstream catchment is likely to be intercepted by subsidence cracking associated with the previous Ivanhoe No. 2 Colliery. These surface flows would have otherwise flown into Cullen Creek. A portion of recharge is also likely to be from water accumulating within the open cut areas where the seam is at outcrop or buried within the spoil and to a lesser degree via natural recharge processes.

To enable the Southern Extension Project area to be mined, it is proposed that the water in the Ivanhoe No. 2 Colliery be pumped / drained into the voids of the former Invincible underground workings.

The primary focus of this assessment was to appraise the potential for the historical underground workings in the Southern Extension Project area to store accumulated water. This assessment estimates the volume of water potentially stored within the Southern Extension Project area and how much of this water will need to be dewatered for the Southern Extension Project to proceed. This assessment also estimates the likelihood of impacts occurring on surrounding water sources, users, and dependent ecosystems, and the potential consequences of these impacts.

The groundwater impact assessment included consideration of:

- existing background data and any data gaps;
- groundwater sources, including hydraulic properties of coal seams and other geological formations, and groundwater quality;
- potential hydraulic interaction between adjacent and nearby historical mining operations;
- extent of groundwater impacts as a result of the operation of the proposed mine, including long term impacts on regional groundwater levels;
- potential impacts on groundwater dependant ecosystems (GDEs);
- potential for groundwater level drawdown in private bores as a result of changes to the regional groundwater system;
- compliance with the NSW Aquifer Interference Policy (AIP) (DPI, 2012); and
- proactive mitigation measures and monitoring.



LEGEND

- Populated place
- Rail
- Road major
- Road
- Watercourse
- Proposed southern extension
- Invincible Colliery Open Cut - existing mine disturbance area
- National parks and reserve boundaries
- Vegetation
- Built up area
- Water area
- Land

Colliery locations

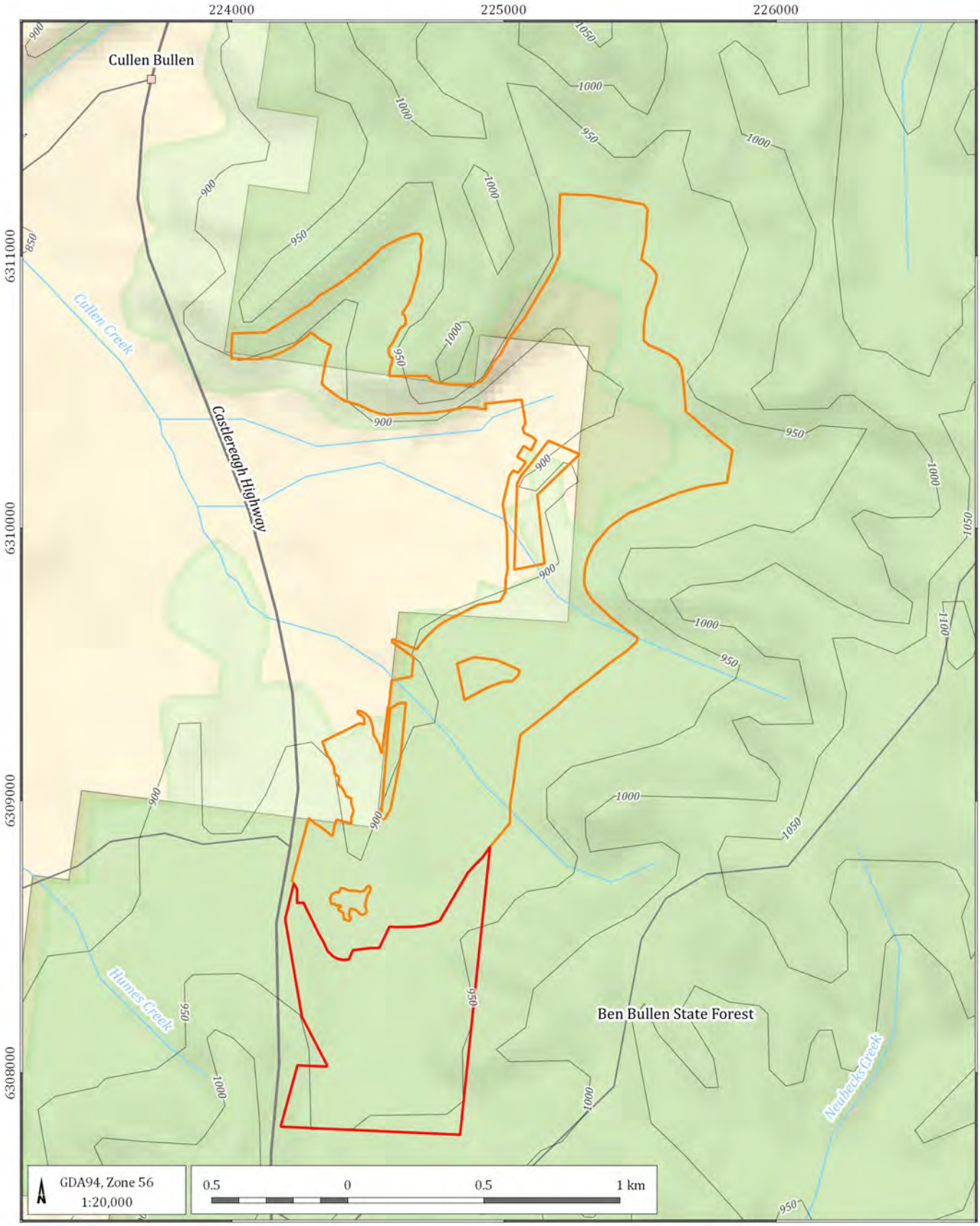
- Baal Bone Colliery
- Invincible Colliery
- Ivanhoe Colliery
- RT108 Colliery
- Tyldesley Colliery

Invincible Southern Extension Project (G1817)

Site location plan

DATE 27/07/2016

FIGURE No: **1**



LEGEND

- Populated place
- Road major
- Road
- Watercourse
- Contour interval 50m
- Proposed southern extension
- Invincible Colliery Open Cut - existing mine disturbance area
- National parks and reserve boundaries
- Vegetation
- Land

Invincible Southern Extension Project (G1817)

Proposed extension

DATE 27/07/2016

FIGURE No: **2**

1.2 Project description

1.2.1 Historical mining operations

Coal mining at Invincible commenced in 1901 with the establishment of an underground mining operation located on the eastern side of the township of Cullen Bullen. This operation (referred to in this document as the Old Invincible Colliery) continued into the mid-1950's, when the mine entrance was relocated approximately 4 km to the south to commence another underground operation (Invincible Colliery) which remained active until 1998, when underground operations were suspended. Limited open cut mining at Invincible Colliery commenced in 1998 and continued until 2001, when the site was placed on care and maintenance.

In 2005, Coalpac secured a contract from Delta Electricity to supply coal to the Mount Piper Power Station (MPPS) over a three-year period. An application for Project Approval under the EP&A Act, supported by the Environmental Assessment for Proposed Extension of Invincible Open Cut Mine and Rehabilitation Activities (Craven Elliston Hayes, 2006), was submitted to Department of Planning (DoP) for an extension to the open cut operations at Invincible. Project Approval (PA 05_0065) was granted in September 2006 for the mine extension and Invincible was taken off care and maintenance. Following the recommencement of open cut mining at Invincible being approved, two further successful applications were made for the modification of PA 05_0065. These modifications gained approval to introduce highwall mining within the open cut mine area.

Current mining operations at Invincible are approved under PA 07_0127 (as modified), which was initially granted on 4th December 2008 for the extension of open cut and highwall mining operations as described in the Environmental Assessment of the Proposed Extension to the Invincible Colliery Open Cut Mine and Production Increase (R.W. Corkery, 2008).

In 2014, Coalpac sought a modification approval (Modification 4 Project) to extend open cut and high wall mining at Invincible in order to continue the mine life by four years (2016-2020). The planning assessment commission (PAC) refused the proposal because it found Coalpac's proposed mining would pose unacceptable risks and impacts to pagoda landform complexes.

The Ivanhoe No. 2 Colliery was operated as a separate mine to Invincible and the two mines are separated by a continuous coal seam barrier. Mining occurred within the Ivanhoe No.2 Colliery and the early phases of Invincible, at similar times. However, unlike Invincible, the Ivanhoe No. 2 Colliery has not recently operated. Very limited information is currently available for this assessment to accurately determine if the historical workings of the Ivanhoe No.2 Colliery are dry or flooded. However, information in the form of survey plans of the historical mine workings suggest they are currently flooded. The former Ivanhoe No. 2 workings in the Southern Extension Project area are shallow with a depth of cover of as little as 12 to 15 metres in many places. There is extensive subsidence cracking in the northern part of the Southern Extension Project area and there is a large sinkhole in one of the drainage lines. The likely cause of flooding in these workings is infiltration through the surface cracking associated with subsidence rather than groundwater seepage.

1.2.2 Proposed modification

The proposed Southern Extension Project will seek approval for a significantly reduced mining area compared to the previous Coalpac proposal. The currently proposed mining area will be restricted to the Southern Extension Project area as shown in Figure 2. The mine plan has had regard to the ecological and conservation values associated with the pagoda landform complexes. The Southern Extension Project does not include any highwall mining.

The proposed Southern Extension Project includes the following main components:

- open cut mining of the area to the south of the existing Invincible open cut operations;
- extraction of coal (nut coal and thermal coal) from the target seams, at rates up to the currently approved cap of 1.2 million tonnes per annum (Mtpa) Run-of-mine (ROM) coal;
- dewatering of former workings prior and during mining;
- rehabilitation of the proposed mining area and existing Invincible disturbance area;
- in-pit placement of overburden;
- maintenance and upgrade of Invincible coal preparation plant;
- modifications to mine water management system associated with proposed mining areas;
- transport of coal (no change to existing conditions on time and mode of transport); and
- hours of operation (no change to existing approved hours of operation).

1.3 Report structure

This report is structured as follows:

- Section 1: Introduction: provides an overview of the Southern Extension Project, assessment scope and an outline of currently approved activities.
- Section 2: Regulatory framework: describes the regulatory framework relating to groundwater.
- Section 3: Environmental setting: describes the environmental setting of the Southern Extension Project, including the climate, terrain, land uses, and other relevant environmental features.
- Section 4: Geological setting: describes the lithology of the main stratigraphic units.
- Section 5: Hydrogeology: describes the existing local groundwater system for the Southern Extension Project area and surrounds.
- Section 6: Impact assessment methods and results: estimates the likelihood of impacts occurring on surrounding water sources, users, and dependent ecosystems, and the potential consequences of these impacts. The estimated groundwater take and licencing requirements are also discussed.
- Section 7: Compliance with NSW Aquifer Interference Policy: compares the predicted impacts to the NSW government policy and comments on the level of compliance.
- Section 8: Groundwater Monitoring and Management Plan: describes the proposed measures for monitoring and management of groundwater impact.
- Section 9: Conclusions.

2 Regulatory framework

The proposed modification requires consideration of the following NSW Government legislation, policy, and guidelines for groundwater:

- *Water Act 1912*;
- *Water Management Act 2000*;
- Water Sharing Plans;
- Groundwater Quality Protection Policy;
- Groundwater Dependent Ecosystems Policy;
- Groundwater Quantity Management Policy; and
- Aquifer Interference Policy (AIP).

Sections below summarise the intent of the legislation, policy, and guidelines and how they apply to the Project.

2.1 Water Act 1912

The NSW *Water Act 1912* regulates water sources including rivers, lakes, and groundwater aquifers across the State. It also manages the trade of water licences and allocations. The *Water Management Act 2000* is progressively replacing the *Water Act 1912* where Water Sharing Plans have been introduced.

2.2 Water Management Act 2000

The NSW *Water Management Act 2000* provides for the *"protection, conservation and ecologically sustainable development of the water sources of the State"*. The *Water Management Act 2000* provides clear arrangements for controlling land based activities that affect the quality and quantity of the State's water resources. It provides for three primary types of approval in Part 3:

- water use approval – which authorise the use of water at a specified location for a particular purpose, for up to 10 years;
- water management work approval; and
- activity approval which includes an aquifer interference activity approval – which authorises the holder to conduct activities that affect an aquifer such as activities that intersect groundwater, other than water supply bores, and may be issued for up to 10 years.

The *Water Management Act 2000* includes the concept of ensuring "no more than minimal harm" for both the granting of water access licences and the granting of approvals. Aquifer interference approvals are not to be granted unless the Minister is satisfied that adequate arrangements are in force to ensure that no more than minimal harm will be done to any water source, or its dependent ecosystems, as a consequence of it being interfered with in the course of the activities to which the approval relates.

Invincible is a 'transitional Part 3A project' for the purposes of Schedule 6A of the *Environmental Planning and Assessment Act 1979*. As a 'transitional Part 3A project, Part 3A of the *Environmental Planning and Assessment Act 1979* (as in force immediately before the repeal of that Part and as modified under this Schedule after that repeal) continues to apply to and in respect of a transitional Part 3A project. Under section 75U of the *Environmental Planning and Assessment Act 1979* (as in force immediately prior to the repeal of Part 3A), a water use approval under section 79, a water management work approval under section 90 or an activity approval (including an aquifer interference approval) under section 91 of the *Water Management Act 2000* are not required for an approved project. Accordingly, an aquifer interference approval is not required for aspects of the Southern Extension Project. Water access licences will however be required for any licensable take.

Nonetheless, impacts on aquifers have been assessed by this report against the NSW Aquifer Interference Policy, which is discussed further in Section 2.4.1.

2.3 Water sharing plans

Provisions within NSW Water Sharing Plans (WSP) provide water to support the ecological processes and environmental needs of high priority groundwater dependent ecosystems (GDEs) and rivers, and direct how the water available for extraction is to be shared between different types of water use such as town supply, rural domestic supply, stock watering, industry, and irrigation.

The NSW Department of Primary Industries Water (DPI Water, formerly NSW Office of Water) is progressively developing Water Sharing Plans for rivers and groundwater systems across NSW following the introduction of the *Water Management Act 2000*.

The purposes of these plans are to protect the health of rivers and groundwater, while also providing water users with access licences, equitable conditions, and increased opportunities to trade water through separation of land and water rights.

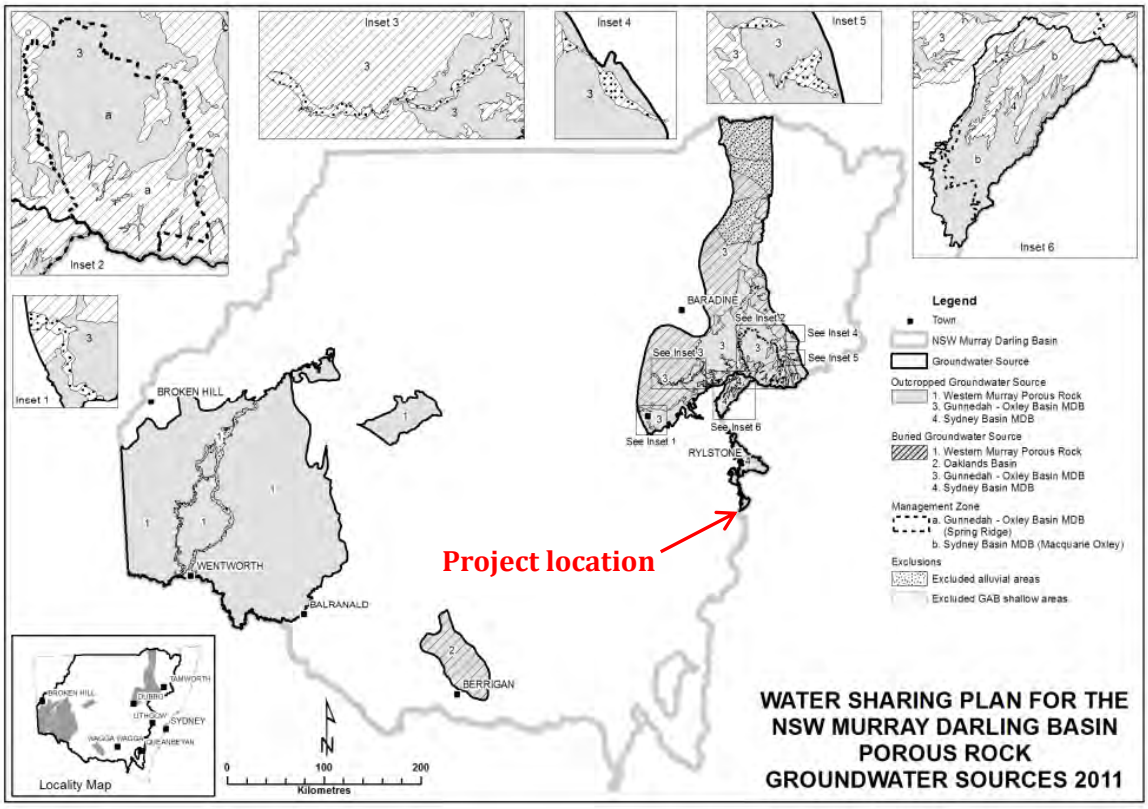
The following WSPs apply to the water sources in the Southern Extension Project area:

- **Macquarie Bogan Unregulated and Alluvial Water Sources** encompass all surface water within the plan area.
- **NSW Murray-Darling Porous Rock Groundwater Source (Sydney Basin)** encompasses all rocks of Permian, Triassic, Jurassic, Cretaceous and Tertiary age, and alluvial sediments within the plan area.
- **NSW Murray-Darling Fractured Rock Groundwater Sources (Lachlan Fold Belt MDB)** encompasses all outcropped and buried rock and alluvial sediments within the plan areas.

As the Southern Extension Project proposes to mine coal from the Permian sequences, the NSW Murray-Darling Fractured Rock Groundwater Sources WSP does not apply to this Project.

2.3.1 NSW Murray-Darling Porous Rock Groundwater Source WSP

The Southern Extension Project is located within the WSP area for the NSW Murray-Darling Porous Rock Groundwater Sources (Sydney Basin). Immediate adjacent areas of the existing Invincible mining areas are also located within this Water Sharing Plan area. The boundaries of the NSW Murray-Darling Porous Rock Groundwater Sources (Sydney Basin) WSP are shown on Figure 3.



(after: NSW Government, 2011)

Figure 3 WSP boundaries for the NSW Murray-Darling Porous Rock Groundwater Sources (Sydney Basin)

The NSW Murray Darling Basin Porous Rock Groundwater Sources WSP is divided into four groundwater sources. Of these, the Southern Extension Project is located in the Sydney Basin Murray Darling Basin (MDB) Groundwater Source. The Sydney Basin MDB Groundwater Source includes all water contained in:

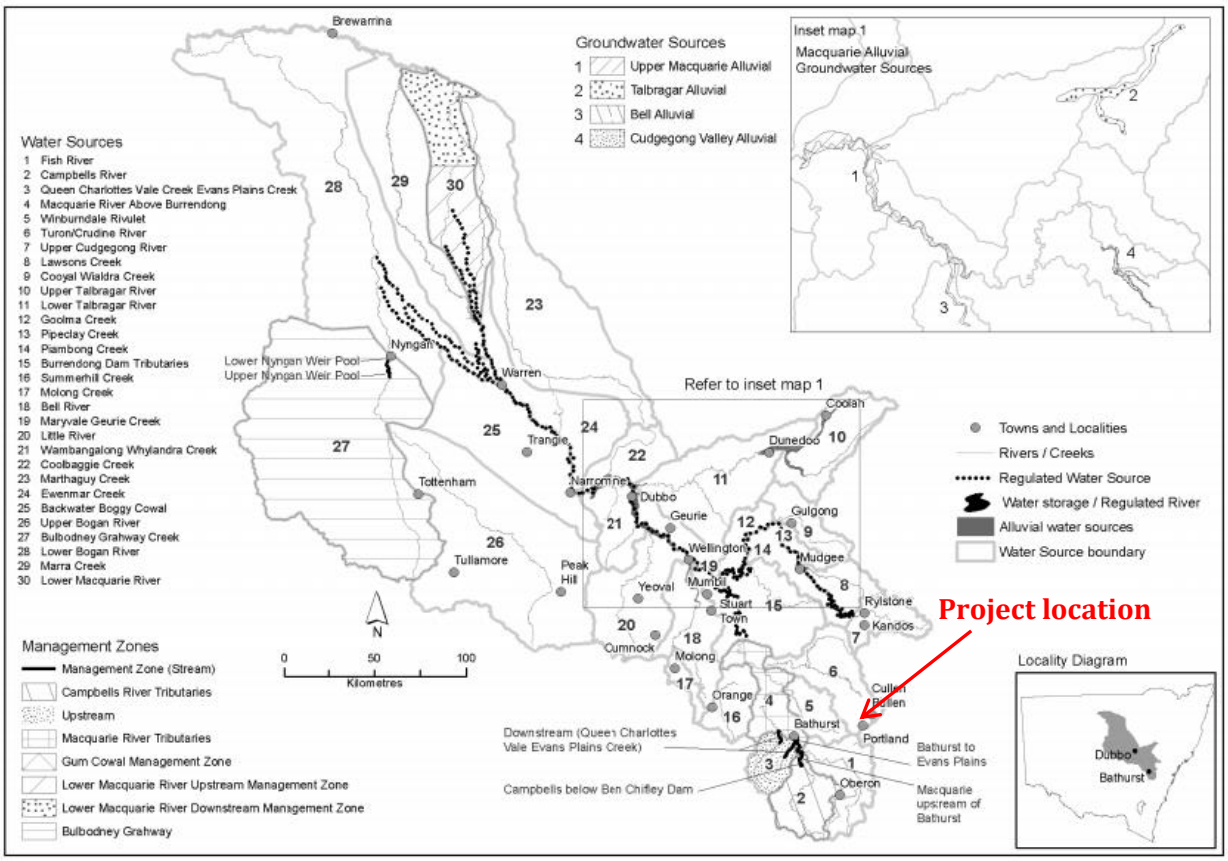
- all rocks of Permian, Triassic, Jurassic, Cretaceous, and Tertiary age within the outcropped and buried areas; and
- all alluvial sediments within the outcropped areas.

The Sydney Basin MDB is further subdivided into two management zones. Of which, the Southern Extension Project is located in the Sydney Basin MDB (Other) Management Zone.

2.3.2 *Macquarie Bogan Unregulated and Alluvial Water Sources WSP*

Water occurring naturally on the ground surface (i.e. creeks, rivers, lakes, and overland flow water) located within the Southern Extension Project area is managed by the WSP for the Macquarie Bogan Unregulated and Alluvial Water Sources. The boundaries of this WSP are shown on Figure 4.

The WSP for the Macquarie Bogan Unregulated and Alluvial Water Sources is divided into 30 water sources and four groundwater sources. Of these, the Southern Extension Project is located in the Turon / Crudine River surface water source and no WSP alluvial groundwater sources are present.



(after: NSW Government, 2011)

Figure 4 WSP boundaries for the Macquarie Bogan Unregulated and Alluvial Water Sources

2.4 State Groundwater Policy

2.4.1 Aquifer Interference Policy (AIP)

All water taken from a water source by an 'aquifer interference activity' needs to be accounted for within the long term average extraction limit specified for that water source. The extraction limit for each water source is specified in a WSP.

The *Water Management Act 2000* defines an aquifer interference activity as that which involves any of the following:

- penetration of an aquifer;
- interference with water in an aquifer;
- obstruction of the flow of water in an aquifer;
- taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations; and
- disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

The AIP (DPI, 2012) describes an aquifer as "a groundwater system that is sufficiently permeable to allow water to move within it, and which can yield productive volumes of groundwater". Examples of aquifer interference activities include mining, coal seam gas extraction, injection of water, and commercial, industrial, agricultural, and residential activities that intercept the water table or interfere with aquifers.

A water access licence (WAL) is required under the *Water Management Act 2000* where any aquifer interference activity causes:

- the removal of water from a water source; or
- the movement of water from one part of an aquifer to another part of an aquifer; or
- the movement of water from one water source to another water source, such as:
    - from an aquifer to an adjacent aquifer; or
    - from an aquifer to a river / lake; or
    - from a river / lake to an aquifer.

The Southern Extension Project is located within a project approved under Section 75U of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act). Under Section 75U of the EP&A Act, the following approvals under the *Water Management Act 2000* are not required for a project which has been approved:

- Water use approvals under Section 89 of the *Water Management Act 2000* – 'that confers a right to its holder to water for a particular purpose at a particular location'.
- Water management works approvals under Section 90 of the Water Management Act 2000, including:
    - water supply work approval;
    - drainage work approval; and
    - flood work approval.
- Activity approval under Section 9 of the Water Management Act 2000 including:
    - controlled activity approval for works in, on or under waterfront land; and
    - aquifer interference approval (e.g. mining activity).

As such, aquifer interference approval will not be required to transfer stored water from the Ivanhoe underground workings to the Invincible underground workings. However, a WAL is required for the initial take of surface water recharging the underground workings. As this recharge is sourced from naturally occurring surface water, the take is regulated by the WSP for the Macquarie Bogan Unregulated and Alluvial Water Sources.

Notwithstanding, this groundwater impact assessment of the Southern Extension Project has regard to the AIP in terms of assessing the acceptability of any impacts. In particular, the AIP describes minimal impact considerations for aquifer interference activities based upon whether the water source is highly productive or less productive and whether the water source is alluvial or porous / fractured rock in nature.

A highly productive groundwater source is defined by the AIP as a groundwater source which has been declared in Regulations and datasets, based on the following criteria:

- has a total dissolved solids (TDS) concentration less than 1,500 mg/L; and
- contains water supply works that can yield water at a rate greater than 5 L/s.

"Highly productive" groundwater sources are further grouped by geology into alluvial, coastal sands, porous rock, and fractured rock. "Less productive" groundwater sources include aquifers that cannot be defined as "highly productive" according to the yield and water quality criteria.

The Sydney Basin MDB (Other) Management Zone of the Water Sharing Plan for the Murray-Darling Porous Rock Groundwater Sources (Sydney Basin) are classified as less productive groundwater sources (NOW, 2013).

There are two levels of minimal impact considerations specified in AIP. If the predicted impacts are less than the Level 1 minimal impact considerations, then these impacts will be considered as acceptable. The AIP describes the required process of evaluation if the predicted impacts are greater than Level 1.

Section 7 of this assessment compares the predicted impacts of the Southern Extension Project against the AIP minimal impact considerations.

2.4.2 Groundwater quality protection

The NSW Groundwater Quality Protection Policy (1998), states the objectives of the policy will be achieved by applying the management principles listed below:

- *"All groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained.*
- *Town water supplies should be afforded special protection against contamination.*
- *Groundwater pollution should be prevented so that future remediation is not required.*
- *For new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource.*
- *A groundwater pumper shall bear the responsibility for environmental damage or degradation caused by using groundwaters that are incompatible with soil, vegetation and receiving waters.*
- *Groundwater dependent ecosystems will be afforded protection.*
- *Groundwater quality protection should be integrated with the management of groundwater quality.*

- *The cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource.*
- *Where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored."*

Section 5.7 of this assessment describes the site-specific groundwater environmental values, quality, and use within the proposed modification and surrounds.

2.4.3 Groundwater dependent ecosystems

The NSW Groundwater Dependent Ecosystems Policy (DLWC, 2002) is specifically designed to protect valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of these dependent ecosystems are maintained or restored for the benefit of present and future generations. The policy defines Groundwater Dependent Ecosystems (GDEs) as "*communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater*".

Five management principles establish a framework by which groundwater is managed in ways that ensure, whenever possible, that ecological processes in dependent ecosystems are maintained or restored. A summary of the principles follows:

- GDEs can have important values. Threats should be identified and action taken to protect them.
- Groundwater extractions should be managed within the sustainable yield of aquifers.
- Priority should be given to GDEs, such that sufficient groundwater is available at all times to meet their needs.
- Where scientific knowledge is lacking, the precautionary principle should be applied to protect GDEs.
- Planning, approval, and management of developments should aim to minimise adverse effects on groundwater by maintaining natural patterns, not polluting or causing changes to groundwater quality and rehabilitating degraded groundwater ecosystems where necessary.

2.4.4 Groundwater quantity management

The objectives of managing groundwater quantity in NSW are to (NOW, 2012):

- *"achieve the efficient, equitable and sustainable use of the State's groundwater;*
- *prevent, halt and reverse degradation of the State's groundwater and their dependent ecosystems;*
- *provide opportunities for development which generate the most cultural, social and economic benefits to the community, region, state and nation, within the context of environmental sustainability; and*
- *involve the community in the management of groundwater resources."*

2.5 Water licensing

The proponent currently holds two WALs for water sourced from the NSW Murray-Darling Porous Rock Groundwater Sources Water Sharing Plan. WAL 35978 entitles the holder to take 26 units (equivalent to 26 megalitre [ML] per year assuming full allocation) and is allocated to Invincible, and WAL 27898 entitles the holder to 80 units/ML, but is allocated to the Cullen Valley Mine.

3 Regional setting

3.1 Location

The Southern Extension Project is located on the western slopes of the Great Dividing Range, approximately 3.0 km south of the township of Cullen Bullen (refer Figure 1), which has a population of approximately 200 people. The closest urban area is the regional centre of Lithgow, situated approximately 25 km to the south-east along the Castlereagh Highway.

The existing mining areas are bounded to the north, east, and south by the Ben Bullen State Forest, and the lower lands of Cullen Valley to the west. Figure 5 shows the lease boundaries of Invincible, along with the lease boundaries of adjacent mining operations in the local area.

3.2 Topography and drainage

The topography surrounding the Southern Extension Project area is generally characterised by steep forested slopes and escarpments within the Ben Bullen State Forest to the north, east and south and the Castlereagh Highway running along the western boundary. Sandstone cliff lines and pagoda formations are key landscape features of the terrain to the north and east of Invincible.

Elevations within the Southern Extension Project area range from approximately 912 metres above the Australian height datum (mAHD) in the north to approximately 997 mAHD in the east. The terrain to the east of the Southern Extension Project area rises to over 1,050 mAHD. The Cullen Valley lies to the west of Invincible and topography falls toward an elevation of approximately 840 mAHD within the valley.

There are no cliff lines or pagodas located within the Southern Extension Project area with the closest pagoda formation located approximately 210 metres to the east of the Southern Extension Project area and all other pagodas are located at least 300 metres to the east and north east of the Southern Extension Project area.

The Project is located in the upper Turon River catchment, a tributary of the Macquarie River system. The upper Turon River flows in a north-west direction joining the Macquarie River north of Bathurst.

Locally, there are a number of minor drainage lines in the vicinity of the Project, with local catchments consisting of ephemeral creeks and watercourses. The Project area is drained by Cullen Creek which flows northwards from the Project, past the township of Cullen Bullen.

3.3 Climate

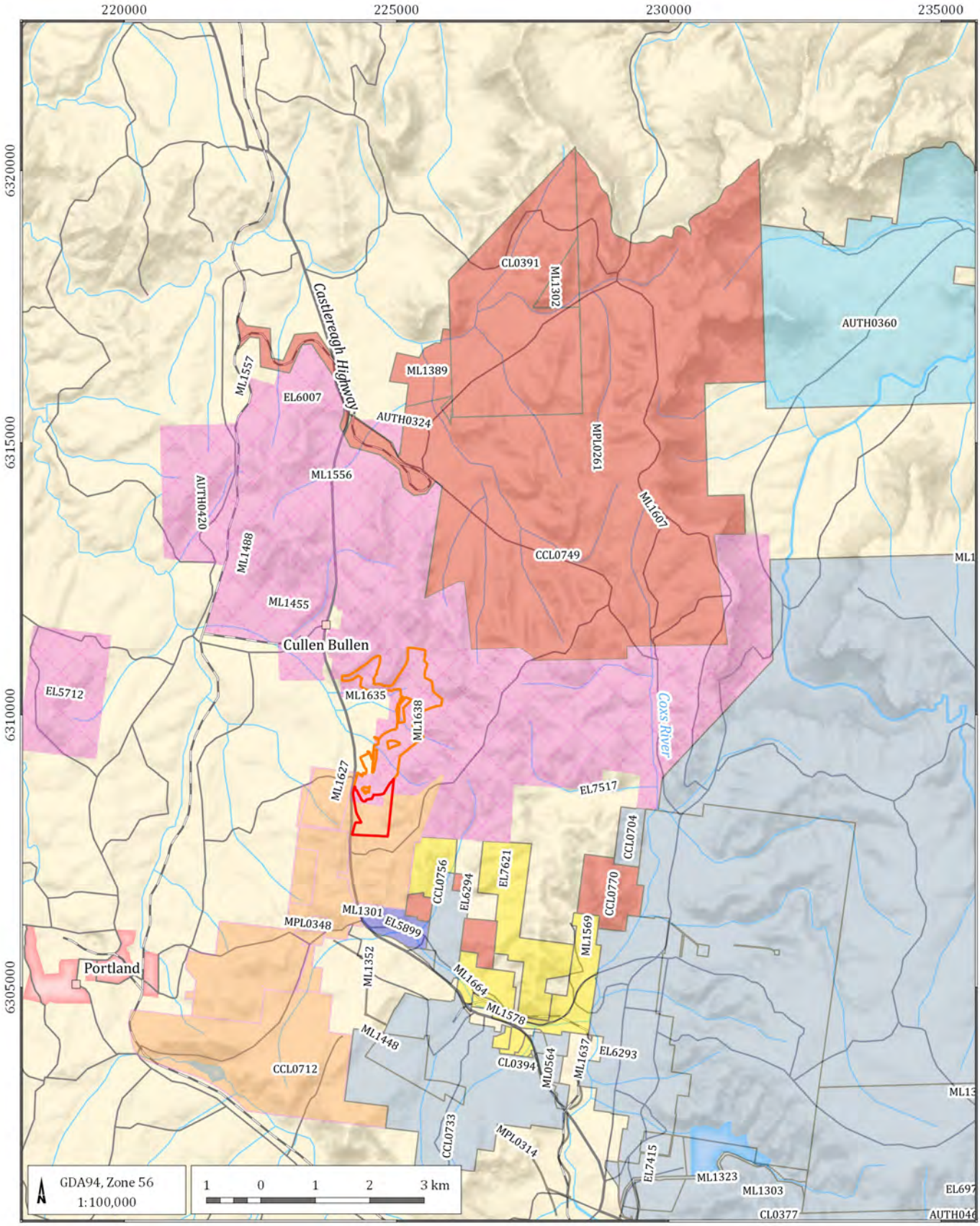
The climate of the region is defined by its latitude, inland location, and the steep ridge and valley escarpments typical of the western slopes of the Great Dividing Range. Generally, the climate is cool-temperate, characterised by relatively mild summers and cold winters. Rainfall patterns are summer dominant. Fog and frost are common in cooler months, although a range of factors including the ridge and valley topography, altitude, aspect, and exposure result in some localised temperature variations.

Between 1960 and 2016, the average annual rainfall at Lidsdale (BOM Station No. 063132) was 762 mm with January typically being the wettest month. Evaporation of about 1,351 mm/year exceeds rainfall throughout most of the year except for the winter months of June, July, and August (BOM Station No. 063005 – Bathurst agricultural station).

3.4 Land use

The Southern Extension Project area is located wholly within Ben Bullen State Forest, consisting of areas of native vegetation and previous disturbance associated with former underground mining and existing powerline infrastructure. Woodland and forest communities in Ben Bullen State Forest surround the Project except for its northern extent, where the existing open cut mine operation of Invincible is located. Significant areas of the existing open cut mining footprint are also located within Ben Bullen State Forest.

Regionally, land is also used for mining, agriculture, power generation, small townships, and recreation.



LEGEND

- Populated place
- Rail
- Road major
- Road
- Watercourse
- Built up area
- Water area
- Land
- Proposed southern extension
- Invincible Colliery Open Cut - existing mine disturbance area

Coal titles

- Boulder Mining Pty Ltd
- Centennial Springvale Pty Ltd
- Enhance Place Pty Ltd
- Ivanhoe Coal Pty Ltd
- Secretary NSW Dept Ind
- Shoalhaven Coal Pty Ltd
- Glencore Baalbone Colliery

Invincible Southern Extension Project (G1817)

Mining lease boundaries

DATE 27/07/2016

FIGURE No: 5

4 Geology

The Southern Extension Project is located within the Western Coalfields of NSW, which is geologically located on the western edge of the Sydney Basin. The Sydney Basin consists of a series of consolidated sedimentary units of Permian age, overlain by massive sandstones of Triassic age (Yoo, et al. 2001). The economic sequences of the Sydney Basin in this area are the coal strata of the Illawarra Coal Measures.

The Western Coalfields extends in an easterly direction, dipping gently at an angle of 1° to 3° to the north-east towards the coast. The Western Coalfields are characterised by prominent cliffs and eroding plateaus of the Triassic age sandstone and shale of the Narrabeen Group.

Historically, Invincible and the adjacent mines extracted coal from the seams of the Illawarra Coal Measures. There are seven identified coal seams in the Illawarra Coal Measures, which in descending stratigraphical order are as follows:

- Katoomba Seam;
- Middle River Seam;
- Moolarben Seam;
- Upper Irondale Seam;
- Irondale Seam (1.5 m to 2.3 m thick);
- Lidsdale Seam (0.7 m to 1.5 m thick); and
- Lithgow Seam (0.1 m to 3.6 m thick).

In the Invincible open cut mine area, coal seams above the Irondale Seam (i.e. Katoomba, Middle River, and Moolarben Seams) are not always present having been largely removed by weathering and are commonly truncated by topography. The Lithgow Coal Seam has been worked extensively in the vicinity of Invincible by historic underground and open cut workings in addition to current approved operations. Commercial scale mining of the Lidsdale and Irondale Coal Seams has only taken place in recent years.

Only the Irondale, Lidsdale, and Lithgow Coal Seam are present within the Southern Extension Project area. Both the Irondale and Lidsdale seams crop out within the Southern Extension Project area. The Irondale and Lidsdale seams within the Southern Extension Project area have not previously been mined. The Lithgow Coal Seam crops out to the east of the Castlereagh Highway within the vicinity of Invincible and to the west of Castlereagh Highway, within the vicinity of the Cullen Valley Mine. The thickness of the Lithgow Coal Seam ranges from 3.6 m down to 0.1 m, but generally has a thickness of above 3 m within the Project area. Historic underground workings at the site did not likely exceed a 2 m cutting height.

The Marangaroo Formation is located beneath the Lithgow Coal Seam (typically separated by carbonaceous mudstone) and crops out persistently throughout the Western Coalfield. The Marrangaroo Formation ranges in thickness from 2 m to 16 m and consists primarily of sandstone and conglomerate. The formation is quarried and crushed locally for the industrial sand market.

5 Hydrogeology

5.1 Existing data and monitoring

No groundwater monitoring bores are currently installed in the Southern Extension Project area. However, groundwater monitoring bores are located proximal to the Southern Extension Project area, across the Invincible and the Cullen Valley mine areas. Figure 6 shows the locations of the monitoring bores, with bore construction details summarised in Table 1.

Table 1 Groundwater monitoring network details

Drill hole ID	Hole depth (mbgl)	Screen (mbgl)	Screen zone geology
Cullen Valley Mine			
CP114	41.9	36.9 – 41.9	Marrangaroo Formation (sandstone / conglomerate)
CP115	71.2	68.2 – 71.2	Lithgow Coal Seam
CP116	56.8	53.8 – 56.8	Lithgow Coal Seam
CP119*	79.5	68.9 – 72.9	Lithgow Coal Seam
CP131	74.59	70.58 – 73.58	Lithgow Coal Seam
CP132	41.38	32.7 – 35.7	Marrangaroo Formation (sandstone / conglomerate)
BHW1	50.78	48.92 – 50.78	Lithgow Coal Seam (Tyldesley Colliery flooded workings)
GW804393	24.03	22.09 – 24.03	Lithgow Coal Seam (Tyldesley Colliery flooded workings)
Invincible Colliery			
CP123*	36.5	33.5 – 36.5	Marrangaroo Formation (sandstone / conglomerate)
LD001	104	100 – 104	Lithgow Coal Seam (Invincible Colliery flooded workings)

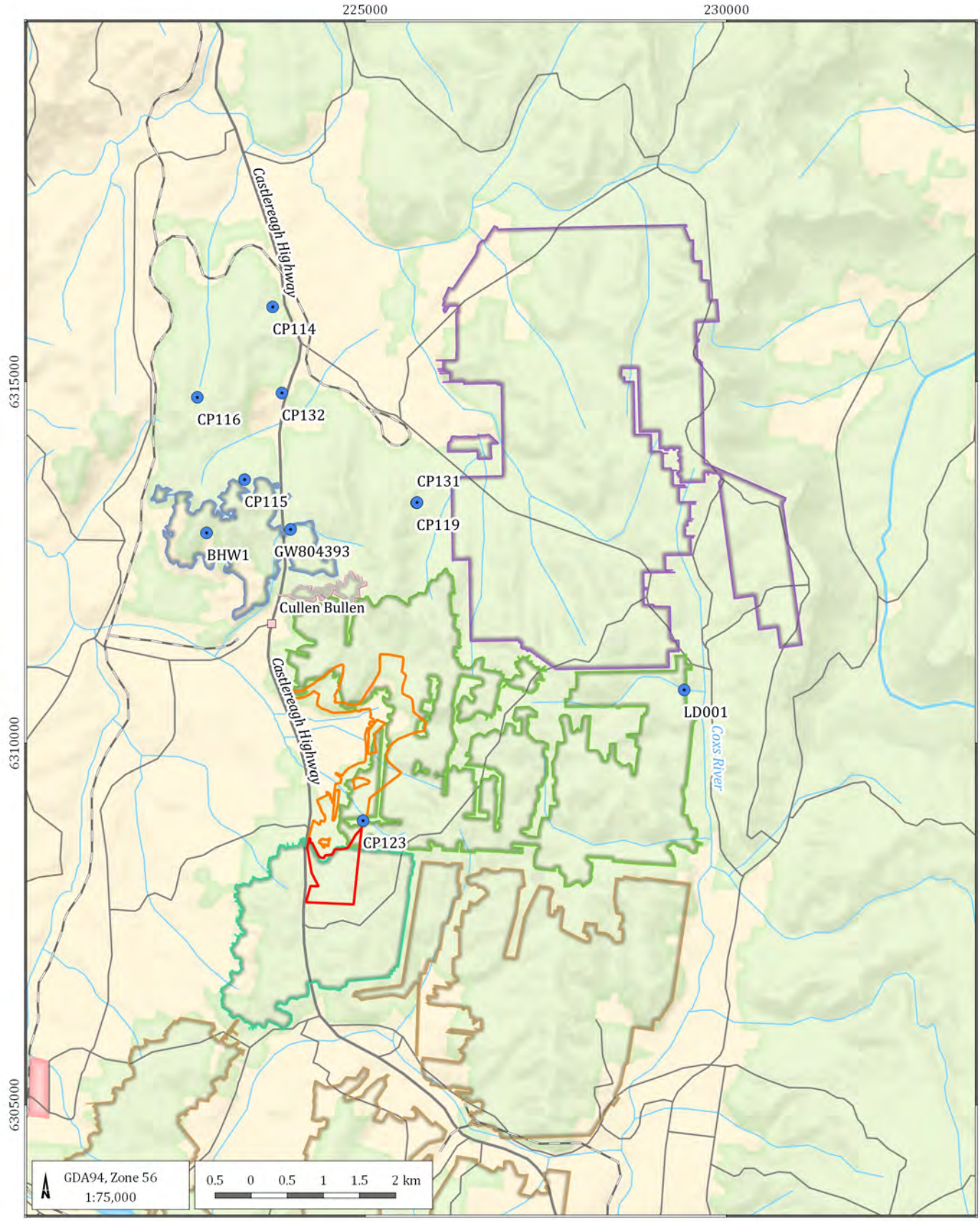
Notes: *mbgl = metres below ground level*
** decommissioned bore*

The standing water level within the flooded workings of the Old Tyldesley Colliery (Cullen Valley Mine area) has been recorded within the Tyldesley Colliery Drainage Bore (GW804393) since 2000. Similarly, the standing water level within the flooded workings of the Invincible Colliery has been recorded within LD001 since 2010.

The northern void in the existing Invincible open cut workings is known to be hydraulically connected to the underground workings and the surface expression of water in the Northern Void is understood to represent the hydraulic head of water in the adjacent Invincible underground workings.

An expanded groundwater monitoring bore network was installed in early 2011 to augment the existing bores at each mining area. Five monitoring bores (CP114, CP115, CP116, CP119, and CP123) were constructed. The sites were selected to provide sufficient spatial coverage over the area proposed to be mined by Coalpac. Two more monitoring bores (CP131 and CP132) were installed in 2012 and one bore (BHW1) was installed in 2013.

In total, the current groundwater monitoring network for the Cullen Valley Mine comprises seven bores, and the Invincible monitoring network comprises one bore.



LEGEND

- NOW registered bores 2011
- Monitoring bores
- Proposed southern extension
- Invincible Colliery Open Cut - existing mine disturbance area
- Populated place
- Rail
- Road major
- Road
- Watercourse
- Built up area
- Vegetation
- Water area
- Land

Colliery locations

- Baal Bone Colliery
- Invincible Colliery
- Ivanhoe Colliery
- RT108 Colliery
- Tyldesley Colliery

Invincible Southern Extension Project (G1817)

Groundwater monitoring locations

DATE 27/07/2016

FIGURE No: 6

5.2 Hydrostratigraphic units and groundwater occurrence

Groundwater within the Southern Extension Project area is found within the:

- Lithgow Coal Seam, where it has been re-saturated by the flooded underground mine workings;
- historical underground mine workings of the Ivanhoe No. 2 Colliery;
- spoil material located within the Invincible open cut workings; and
- Marrangaroo (sandstone / conglomerate) Formation, which underlies the Lithgow Coal Seam and will not be mined nor intersected by the mine operations.

5.2.1 Lithgow Coal Seam

In areas where the Lithgow Coal Seam has not been mined, the coal typically has low hydraulic conductivity but is the prime water bearing strata within the Illawarra Coal Measures. Groundwater within the Lithgow Coal Seam is typically associated with secondary permeability features such as cleat fractures, joints, and major bedding structures. The Lithgow Coal Seam crops out near the Southern Extension Project area and also at the Wolgan Valley escarpment located approximately 6.5 km north east of the Southern Extension Project area.

However, in the near vicinity of the Southern Extension Project area the Lithgow Coal Seam would have been completely depressurised / dewatered for long periods of time as a result of historical mining. This current groundwater assessment presumes the Lithgow Coal Seam within the Southern Extension Project area has re-saturated to some extent, and the vast majority of this water would have originated from the flooded workings of the Ivanhoe No. 2 Colliery and other adjacent mine workings. Rock units located vertically above and below the Lithgow Coal Seam (and the underground workings) are presumed to have contributed very little water via natural seepage because of their low hydraulic conductivity (particularly in the vertical direction).

The majority of the Illawarra Coal Measures comprise very low yielding, to essentially dry interbedded strata of sandstone, siltstone, and mudstone. The sandstones, siltstones, and mudstones typically have significantly lower hydraulic conductivity compared to the coal seams (by one or more orders of magnitude) and they generally act as aquitards that confine the coal seams.

5.2.2 Underground mine workings

Historical underground mining at the Old Tyldesley Colliery, Old Invincible Colliery, the Invincible Colliery, Ivanhoe No. 2 Colliery, Wallerawang Colliery, and Baal Bone Colliery have all targeted the Lithgow Coal Seam because it is the deepest, thickest, and most continuous coal seam within the region. Parts of these historical mine workings have flooded with water that has accumulated since active dewatering ceased. Baal Bone Colliery is the only mine operation nearby the Project that is currently dewatering significant areas of its underground workings. The location of the Baal Bone underground mine workings are shown on Figure 6.

The underground collieries are separated by coal seam barriers which in some cases are coincident with structural lineaments and in other cases by buffer zones around mining lease boundaries. The coal seam barrier between the Wallerawang No. 1 and No. 2 Collieries, and Invincible underground workings has previously been considered by Aquaterra (2010) to have been intentionally left intact to provide a barrier between these voids. Groundwater from the Wallerawang Colliery has previously been assessed to flow into the Invincible Colliery through the coal seam barrier (Bish, 1999). The location of the coal seam barrier between Invincible Colliery and Wallerawang Colliery is shown on Figure 6.

Similarly, the coal seam barriers between the Ivanhoe No. 2 Colliery (incorporating the Southern Extension Project area) and the adjacent Invincible and Wallerawang Colliery are also assumed to have been intentionally left intact to provide a barrier between these voids. The location of the coal seam barrier between the Ivanhoe No. 2 Colliery and the adjacent Invincible Colliery and Wallerawang Colliery is also shown on Figure 6.

The westernmost parts of Invincible and those immediately adjacent to the Southern Extension Project area are dry (AGE, 2012 and 2014). As the Invincible underground workings dip to the northeast they become saturated.

Very limited information is currently available for this assessment to accurately determine if the historical workings of the Ivanhoe No. 2 Colliery in the Lithgow Seam are dry or flooded. However, information in the form of survey plans of historical mine workings suggest they are potentially flooded. If these workings are indeed flooded, they are positioned adjacent to dry workings of the Invincible underground workings.

5.2.3 Spoil material

The spoil material from the Southern Extension Project's open cut workings is proposed to be emplaced in the existing open cut voids of Invincible, and then rehabilitated. Spoil material has already been emplaced in most of the northern areas of the void. However, three open voids currently remain in the north, east, and south of the existing approved mining area. These voids will be filled as part of the rehabilitation process undertaken as part of the Southern Extension Project. In some areas, this spoil material is likely to become saturated and act as a water storage body and some of the spoil material adjacent to the Northern Void is already likely to be saturated. Water intercepted by the open cut workings (whether as rainfall or runoff from upstream areas) will percolate through the void to the north east where it will flow into the Invincible underground workings where the Northern Void and former workings are interconnected through the Lithgow Seam.

5.2.4 Marrangaroo Formation

The Marrangaroo Formation is comprised of sandstone and conglomerate and is typically separated from the overlying Lithgow Coal Seam by carbonaceous mudstone which is likely to be of very low permeability. The permeability of the Marrangaroo Formation is regionally variable and in some locations will be high enough to form a productive aquifer.

The Marrangaroo Formation will not be mined by the Southern Extension Project nor intersected by the mine operations.

Groundwater recharge to the Marrangaroo Formation is likely to occur by direct rainfall infiltration and local runoff into the outcrop in low-lying areas. Similar to the Permian coal seam aquifers, groundwater within the Marrangaroo Formation is expected to flow towards the north-east (down-gradient) and discharge at outcrop areas (i.e. hillsides and gullies including the escarpment of the Wolgan Valley).

5.3 Hydraulic properties

The hydraulic conductivity of the Lithgow Coal Seam ranges between 0.03 m/day to 0.09 m/day, which is typical for coal seam aquifers (AGE, 2012; Aquaterra, 2010). Investigations at the Springvale Colliery (located 10 km to the south east) have shown that the strata overlying the Lithgow Seam have lower hydraulic conductivity with a range from 0.001 m/day to 0.01 m/day (Aurecon, 2010). The hydraulic conductivity for the Marangaroo Formation is expected to range between 0.05 m/day up to about 0.5 m/day (AGE, 2012). Hydraulic conductivity of spoil is generally accepted to be in the order of 1 m/day.

5.4 Recharge and discharge processes

5.4.1 Southern Extension Project

Recharge of groundwater into the Southern Extension Project area (Ivanhoe No. 2 Colliery) underground workings would most likely occur where subsidence and fracturing has resulted above areas where coal seams have been extracted and overland flow water has inadvertently been captured in the former workings. Diffuse recharge through solid rock is expected to be minimal because layering of mudstones and siltstones within the Permian Coal Measures restricts the vertical movement of water within the Illawarra Coal Measures. The provenance of a portion of recharge is also likely to be water accumulating within the open cut areas where the seam is at outcrop or buried within the spoil and to a lesser degree via natural recharge processes. The exact proportion of this recharge is difficult to estimate.

Natural discharge of groundwater from the Ivanhoe No. 2 Colliery underground workings is expected to be dominated by seepage through coal seam barriers into the adjacent mine workings of the Invincible Colliery. Evidence of this seepage would be most evident in the south eastern areas of the existing open cut mining area where the mined areas of the seam are down dip from the Ivanhoe No. 2 workings. It is noted that there is no evidence of any seepage from the Lithgow seam in these areas of the open cut.

Water movement within the Ivanhoe No. 2 Colliery underground workings is expected to be almost exclusively horizontal, since they are bounded by fine-grained sediments which act as aquitards. The hydraulic gradient is expected to be towards the north-east following the general dip of the coal measures.

The water level within Ivanhoe No. 2 Colliery underground workings is presumed to be relatively static because the mine has been closed for a long-period and there has been no previous dewatering of the mine workings since closure. Therefore, this assessment assumes the water level within the flooded workings has reached steady state equilibrium where water seepage (outflow) is approximately equalled by recharge (inflow). In this case, the amount of total recharge to the Ivanhoe No. 2 Colliery underground workings can be back-calculated by estimating the amount of seepage from the workings.

The amount of natural seepage from the mine workings was made using Darcy's Law that describes the flow of a fluid through a porous medium. Darcy's Law is expressed as:

$$Q = KiA\ (m^3/day)$$

Where: Q = seepage through the coal seam barrier separating the presumed flooded workings of the Ivanhoe No. 2 Colliery and the adjacent dry workings of the Invincible Colliery (m^3/day);

K = hydraulic conductivity / permeability of the coal seam barrier separating the underground mine workings is assumed to range between 0.03 m/day and 0.09 m/day;

i = steady state hydraulic gradient through the coal seam barrier, assuming:

- the groundwater head within the Ivanhoe No. 2 Colliery is 908 mAHD;
- the floor of the adjacent dry workings of the Invincible Colliery is 900 mAHD; and
- the width of the coal seam barrier is 30 m.

A = cross section area (m^2) of the seepage face, assuming:

- the height of the coal seam barrier is 3 m; and
- the length of the seepage face between the flooded workings and the dry workings is about 750 m.

Using these assumptions, the total seepage outflow from the flooded Ivanhoe No. 2 Colliery into the Invincible Colliery is estimated to range between about 18 m^3/day and 54 m^3/day (~7 ML/year to ~20 ML/year). Although this range of seepage is acknowledged to be uncertain, it demonstrates that the natural seepage loss to the Invincible Colliery it not high.

5.4.2 Invincible Colliery

As previously discussed, due to the presence of extensive underground workings and their proximity to the outcrop of the Lithgow Coal Seam, any water contained within the flooded underground workings may be a combination of some groundwater and the majority being meteoric run-off.

Recharge processes that contribute water to the Invincible Colliery underground workings would include (in descending order of volume contribution):

- point sources where surface water runoff can enter fractures caused by ground subsidence above mining areas;
- diffuse rainfall infiltration into the remaining coal seam pillars and local runoff into the outcrop in low-lying areas; and
- water seepage from the Wallerawang Colliery and Ivanhoe No. 2 Colliery through the coal seam barriers.

The seepage rate from the Invincible Colliery to the Baal Bone underground was estimated by AGE (2012). The estimate was made using Darcy's Law and similar assumptions to those listed above in Section 5.4.1. The estimated seepage outflow from the flooded Invincible Colliery into the Baal Bone Colliery was estimated to range between about 304 m^3/day and 868 m^3/day (~111 ML/year and 317 ML/year), depending upon the hydraulic conductivity of the coal seam barrier. This volume was considered by AGE (2012) to be a significant proportion of the water abstracted from Baal Bone colliery. As previously stated, the majority of the water in the underground workings in Ivanhoe No.2 Colliery and in Invincible Colliery is likely to be sourced from surface water via subsidence cracks and seam outcrop within the open cut areas and to a lesser degree via natural recharge process.

5.5 Groundwater chemistry

5.5.1 Groundwater chemistry characteristics

No groundwater samples were collected directly from the Ivanhoe No. 2 Colliery underground workings (within the Project area) for this assessment. However, other recent assessments (AGE, 2012 and 2014) provide groundwater chemistry data for neighbouring parts of the Invincible Colliery. The chemistry of groundwater within the Invincible Colliery underground workings (and surrounding coal seams) is expected to be similar to that found within the Ivanhoe No. 2 Colliery and surrounding coal seams.

The Permian aquifers host fresh to slightly brackish water with an average EC value of about 500 µS/cm (TDS = 280 mg/L) (AGE, 2012). Water stored within the Invincible Colliery underground workings is very fresh with an EC value of about 150 µS/cm (TDS = 84 mg/L) (AGE, 2012).

The lower salinity of the water stored within the Invincible Colliery underground workings is most likely the result of higher recharge rates into underground workings from surface water flows. The higher recharge rate occurs through vertical fractures extending above subsided underground extraction panels and rainfall infiltration that directly enters the mine workings.

The water stored within the underground workings is slightly acidic with a pH value of 5.9 (AGE 2014). Groundwater in the Lithgow Coal Seam is typically near neutral, but ranges from slightly alkaline to slightly acidic with pH values between 6.6 and 7.2.

Groundwater in the Marrangaroo Formation is typically fresh and has a near neutral pH ranging between 6.3 and 7.3 (AGE 2014).

5.5.2 Environmental value of groundwater

Groundwater quality data provides useful information on the beneficial use of the groundwater associated with the major stratigraphic units. Salinity is a key constraint to water management and groundwater use, and can be described by TDS concentrations. TDS concentrations are commonly classified on a scale ranging from fresh to extremely saline. FAO (2013) provide a useful set of categories for assessing salinity based on TDS concentrations, which is summarised in Table 2.

Table 2 Water salinity categories

Water salinity category	TDS concentration (mg/L)
Fresh water	<500
Brackish (slightly saline)	500 to 1,500
Moderately saline	1,500 to 7,000
Saline	7,000 to 15,000
Highly saline	15,000 to 35,000
Brine	>35,000

An assessment was made of the groundwater quality in terms of Australia New Zealand Environment Conservation Council (ANZECC) criteria and environmental value. The ANZECC (2000) guideline refers to "environmental value" rather than "beneficial use" which is often used, and state that the term beneficial use has lost favour because of its exploitative connotations. For this reason the term "environmental value" has been adopted by the National Water Quality Management Strategy (NWQMS). The following environmental values are recognised in the NWQMS Guidelines:

- aquatic ecosystems;
- primary industries (irrigation and general water uses, stock drinking water, aquaculture and human consumption of aquatic foods);
- recreation and aesthetics;
- drinking water;
- industrial water; and
- cultural and spiritual values.

The guidelines state that "*where two or more agreed environmental values are defined for a water body, the more conservative of the associated guidelines should prevail and become the water quality objective*". The assessment of environmental value given in this assessment is based on this guideline.

AGE (2012) found groundwater in the Permian aquifers and the water contained within the former underground workings of Invincible, have concentrations of iron and manganese that exceed Australian Drinking Water Guideline values and the ANZECC guideline for irrigation. In addition, the groundwater resources appear to have a slightly elevated zinc concentration which may make this water unsuitable for aquatic ecosystems. However, it should be noted that it is unlikely that mining operations have caused the elevated concentrations of iron, manganese, and zinc as these metals can be naturally occurring at elevated concentrations.

In addition, during pre-mining conditions, groundwater is likely to have naturally discharged to low elevation areas where the water is likely to have entered watercourses, and diluted with surface water flows to some degree. However, given the guideline recommendations and the measured quality of the groundwater in the Permian aquifers and the water contained within the underground workings of Invincible, these resources are best allocated for industrial purposes and use in primary industries unless appropriately treated prior to discharge.

5.6 Groundwater levels

No groundwater level data were collected directly from the Ivanhoe No. 2 Colliery underground workings or neighbouring mines for this assessment. Instead, this assessment has relied upon data gathered during other recent assessments (AGE, 2012 and 2014) that provide groundwater level data for the neighbouring Invincible underground workings.

The groundwater level data available from the Invincible underground workings (and surrounding coal seams) is expected to be relevant for the current assessment because no mining or other activities have occurred during the interim period that could have influenced groundwater levels within the coal seams and flooded underground workings of Invincible. Also, the relatively static water levels previously measured within the flooded workings suggests steady state equilibrium has been reached, where water seepage (outflow) is approximately equalled by recharge (inflow).

The previous assessments found the Invincible underground workings adjacent to the Southern Extension Project area to be dry. The flooded extent (i.e. 'tidemark') of the Invincible underground workings is located to the east and down-dip of the Project (AGE 2014). As discussed above, the north eastern extent of the Invincible open cut workings is hydraulically connected to the former underground working and the water level in the Northern Void is considered to represent the upper elevation of the tidemark in the Invincible underground workings. This level is approximately 884 mAHD.

A location of water within the Invincible underground workings proximal to the Invincible open cut had previously been provided to AGE as part of the Coalpac assessment. It is understood that this tidemark was based on observations from people walking into the former UG workings and recording the water levels. No information on the dates of these observations or their accuracy is known. The tidemark based on these observations is shown in Figure 7 and reaches an 'upper' elevation of about 905 mAHD in the southern area of the underground mine workings.

There is no existing information to confirm the observations of tidemark in the Invincible underground workings above the elevation of water observed in Northern Void; the workings in this area are all interconnected through multiple working areas and there is no significant changes in seam depth which would suggest a physical reason for water being stored at a higher elevation in one part of the eastern area of workings relative to areas around the Northern Void. In reality, it is possible that the tidemark of flooding in the underground workings proximate to the open cut follows the 884 m contour (being the observed water level in the Northern Void) for the bottom of the Lithgow seam (refer to Figure 7).

The water level in monitoring bore LD001 is very high in contrast to the expected groundwater level in the area. Data for this bore is limited and is likely not representative of the general groundwater system. This water level is likely influenced by the bore construction or a localised effect. The bore is adjacent Baal Bone Colliery which is currently dewatered and even though the dewatering does not directly impact the water level in Invincible Colliery, it is likely to influence it to some degree locally and the elevated water level in LD001 does not reflect an influence from dewatering in Baal Bone Colliery.

Notwithstanding the potential limitation around the previously derived tidemark level, the groundwater level in the Invincible underground workings derived from these observations have been used to calculate the available storage area in the Invincible underground workings and spoil below 893 mAHD. The potential storage if the workings are flooded to 884 mAHD has also been calculated. A number of other assumptions have been used to calculate a volume of water potentially stored in the Ivanhoe No. 2 Colliery underground workings within the Southern Extension Project area. These calculations have been used to inform both the Site Water Balance for the Southern Extension Project which is assessed in the Surface Water Assessment prepared by Umwelt and to understand whether there is sufficient capacity within the Invincible underground workings to store water removed from the Ivanhoe Underground workings as part of the Southern Extension Project. This concept is explored further in Section 6.

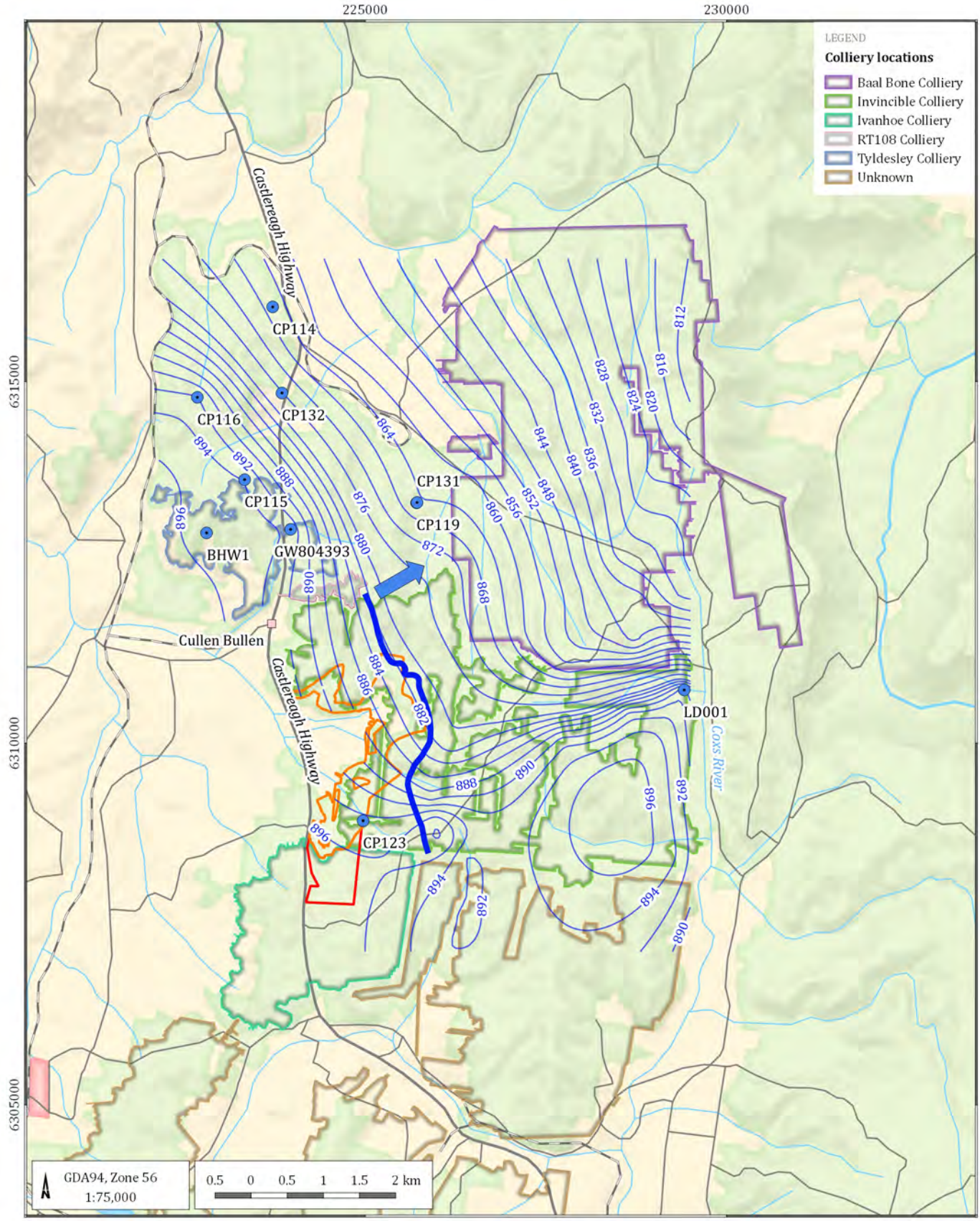
5.7 Groundwater use

5.7.1 Registered bores

A search of the DPI Water database of bores and wells within a 3 km radius of the Southern Extension Project area identified 16 registered bores. The locations of these registered bores are shown on Figure 8. Details for each of these registered bores are summarised in Table 3.

With the exception of one bore, all other bores are used for groundwater monitoring at adjacent coal mining operations. The one exception (GW111942) is a bore which is used to supply industrial water to Invincible. The majority of the monitoring bores access water from the shallow fractured shale and sandstone of the Illawarra Coal Measures.

The nearest private bores used for stock and domestic purposes are located more than 3.5 km west of the Southern Extension Project. These bores access water from rock formations located stratigraphically below the Lithgow Coal Seam, either from the Nile Subgroup or the deeper Shoalhaven Group.



LEGEND

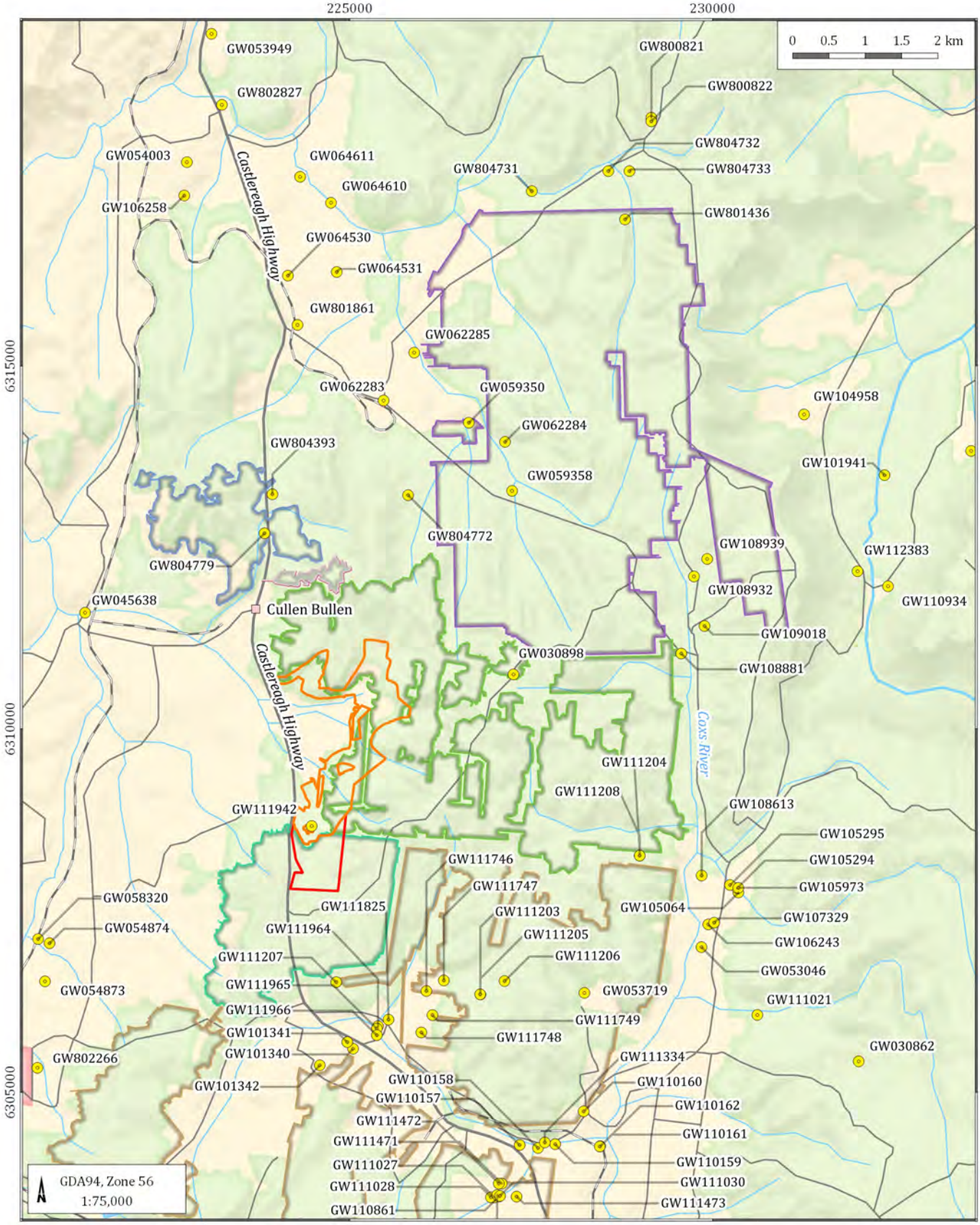
- Monitoring bores
- Invincible UG water level 2014
- Groundwater potentiometric - surface contour (2m interval) year 2014
- Proposed southern extension
- Invincible Colliery Open Cut - existing mine disturbance area
- Populated place
- Rail
- Road major
- Road
- Watercourse
- Built up area
- Vegetation
- Water area
- Land
- Groundwater flow direction

Invincible Southern Extension Project (G1817)

2014 Water level within Invincible underground workings

DATE 27/07/2016

FIGURE No: 7



LEGEND

- Registered bores
- Proposed southern extension
- Invincible Colliery Open Cut - existing mine disturbance area
- Populated place
- Rail
- Road major
- Road
- Watercourse
- Built up area
- Vegetation
- Water area
- Land

Colliery locations

- Baal Bone Colliery
- Invincible Colliery
- Ivanhoe Colliery
- RT108 Colliery
- Tyldesley Colliery

Invincible Southern Extension Project (G1817)

Location of registered bores

DATE 27/07/2016

FIGURE No: 8

Table 3 Summary of registered bores located within 3 km of the Project

Work No.	Licence No.	Property	Authorised purpose	Screened formation	Completed Depth (mbgl)	Distance from Project (~ km)
GW101340	10BL158032	-	Monitoring	Coal measures	26.4	2.2
GW101341	10BL158032		Monitoring	Coal measures	30.6	2.1
GW101342	10BL158032		Monitoring	Coal measures	28.7	2.4
GW111203	10BL603588	Pine Dale Coal Mine	Monitoring	Coal measures	84	2.4
GW111205	10BL603588		Monitoring	Coal measures	87	2.4
GW111206	10BL603588		Monitoring	Coal measures	38.94	2.6
GW111207	10BL603588		Monitoring	Coal measures	50	1.2
GW111746	10BL604869	Angus Place Colliery	Monitoring	Coal measures	53	1.8
GW111747	10BL604869		Monitoring	Coal measures	30	1.9
GW111748	10BL604868		Monitoring	Coal measures	30	2.2
GW111749	10BL604868		Monitoring	Coal measures	57.5	2.1
GW111825	10BL604870		Monitoring	Coal measures	20	2.0
GW111942	10BL602584	Invincible Colliery	Industrial	Coal measures	48	0.1
GW111964	10BL605162	Neubecks Creek Project	Monitoring	Sand and gravel	2.2	1.9
GW111965	10BL605162		Monitoring	Sand and gravel	4.5	2
GW111966	10BL605162		Monitoring	Sand and gravel	2.9	2.1

5.7.2 Culturally significant sites

A detailed Aboriginal cultural heritage assessment has been undertaken for Southern Extension Project and no culturally significant sites associated with surface water / groundwater interactions are currently known to exist within or adjacent to the Southern Extension Project area.

However, the Water Sharing Plan for NSW Murray-Darling Basin Porous Rock Groundwater states that, "*culturally significant sites will be identified as a part of the assessment undertaken by the NSW Office of Water during the processing of an application for the granting or amending of a water supply work approval*".

5.7.3 High priority groundwater dependent ecosystems

No high priority GDEs are located within or adjacent to the Southern Extension Project area. The nearest high priority GDE is located approximately 5 km south west of the Southern Extension Project in proximity to Portland. This high priority GDE is located within the Water Sharing Plan area for the Greater Metropolitan Region Groundwater Sources 2011 (Sydney Basin Coxs River Groundwater Source). This high priority GDE is also categorised as a potential karst GDE.

The nearest high priority GDE listed within the NSW Murray-Darling Basin Porous Rock Groundwater Water Sharing Plan is located approximately 44 km north east of the Southern Extension Project, located near the township of Ilford. This high priority GDE is categorised within the Water Sharing Plan as a potential karst GDE.

Karst environments are formed from the dissolution of soluble rocks such as limestone, dolomite, and gypsum. They are typically characterised by underground drainage systems with sinkholes and caves. The karst environments found near Ilford and Portland are not common and are not found within the economic coal reserves of the Illawarra Coal Measures.

The cast environments located near Ilford and Portland are found within rock formations located stratigraphically below the Lithgow Coal Seam, either from the Nile Subgroup or the deeper Shoalhaven Group. The potential for these karst environments to have any hydrogeological connection with the Southern Extension Project area is highly unlikely.

Potential impacts to GDEs are discussed in Section 6.7.

5.7.4 Other groundwater dependent ecosystems

The Federal Government has established the National Atlas of GDEs. The atlas shows the locations of known GDEs and ecosystems that potentially use groundwater, and is considered the most comprehensive inventory of the location and characteristics of GDEs in Australia. The GDE Atlas was created using remote sensing data, previous mapping, and literature reviews.

The GDE Atlas shows there are no rivers, springs, or wetlands located within or adjacent to the Southern Extension Project area. The GDE Atlas also shows that the state forest located above (and adjacent to) the Southern Extension Project area has only a moderate potential for interaction with groundwater.

The GDE Atlas defines a moderate potential for interaction with groundwater as "… e*cosystems that may interact with groundwater. It indicates that groundwater is possibly present, and the ecosystem may use it. Where data is conflicting (some data suggests that groundwater interaction is occurring, while other data suggests it is not), and it is weighted equally (both datasets are considered equally good indicators of groundwater interaction)*".

6 Impact assessment

6.1 Method

The following groundwater assessment was based on a conceptual hydrogeological model to assess potential groundwater flow pathways, the potential volume of groundwater stored within the Southern Extension Project area, and the potential impacts on the groundwater system resulting from the Southern Extension Project. The use of a conceptual hydrogeological model to assess the potential impacts on the groundwater system is considered an appropriate method in the absence of significant interaction of the proposed mine modification and the surrounding groundwater systems.

As previously discussed, the Lithgow Coal Seam has been mined extensively in the vicinity of Invincible by historic underground and open cut workings in addition to current approved operations. This past mining has largely removed the coal seam aquifer (being the main aquifer within the Southern Extension Project area), and depressurised the remaining un-mined coal. The former underground workings are possibly wholly or partly flooded. However, this partial recharge of the aquifer does not represent a repressurisation of the aquifer to pre-mining conditions. Hence, as the main body of the aquifer within the Southern Extension Project area has largely been replaced by underground open voids the key water related issue for the Project is managing the water stored within flooded former underground workings.

Therefore, a numerical groundwater model was not developed to assess the potential impacts resulting from the Southern Extension Project. The predictions made by a numerical model would be unlikely to be significantly more accurate than the predictions made by the analytical assessment, nor reduce the already low uncertainty in the predicted impacts.

6.2 Stored water volume

The area of the Southern Extension Project has historically been mined via the underground bord and pillar method. As stated previously, there is no data available to determine the extent of water storage within the former Ivanhoe mine workings. Accordingly, for the purposes of this impact assessment, a worst case scenario was assumed, including flooded underground workings in the area of the Southern Extension Project, and that volume of water will require management (refer Figure 9). The historical water level within the Invincible underground workings was assumed to be at the same level identified by observations provide by Coalpac (refer Figure 10). Due to the uncertainty surrounding some of these observations (refer to Section 5.6), the storage within the Invincible Colliery underground workings has been calculated assuming the Coalpac water level and an assumed level based on the 884 mAHD Lithgow seam floor contour (Figure 11 and Figure 12., respectively).

The volume of water stored within the underground mine workings located within the Southern Extension Project area was calculated using a number of assumptions, including:

- The Invincible underground and the Ivanhoe No.2 Colliery workings are separated by a 20 m to 40 m thick coal seam barrier. This assessment has assumed the coal seam barrier is still intact and has not been breached during historical mining at either site.
- The natural rate of groundwater seepage through the coal barrier is dependent upon the hydraulic conductivity of the coal seam and the hydraulic gradient between the flooded Ivanhoe No. 2 Colliery and the adjacent underground workings of Invincible and Wallerawang.
- The water level in the Ivanhoe No. 2 Colliery is constrained (refer Figure 10):
    - West – by the elevation of the Ivanhoe underground portal (908 mAHD);
    - North - by the coal barrier;
    - East – by the limit of the workings and the seam floor elevation of 908 m AHD as per the mine portal; and
    - South – by groundwater divide based on the seam floor elevation.

- The underground working height is assumed to be 2 m. There is anecdotal evidence that the working height was in the order of 5 ft 7 in (~1.7 m).
- The Project is surrounded by historic underground workings. Complete mine plans for the Ivanhoe No. 2 Colliery are not available. However, it is assumed that the underground mine void extends outside of the calculation area.
- The underground workings are assumed to be open void spaces.
- The water in the Ivanhoe No. 2 Colliery is constrained vertically by the working height and does not extend into subsidence induced fractures.
- Once at a steady state, the groundwater level in underground workings will stabilise with discharge and recharge rate being similar, as such no allowance for seepage loss has been made.

If all of these assumptions hold true, the former Ivanhoe No 2 Colliery underground workings within the Southern Extension Project area could potentially hold 2,121,000 m^3 (2,121 ML) which is considered to be the worst case extent of flooding within the former workings (refer Figure 10).

A proportion of this volume could be drained into the dry workings of the Invincible open cut located to the north through the existing coal barrier. On the basis, the Invincible underground workings would flood up-gradient of the existing tidemark and saturate underground workings and spoil emplaced in the Invincible open cut that were previously dry.

The volume of available storage within the dry underground workings of Invincible and spoil emplaced in the Invincible open cut was calculated in the same manner as above, with the following assumptions:

- the tidemark water level within the Invincible Colliery is the observed levels provided for previous assessment (refer Figure 9);
- no water is lost through seepage to surrounds nor adjacent workings;
- the water level cannot exceed 893 mAHD if decant from the low point of the open cut is to be avoided;
- the underground workings are assumed to be open void spaces;
- the water in the underground void is constrained vertically by the working height of coal seam mining and does not extend into subsidence induced fractures;
- the open cut is back-filled with un-compacted / un-engineered spoil with a pore space of 15 %; and
- the open cut spoil will develop a “water table” that is relatively flat.

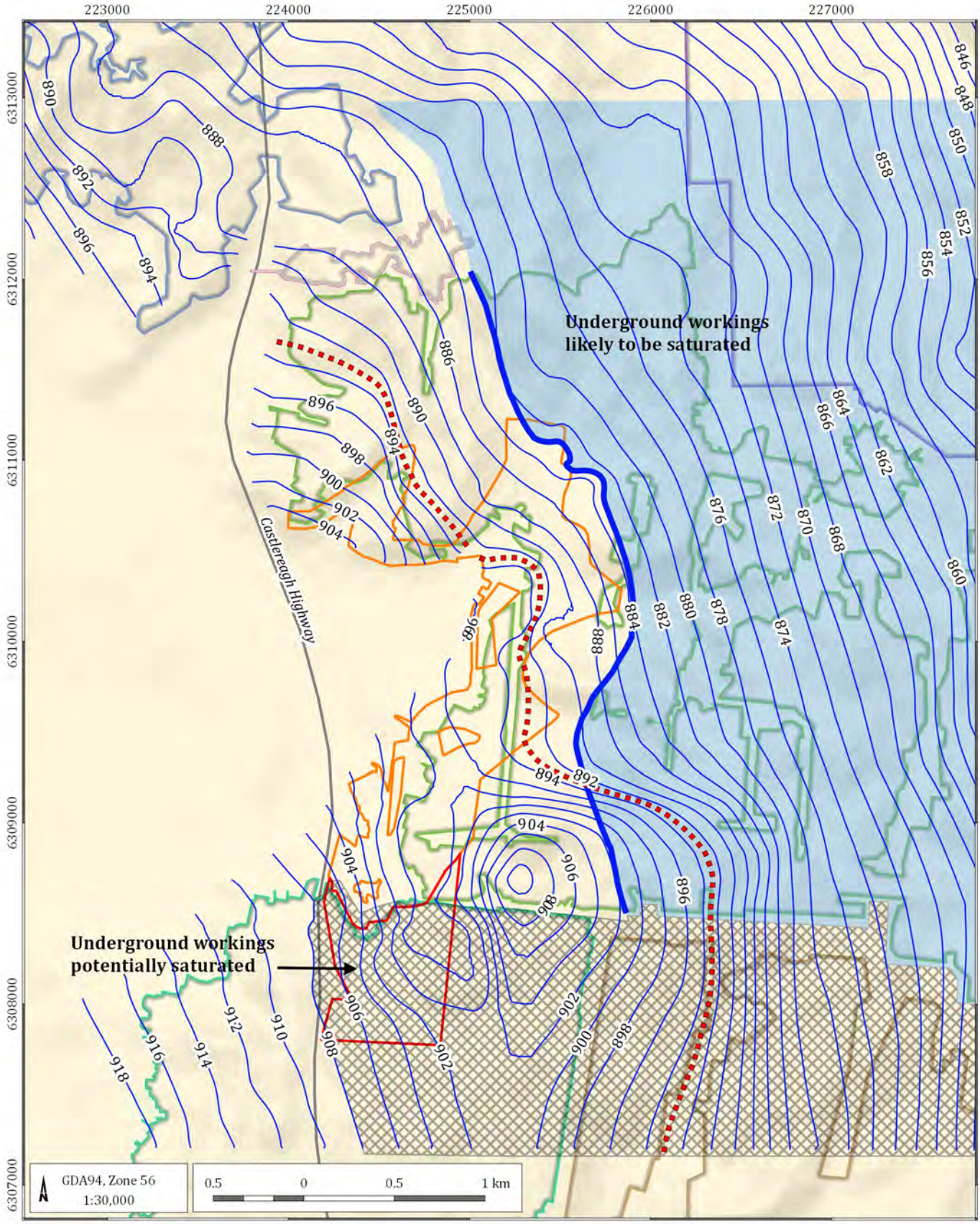
These assumptions are summarised in Figure 11.

If all of these assumptions hold true, the historic Invincible underground workings and the Invincible open cut spoil could potential store 1,219,000 m^3 (1,219 ML) and 366,000 m^3 (366 ML) of water, respectively. The total storage within these areas is estimated to be 1,585,000 m^3 (1,585 ML).

Based on these assumptions, the volume of available storage within the historic Invincible underground workings and the Invincible open cut spoil is calculated to be less than the volume of water potentially stored within the Ivanhoe No. 2 Colliery by about 536 ML. This surplus could be managed by either discharging to Cullen Creek after it had transferred the majority of the water from the Ivanhoe No. 2 Colliery into the Invincible underground workings, or spacing discharge over an extended period to allow for water moving from the Invincible underground workings into the Lithgow seam to create additional volume. It is noted that the Environment Protection Licence (EPL) for Invincible includes a licensed discharge point on Cullen Creek.

The assumptions are considered to be conservative and there is a reasonable likelihood that there is less water in the Ivanhoe No. 2 workings than assumed in the calculations and / or the storage levels in the Invincible underground workings are larger than assumed in the calculation. As discussed in Section 5.6, if the tidemark in the Invincible UG workings is at 884 mAHD (as this accords with the observed connected water levels in the Northern Void) there is an additional 526 ML of storage potentially available (refer Figure 12). Should this additional space be available there would be sufficient volume to store the assumed water from Ivanhoe workings in the Invincible underground workings, with a slight discrepancy of 10 ML which will require management.

The need for any discharge or extended duration of transfer could be assessed through monitoring of water levels in the Northern Void (which will remain open for the duration of any dewatering activities) and the potential decant point. Dewatering activities could be managed to ensure there is no unintended discharge to the environment, and where discharge is required this would be managed in accordance with the requirements of the Invincible EPL. Further detail on this is outlined in Section 8.



LEGEND

- Lithgow Seam top of seam floor 893 mAHD
- Invincible Colliery water level 2014
- Lithgow Seam top seam floor
- Road major
- Underground workings potentially saturated
- Underground workings likely to be saturated
- Proposed southern extension
- Invincible Colliery Open Cut - existing mine disturbance area
- Land

Colliery locations

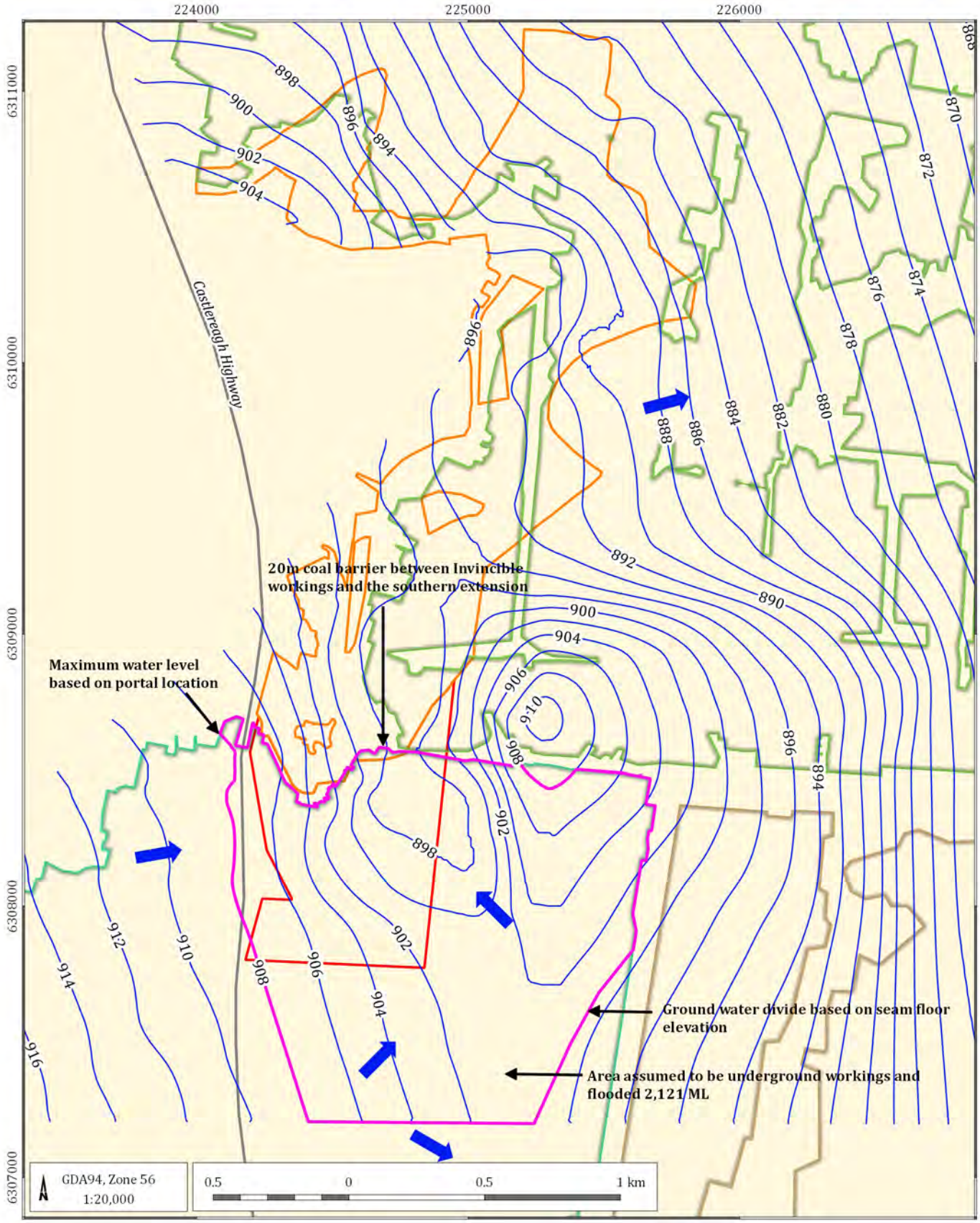
- Baal Bone Colliery
- Invincible Colliery
- Ivanhoe Colliery
- RT108 Colliery
- Tyldesley Colliery

Invincible Southern Extension Project (G1817)

Assumed water level within Invincible Colliery workings

DATE 27/07/2016

FIGURE No: 9



LEGEND

- Lithgow Seam top seam floor
- Road major
- Potential groundwater 2,121 ML
- Proposed southern extension
- Invincible Colliery Open Cut - existing mine disturbance area
- Groundwater flow direction

Colliery locations

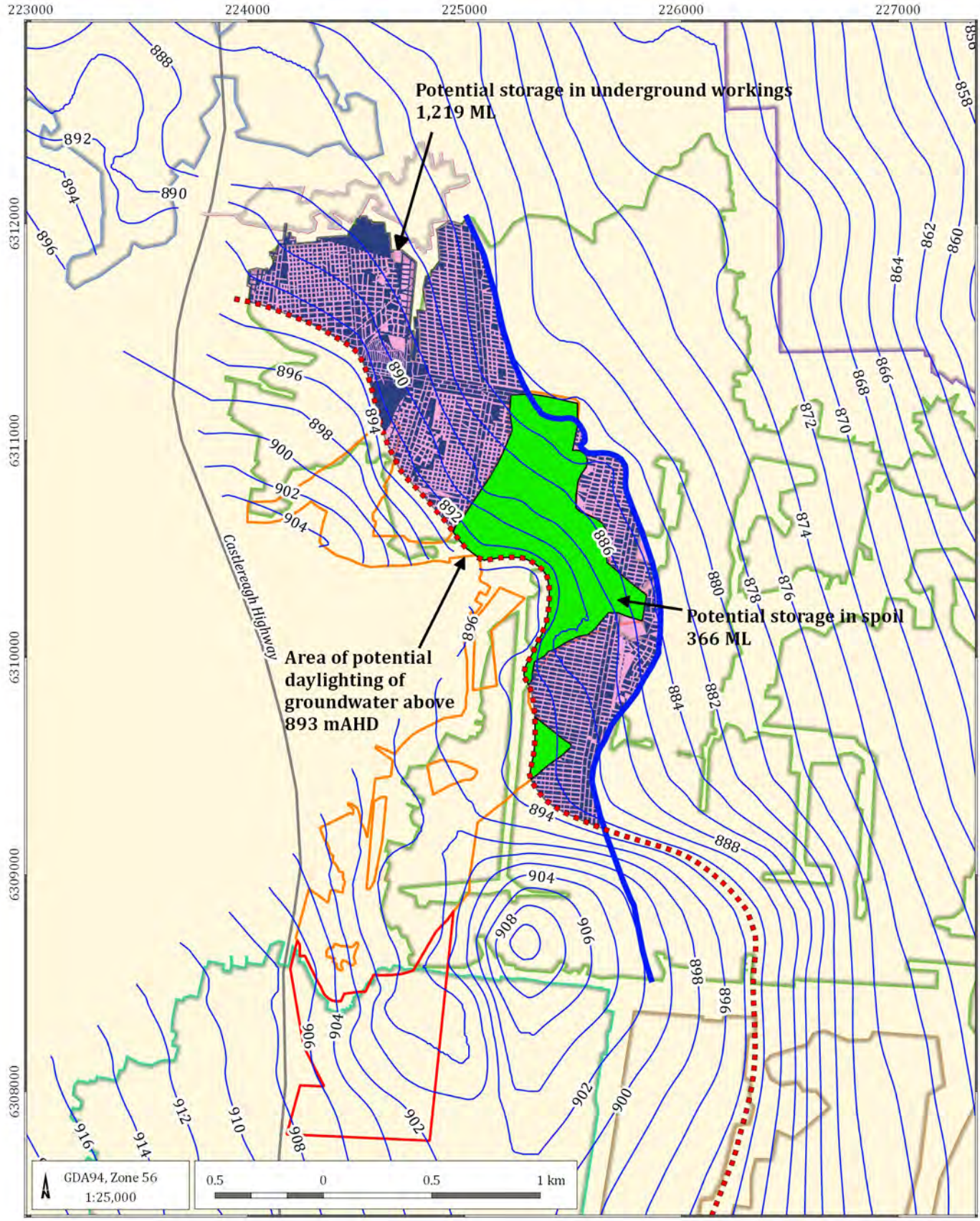
- Baal Bone Colliery
- Invincible Colliery
- Ivanhoe Colliery
- RT108 Colliery
- Tyldesley Colliery

Invincible Southern Extension Project (G1817)

Southern extension workings and volume assumptions

DATE 27/07/2016

FIGURE No: 10



LEGEND

- Invincible Colliery water level 2014
- Lithgow Seam floor elevation mAHD
- Road major
- Lithgow Seam top of seam floor 893 mAHD
- Proposed southern extension
- Invincible Colliery Open Cut - existing mine disturbance area
- Potential storage area 1,219 ML
- Open cut area 366 ML
- Coal pillars
- Land

Colliery locations

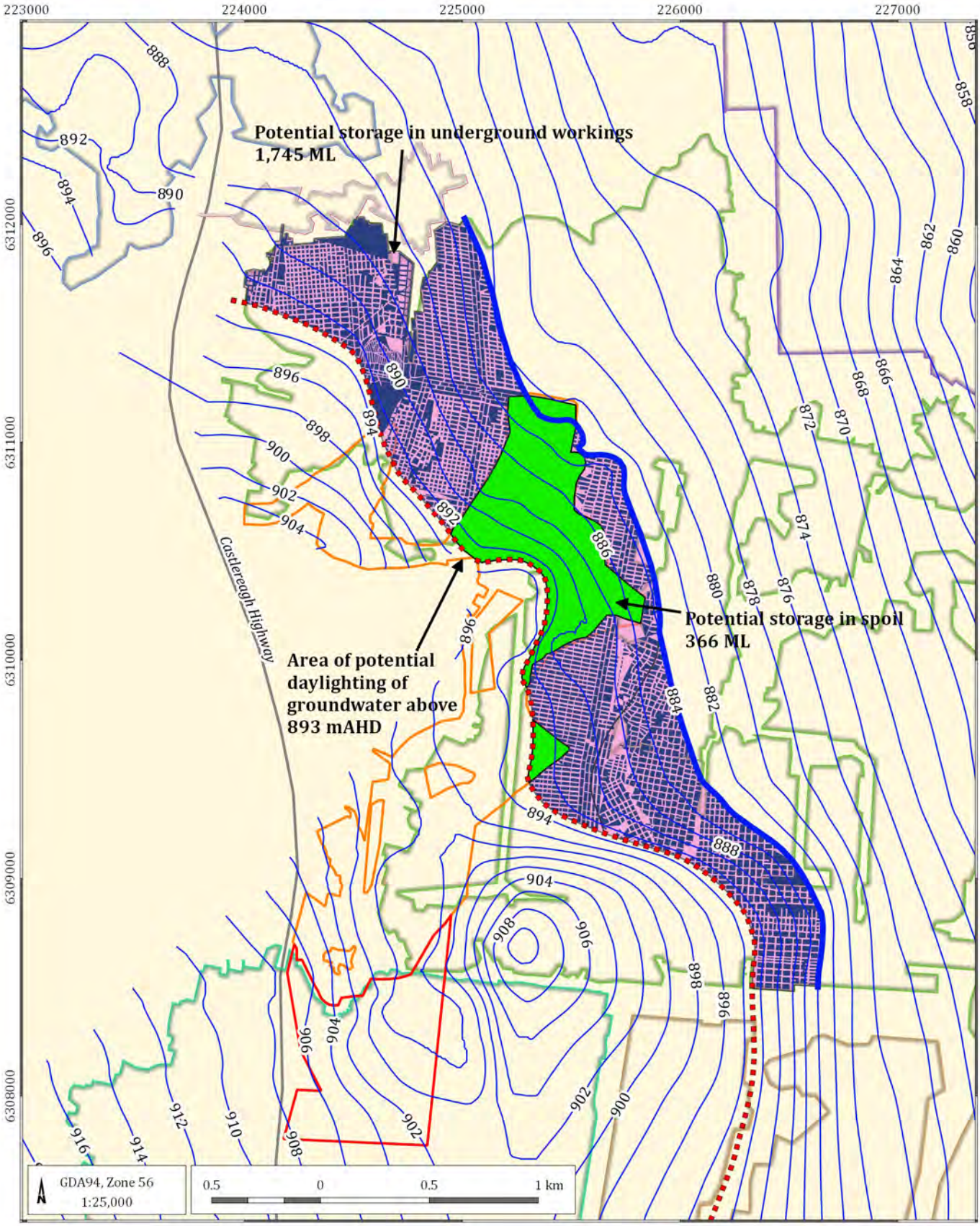
- Baal Bone Colliery
- Invincible Colliery
- Ivanhoe Colliery
- RT108 Colliery
- Tyldesley Colliery

Invincible Southern Extension Project (G1817)

Potential storage available using 2014 Invincible Colliery water level

DATE 27/07/2016

FIGURE No: 11



LEGEND

- Invincible Colliery water level to 884mAHD
- Lithgow Seam floor elevation mAHD
- Road major
- Lithgow Seam top of seam floor 893 mAHD
- Proposed southern extension
- Invincible Colliery Open Cut - existing mine disturbance area
- Potential storage area 1,745 ML
- Open cut area 366 ML
- Coal pillars
- Land

Colliery locations

- Baal Bone Colliery
- Invincible Colliery
- Ivanhoe Colliery
- RT108 Colliery
- Tyldesley Colliery

Invincible Southern Extension Project (G1817)

Potential storage available using water level at 884mAHD

DATE 27/07/2016

FIGURE No: 12

6.3 Potential impact on flooded underground mine workings

The predominant groundwater recharge pathway for the Lithgow Seam aquifer in the Southern Extension Project area is likely to be infiltration from the surface at the seam subcrop and via subsidence cracking which extends to the surface. The Southern Extension Project area is located adjacent to the seam subcrop, therefore dewatering of the underground workings of the Ivanhoe No. 2 Colliery within the Southern Extension Project area will not likely have a measurable impact on the water levels within adjacent workings.

During the life of mining during the Southern Extension Project there may be a slight increase in the amount of surface water flows captured and diverted into former Ivanhoe No. 2 workings in the Lithgow seam relative to existing conditions. However, pit dewatering activities and the slope of the Lithgow Seam bedding plane north towards the existing Invincible open cut void will minimise the extent of any inflows.

All water falling into disturbed areas of the open cut (with the exception of rainfall events which exceed the design criteria of sediment dams) as either rainfall of inflows from upstream catchment will be diverted first into the open cut and then ultimately into the former Invincible underground workings. Water will be extracted from the Northern Void for operational purposes (e.g. washery use and dust suppression) which will remove water from the underground workings.

Rehabilitation of the former open cut areas and Southern Extension Project area will ultimately reduce inflows into the former Invincible and Ivanhoe underground workings as increased amounts of runoff are diverted into Cullen Creek.

The Southern Extension Project and the Invincible open cut / underground is located up-gradient of Baal Bone Colliery. Both the Southern Extension Project and the Invincible open cut / underground are likely to contribute groundwater to Baal Bone Colliery by way of seepage from the workings. This volume of seepage to the Baal Bone Colliery has previously been estimated to range between ~111 ML/year and ~317 ML/year. The transfer of water from the Ivanhoe underground workings to the Invincible open cut / underground will increase the pressure head and potentially increase the seepage rate into the Baal Bone, by as much as 30%.

Given that Baal Bone is currently on care and maintenance, dewatering at Baal Bone Colliery is likely to cease at some stage in the future. The water level within the Invincible underground will likely rise if the Baal Bone Colliery ceases to dewater their underground workings. However, this increase would not occur until the Baal Bone workings and associated goaf had filled and the remnant coal in the Lithgow Seam becomes saturated. This process will take many years and recharge into the Invincible underground workings will be significantly reduced relative to existing levels as a result of the rehabilitation of the Invincible open cut. As a result, any increase in water levels in the Invincible underground workings is expected to be extremely slow.

6.4 Estimated groundwater seepage to open cut

Currently, there is the potential to store a volume of groundwater within the Invincible open cut / underground workings. However, if the Ivanhoe No. 2 workings are flooded and the Invincible underground workings are flooded to the tidemark used in calculation of available storage, there is potential for water to discharge into the corner of the Invincible open cut area to the north of the Southern Extension Project. As outlined in Section 6.2, Castlereagh Coal will commit to establishment of monitoring of the water level within the northern areas of spoil to monitor an increase that may give rise to decant. Discharges from the Invincible water management system will be managed in accordance with the Invincible EPL to remove any risk of decant.

6.5 Potential aquifer depressurisation

The Southern Extension Project area is located close to the Lithgow Coal Seam subcrop and recharge zone. Depressurisation of the Lithgow Coal Seam due to dewatering within the Project area will likely be minimal and is assumed to generate a localised zone of depressurisation. The Lithgow Coal Seam has been extensively mined down-dip of the Project, so this aquifer has already been highly modified from its natural state and has already experienced significant regional dewatering and then subsequent re-wetting. The extent of any localised depressurisation would be limited to the barrier coal between the Ivanhoe and Invincible workings and the Ivanhoe and Wallerawang workings.

Most of the surrounding historical underground mine workings are currently flooded. With the exception of the Ivanhoe No. 2 workings, these are all located down dip from the Southern Extension Project area. The groundwater head in nearby underground workings is unlikely to be measurably lowered because these workings are located down dip and the coal seam barriers that separate the underground workings will partially restrict the zone of depressurisation. The very large storage capacity of the underground workings will also buffer any potential water level changes.

Dewatering of the Project area may reduce the groundwater head within the underlying Marangaroo Formation. However, this impact on the head within the Marangaroo Formation is expected to be limited to a very small area immediately surrounding the Southern Extension Project area and may not be measurable because of its limited hydraulic connection with the Lithgow Coal Seam.

6.6 Potential impact on groundwater users

The only registered bore within the Project area is a bore associated with Invincible. The closest registered bore (a monitoring bore at the Pine Dale Coal Mine) is located approximately 1,200 m to the south of the Southern Extension Project area. The closest bore potentially used for productive (i.e. non mine related) purposes is located approximately 3.5 km to the west of the Southern Extension Project area. Dewatering of the Southern Extension Project area is not anticipated to impact the water levels in this bore.

6.7 Potential impact on groundwater dependent ecosystems

No high priority GDEs are located within the footprint of the Southern Extension Project area. The absence of any groundwater seepage and aquifer depressurisation will ensure that no GDEs will be impacted.

6.8 Water take and licensing

In order to comply with the AIP, all groundwater take, either direct or indirect, must be accounted for, unless exempt. As the Invincible project was originally approved under Section 75U of the EP&A Act, aquifer interference approval will not be required to transfer stored water from the Ivanhoe underground workings to the Invincible underground workings (refer Section 2.4). However, a water access licence (WAL) is required for the initial take of surface water recharging the underground workings. As this recharge is sourced from naturally occurring surface water, the take is regulated by the WSP for the Macquarie Bogan Unregulated and Alluvial Water Sources.

As discussed in Section 5.4.1, it has been assumed that the water level within the flooded Ivanhoe Colliery workings has reached steady state equilibrium where water seepage (outflow) is approximately equalled by recharge (inflow). In this case, the amount of total recharge to the Ivanhoe No. 2 Colliery underground workings, which is considered to be predominantly from the surface, is estimated to be in the range between ~7 ML/year to ~20 ML/year. As the recharge is sourced from surface water inadvertently captured in an aquifer, this initial take is encompassed under the WSP for the Macquarie Bogan Unregulated and Alluvial Water Sources.

As discussed in Section 6.2, the Southern Extension Project may need to transfer approximately 2,121 ML of water from the Ivanhoe No. 2 Colliery to the Invincible Colliery to dewater the Southern Extension Project area.

In addition, not all of the water potentially stored within the Ivanhoe No. 2 Colliery may be able to be stored within the Invincible underground workings and spoil, based on conservative assumption on available storage within the Invincible underground workings. This assessment has estimated that 536 ML of water may need to be disposed of by other methods (i.e. discharging to Cullen Creek subject to the requirements of the Invincible EPL). Castlereagh Coal will commit to monitoring of Northern Void spoil to appropriately manage any water surplus to available storage.

It is noted that there is potentially additional area of storage located in the Invincible underground workings that could provide an additional 524 ML for assumed water from the Ivanhoe workings. Should this additional space be available there would be sufficient volume to store the assumed water from Ivanhoe workings in the Invincible underground workings, with a slight discrepancy of 10 ML which will require management.

As discussed in Section 2.3.1, the movement of water from the Ivanhoe underground workings to the Invincible underground workings will not require aquifer interference approval.

7 Compliance with NSW Aquifer Interference Policy

Table 4 compares the predicted impacts of the Southern Extension Project against the AIP Level 1 minimal impact considerations for the less productive groundwater of the Permian coal measures. No Level 1 minimal impact considerations have been identified in this assessment.

Table 4 Comparison of predicted impacts and the AIP minimal impact considerations

Aquifer: Permian coal measures (porous or fractured rock)	
Category: Less productive water source	
Level: 1 minimal impact consideration	**Assessment**
Watertable 1. Less than or equal to a 10 % cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan; or A maximum of a 2 m decline cumulatively at any water supply work.	**Level 1 – acceptable** At the time of writing there were no known culturally significant sites or high priority GDEs in the Project area (Section 6). Hence there are no known risks of mine development to such sites. No drawdown in excess of the criterion is predicted to occur within water supply work
Water pressure 1. A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2 m decline, at any water supply work.	**Level 1 – acceptable** The only registered bore within the Project area is a bore associated with Invincible. The closest registered bore not associated with the Southern Extension Project is 1,200 m from the southern boundary of the Southern Extension Project area. It is anticipated that these bores will not be impacted by a drawdown in excess of 2 m.
Water quality 1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.	**Level 1 – acceptable** The beneficial use of the Permian coal measures is not anticipated to be impacted during mining or post mining.

8 Groundwater monitoring and management plan

8.1 Groundwater level monitoring plan

The existing monitoring bore network is not currently adequate to monitor potential impact on the groundwater regime as a result of mining within the Southern Extension Project area. Therefore, it is recommended that Castlereagh Coal expand the existing network to fulfil the requirements of the approval conditions together with commitments made in the respective environmental assessments, environmental impact statements and relevant legislation, standards, and guidelines.

The main purpose of the monitoring bore network will be to monitor water levels in the spoil in the northern areas of the Invincible open cut to monitor the risk of decant and to monitor for aquifer depressurisation, principally in the Lithgow Seam on an on-going basis.

Monitoring of groundwater levels within the flooded (and dry) areas of historic Invincible underground workings will be particularly important if those areas are intended for water storage, to monitor the extent to which the tide mark responds to the transfer of water from the Ivanhoe No. 2 Colliery.

8.2 Groundwater quality monitoring plan

Water samples should be collected from the monitoring bores on a six-monthly basis (or as otherwise agreed with NOW) and the samples analysed for:

- General parameters: pH, EC, and TDS;
- Major cations: Na, K, Ca, and Mg;
- Major anions: Cl, SO_4, HCO_3, CO_3, and F; and
- Selected metals : Al, Sb, As, Ba, Be, B, Cd, Cr, Co, Cu, Fe, Pb, Li, Mn, Mo, Ni, Se, Ag, Ti, Th, Sn, U, V, Zn, and bromine.

Water quality trigger values will be derived for each monitoring bore in the water management plan for the Southern Extension Project. However, in the absence of long-term historical groundwater quality data, the use of ANZECC guideline trigger values for stock watering should be utilised until site specific trigger values are available.

8.3 Data management and reporting

Data management and reporting will include:

- Annual assessment of departures from identified monitoring data trends. If consecutive monitoring data over a period of 6 months exhibit an increasing divergence in an adverse impact sense from anticipated trends, then such departures should initiate further actions. These may include a need to conduct more intensive monitoring or to invoke impact re-assessment and / or mitigative measures.
- If more intensive monitoring is initiated (under Point 1 above) then normal review of depressurisation of coal measures should be undertaken by a suitably qualified hydrogeologist. The reporting will include consideration of all relevant water level and water quality data.

9 Conclusions

The Southern Extension Project poses a low risk to the groundwater regime for the following reasons:

- The Lithgow Coal Seam has been mined extensively in the vicinity of Invincible by historic underground and open cut workings in addition to current approved operations. This past mining has largely removed the coal seam aquifer (being the main aquifer within the Southern Extension Project area), and depressurised any remaining un-mined coal. Therefore, the main aquifer within the Southern Extension Project area has largely been replaced by underground open voids that are wholly or partly flooded, and the key water related issue for the Project is managing the water stored within flooded former underground workings.
- The Southern Extension Project is located close to the Lithgow Coal Seam subcrop and recharge zone. Depressurisation of the seam due to mining within the Southern Extension Project area will likely be minimal and is assumed to generate a localised zone of depressurisation in the coal seams, but this is not expected to impact on adjacent registered bores.
- Within the Project area, only parts of the Lithgow Coal Seam are likely to be saturated. The overlying coal seams are likely to be unsaturated.
- The predominant recharge mechanism of water stored in the underground workings is through inadvertent capture of surface water via subsidence induced cracking.
- No high priority GDEs have been identified within the Project area.
- The neighbouring state forest is classified as having a moderate potential for interaction with groundwater and is therefore expected to not be impacted by dewatering within the Project area.

The Project area historic underground workings (Ivanhoe No. 2 Colliery) may be flooded. The volume of water potentially stored in that area is in the order of 2,121 ML. This volume of water, if present, will need to be managed either through disposal to surface storage or discharge, or diverted to the historic Invincible underground and open cut workings. The volume of potential storage available (1,585 ML) is not likely to be sufficient to store the water from the Project. The water level within the historic workings should not exceed 893 mAHD as there is the risk that groundwater could discharge from the underground workings into the Invincible open cut area.

It is noted that there is potentially additional area of storage located in the Invincible underground workings that could provide an additional 524 ML for assumed water from the Ivanhoe workings. Should this additional space be available there would be sufficient volume to store the assumed water from Ivanhoe workings in the Invincible underground workings, with approximately 10 ML requiring management.

The Project and the Invincible open cut / underground is located up-gradient of Baal Bone Colliery. It is likely that the Project and the flooded Invincible Colliery contribute groundwater to Baal Bone Colliery by way of seepage from the workings. The transfer of water from the Project to the Invincible Colliery will increase groundwater head pressure and potentially increase the seepage rate into the Baal Bone Colliery. Vice versa, the water level within the Invincible Colliery will likely rise, when the Baal Bone Colliery ceases to dewater their underground workings.

As discussed in Section 2.3.1, the movement of water from the Ivanhoe underground workings to the Invincible underground workings will not require aquifer interference approval.

In order to comply with the AIP, all groundwater take, either direct or indirect, must be accounted for, unless exempt. As the Invincible project was originally approved under Section 75U of the EP&A Act, aquifer interference approval will not be required to transfer stored water from the Ivanhoe underground workings to the Invincible underground workings (refer Section 2.4). However, a WAL is required for the initial take of surface water recharging the underground workings. As this recharge is sourced from naturally occurring surface water, the take is regulated by the Macquarie Bogan unregulated and alluvial water source WSP, estimated to be in the range between ~7 ML/year to ~20 ML/year. As the recharge is sourced from surface water inadvertently captured in an aquifer, this initial take is encompassed under the Macquarie Bogan unregulated and alluvial water source WSP.

10 References

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