Centennial Mandalong Pty Ltd

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

November 2016

Executive summary

Introduction

Mandalong Mine is an underground coal mine located approximately 35 km south-west of Newcastle on the western side of Lake Macquarie operated by Centennial Mandalong Pty Limited. Mandalong Mine consists of underground mine workings and surface facilities located at three sites: Mandalong Mine Access Site, Mandalong South Surface Site and Delta Entry Site.

GHD Pty Ltd was commissioned to prepare a Water Resources Impact Assessment to assess potential impacts of the Mandalong Longwall Panel 22 to 23 Modification (the Project) on groundwater and surface water environments. The Project is seeking to modify Mandalong Mine's development consent SSD-5144 to undertake the secondary extraction of extended longwall panels 22 and 23.

Site description

The study area is located within the Morans Creek and Tobins Creek catchment. These creeks are ephemeral and do not have surface water flow for the entire year. Generally, these watercourses flow for relatively brief periods following significant rainfall events. Morans Creek and Tobins Creek contribute to the wider Dora Creek catchment via Stockton Creek.

The groundwater sources in the Mandalong Mine area are generally low yielding and predominantly weathered and/or fractured sandstone, coal seams and clayey quaternary alluvium. Two key hydrogeological units exist within the study area, which include the alluvial and fractured and porous rock (comprising of both coal seam and overburden rock) groundwater sources.

Water management

The objective of the water management system at Mandalong Mine is to separate clean and dirty water in order to manage impacts to water quality and to manage transfers between surface and underground storages. Underground water is transferred to the Cooranbong underground storage where it is dewatered to the Borehole Dam for discharge through a licensed discharge point (LDP001) at Cooranbong Entry Site (part of the Northern Coal Logistics Project SSD-5145). Sources of water that contribute to the underground storage include groundwater seepage, potable water required for underground mining equipment and various transfers from surface water storages.

The existing groundwater monitoring network consists of standpipe monitoring bores installed in alluvial and fractured and porous rock groundwater sources and five vibrating wire piezometers. Monitoring is undertaken monthly for levels and quality (pH and electrical conductivity). Some bores contain water level loggers for continuous monitoring of groundwater levels.

The existing surface water monitoring program consists of monthly and quarterly surface water quality monitoring at ten locations, two of which are located on Morans Creek upstream of the study area. Flow and level monitoring of Morans Creek was undertaken between 2006 and 2009.

Groundwater levels

Alluvial groundwater levels have generally fluctuated over time within a range of 2 m to 3 m below ground level. A significant relationship exists between alluvial groundwater levels and rainfall at most monitoring locations. No long term changes in alluvial groundwater levels as a result of mining at Mandalong are evident.

Analysis of monitoring data for fractured and porous groundwater sources indicates that depressurisation (by greater than 2 m) occurs up to 230 m above longwall panels at Mandalong, with the greatest depressurisation occurring up to 120 m above longwalls. At a number of monitoring locations that have shown depressurisation due to mining, groundwater levels have stabilised or started to gradually increase towards pre-mining levels approximately three to five years after undermining occurring.

Hydrogeological modelling was undertaken to estimate groundwater seepage into the Mandalong Mine workings and determine groundwater drawdown associated with Mandalong Mine and the proposed workings. The model predicts that underground mining at Mandalong Mine (including the proposed extension to longwalls 22 and 23) is unlikely to result in a water table drop greater than 0.1 m (limit of accuracy of the model) within the alluvial groundwater throughout the period of mining. Any reductions in alluvial groundwater levels are expected to be temporary and localised and may occur during undermining as a result of the development of shallow tensile and compressive cracks and resulting localised increases in hydraulic conductivity and porosity. It is expected that these cracks would fill over time and the hydraulic conductivity and porosity should return to pre-mining values.

Loss of groundwater from the fractured and porous rock groundwater to the existing, proposed and approved Mandalong and Mandalong South workings is predicted by the hydrogeological modelling to increase over the period of mining from 0.9 ML/day in 2016 to a peak of 2.1 ML/day in 2036. Depressurisation greater than 2 m of fractured and porous rock water sources in the vicinity of longwalls 22 and 23 may occur up to approximately 230 m above the proposed longwalls. The greatest depressurisation is likely to occur up to 120 m above the longwalls. Depressurisation within 120 m of the longwalls may be due to continuous fracturing with groundwater pressures in this zone and is expected to stabilise or gradually recover at least three to five years after undermining. Depressurisation within heights greater than 120 m is likely to be due to discontinuous fracturing. It is noted that depth of cover above the proposed extension of longwalls 22 and 23 is approximately 300 m and therefore it is unlikely that there would be depressurisation of shallow rock aquifers (and associated potential GDEs) within this area.

The predicted impacts on alluvial groundwater and fractured and porous rock groundwater attributable to the proposed extension of longwalls 22 and 23 is expected to be less than the Level 1 minimal impact considerations from the NSW Aquifer Interference Policy and are therefore considered to be acceptable.

Groundwater quality

Alluvial groundwater pH is consistently within the range of 5 to 8 and groundwater EC varies considerably within the alluvium across the mining area, ranging from less than 1,000 µS/cm to over 10,000 µS/cm. Fractured and porous rock groundwater is consistently between pH 6 and 8, with EC typically ranging from about 6,000 µS/cm to over 10,000 µS/cm. No change in groundwater pH or EC resulting in a lowering of the beneficial use category is evident since longwall mining began in 2005.

It is not expected that the proposed extension to longwalls 22 and 23 would reduce the beneficial use category of alluvial groundwater or fractured and porous rock groundwater in the vicinity of longwalls 22 and 23.

Water and salt balance

Water and salt balance modelling for Mandalong Mine was undertaken for the projected life of the mine, from current conditions in 2016 to the end of mining in 2037. The predicted groundwater inflows that were obtained from hydrogeological modelling were incorporated into the water and salt balance model. To assess the impact of rainfall on the site, modelling was completed by using a historical time series of daily rainfall data extending over 127 years.

The greatest change in the water and salt balance modelling results was the predicted increase in groundwater inflows into the underground mining areas. This was modelled to increase from 326 ML/year in 2016 to a peak of 751 ML/year in 2036. Salt associated with groundwater inflows was modelled to account for approximately 1,283 tonnes of salt on average annually in 2016, increasing to approximately 2,958 tonnes of salt in 2036. The average salinity of groundwater inflows was estimated to be 5,880 µS/cm.

The predicted increase in groundwater inflows will be managed through transfer to the Borehole Dam and subsequent discharge through LDP001 at Cooranbong Entry Site. Under existing conditions in 2016, discharge from the Borehole Dam to LDP001 was predicted to be 814 ML/year on average. Approximately 1,383 tonnes of salt on average was estimated to be associated with this water transfer, with an average salinity of approximately 2,450 µS/cm. Discharge to LDP001 was modelled to peak at approximately 1,264 ML/year on average in 2036, with an associated salt load of 3,009 tonnes. The average salinity of discharge from the Borehole Dam to LDP001 in 2036 was predicted to be approximately 3,550 µS/cm.

Flooding

Umwelt (Australia) Pty Limited has prepared a flood assessment to determine the impact on the flooding regime in the Mandalong Valley as a result of underground mining of extended longwalls 22 and 23 at Mandalong Mine. The main impacts of the Project on flooding predicted by modelling include a reduction in freeboard at some properties and an increase in flood hazard at some properties. Changes in flooding regimes and increased potential remnant ponding areas were predicted to be isolated to the zone of predicted subsidence.

Geomorphology

A desktop assessment and site visit were undertaken to assess the existing geomorphic characteristics of the reaches of watercourses that may be affected by the Project. Morans Creek and Tobins Creek are classified as fine-grained meandering systems. Banks are typically well-vegetated with a range of native and exotic species. As a result, in combination with relatively cohesive bank sediments, the occurrence and rates of bank erosion are low.

Given the nature of channels within the study area, the resilience to subsidence as a result of the Project is high. The geomorphic field investigation identified only one area of risk due to the predicted subsidence as a result of the Project. This area was within the Tobins Creek channel, where a low headcut in the order of 0.2 m was observed along Tobins Creek, where it crosses the proposed extension of Longwall 23. Given the location of the headcut, it is likely to be maintained as a result of the Project and is unlikely to be promoted.

Surface water quality

Baseline surface water quality monitoring indicated typical physicochemical, nutrient and metal concentrations present within Morans Creek, upstream of longwalls 22 and 23. Results indicated fresh waters with electrical conductivity between 150 µS/cm and 1,000 µS/cm. The pH levels indicated neutral to slightly acidic water, with samples typically ranging between 6 and 7.

The majority of results for dissolved arsenic, boron, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, silver and zinc were reported to be below relevant ANZECC (2000) default guideline values. Elevated concentrations of dissolved aluminium, cobalt and iron were identified from baseline monitoring.

Localised changes to water quality, including elevated levels of TSS and turbidity, may occur due to the mobilisation of sediments caused by changes to the surface as a result of subsidence. However, these changes are expected to be negligible (not measurable) and temporary. It is expected that the environmental value of the surface water will be maintained.

Downstream water users

A total of 127 groundwater bores were identified in a 5 km radius of the existing, approved and proposed Mandalong Mine workings. The majority of the bores are registered as monitoring/test bores. Potential groundwater dependent ecosystems were identified to generally coincide with the reaches of Morans Creek and Tobins Creek.

A total of 14 properties within a 5 km radius of the study area were identified to be licensed for surface water extraction. The designated use or purpose of these licences includes irrigation, farming and industrial. No approvals for basic landholder rights were identified.

Adverse impacts to downstream water users are unlikely to occur as a result of the Project due to the low risk of potential impacts and the ephemeral nature of waterways. The predicted impacts on groundwater sources are less than the Level 1 minimal impact considerations from the NSW Aquifer Interference Policy.

Mitigation, management and monitoring

A regional water management plan has been developed to provide an overview of the water management requirements across Centennial's northern operations. A site-specific water management plan for Mandalong Mine has also been developed to address specific water management requirements for the site. An extraction water management plan will also be developed prior to extraction of longwalls 22 and 23. The water management plans ensure the operation of the mine, with respect to water, meets all relevant regulatory requirements. Trigger action response plans within water management plans should be referenced to determine the appropriate actions in response to any impacts of the Project identified as part of the monitoring program.

Groundwater and surface water monitoring for the Project will be undertaken as a continuation of the monitoring currently undertaken. The main objective of monitoring is to ensure that water management measures implemented function as designed.

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Glossary

Alkalinity	A measure of the ability of an aqueous solution to neutralise acids. Alkalinity of natural waters is due primarily to the presence of hydroxides, bicarbonates and carbonates. It is expressed in units of calcium carbonate ($CaCO_3$).
Alluvial	Deposition from running waters.
Ambient	Pertaining to the surrounding environment or prevailing conditions.
Aquifer	An underground layer of permeable material from which groundwater can be usefully extracted.
Australian Height Datum	A common national surface level datum approximately corresponding to sea level
Average recurrence interval	A statistical estimate of the average period in years between the occurrence of a flood of a given size or larger, e.g. floods with a discharge equivalent to the 1 in 100-year average recurrence interval flood event will occur on average once every 100 years.
Baseflow	The component of flow in a watercourse that is driven from the discharge of underground water.
Baseline monitoring	Monitoring conducted over time to collect a body of information to define specific characteristics of an area (e.g. species occurrence or water quality) prior to the commencement of a specific activity.
Bore	Constructed connection between the surface and a groundwater source that enables groundwater to be transferred to the surface either naturally or through artificial means.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular location.
Clean water	Water that has not come into physical contact with coal or mined carbonaceous material.
Cumulative rainfall departure	Monthly accumulation of the difference between the observed monthly rainfall and long-term average monthly rainfall.
Dewatering	The removal or pumping of water from an above or below ground storage, including the mine water within the water collection system of mine workings. Water removed from mine workings is regarded as dewatering unless the workings are flooded and at equilibrium with the surrounding strata (in which case the removal is considered groundwater extraction).
Dirty water	Water that has an elevated sediment load.
Discharge	The quantity of water per unit of time flowing in a stream, for example cubic metres per second or megalitres per day.
Drawdown	A reduction in piezometric head within an aquifer.

Electrical conductivity	A measure of the concentration of dissolved salts in water.
Ephemeral	Stream that is usually dry, but may contain water for rare and irregular periods, usually after significant rain.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Floodplain	Area of land that is periodically inundated by floods up to the probable maximum flood event.
Fracture	Cracks within the strata that develop naturally or as a result of underground works.
Geomorphology	Scientific study of landforms, their evolution and the processes that shape them. In this report relates to the form and structure of waterways.
Goaf	The part of a mine from which the mineral has been partially or wholly removed, including the waste left in workings.
Groundwater	Water occurring naturally below ground level.
Groundwater extraction	For the purposes of this report, groundwater extraction has been defined as the removal of groundwater from a groundwater source or aquifer, either via direct removal for use via a production bore or via incidental flow of groundwater from the aquifer into the mine workings during and after mining. Groundwater extraction includes the pumping of underground water from flooded mine workings in equilibrium with the surrounding strata as well as the removal of water from perched aquifers recharged directly from rainfall infiltration.
Guideline value	The concentration or load of physicochemical characteristics of an aquatic ecosystem, below which there exists a low risk that adverse ecological effects will occur. They indicate a risk of impact if exceeded and should ‘trigger’ action to conduct further investigations or to implement management or remedial processes.
Headcut	Erosional feature where an abrupt vertical drop in the stream bed occurs, resembling a small waterfall when the stream is flowing or a short bluff when the stream is dry.
Hydrogeology	The area of geology that deals with the distribution and movement of groundwater in soils and rocks.
Hydrology	The study of rainfall and surface water runoff processes.
Infiltration	The downward movement of water into soil and rock. It is largely governed by the structural condition of the soil, the nature of the soil surface (including presence of vegetation) and the antecedent moisture content of the soil.

Interseam	The strata between the coal seams.
Ion	Electrically charged atom.
Licensed discharge point	A location where the premises discharge water in accordance with conditions stipulated within the site environmental protection licence.
Longwall	Longwall mining is a form of underground coal mining where a block of coal is mined using a longwall shearer. The longwall mining method is supported by roadway development, mined using a continuous miner unit.
Median	The middle value, such that there is an equal number of higher and lower values. Also referred to as the 50th percentile.
Overburden	The strata between the recoverable topsoil and the upper coal seam.
Percentile	The value of a variable below which a certain percent of observations fall. For example, the 80th percentile is the value below which 80% of values are found.
Permian Age	The youngest geological period of the Palaeozoic era, covering a span between approximately 250 and 290 million years.
pH	The value taken to represent the acidity or alkalinity of an aqueous solution. It is defined as the negative logarithm of the hydrogen ion concentration of the solution.
Potable water	Water of a quality suitable for drinking.
Reach	Defined section of a stream with a uniform character and behaviour.
Recharge	Inflow of water from surrounding strata into underground mine workings via infiltration. This can be as a result of rainfall events or from surrounding aquifers.
Riparian	Pertaining to, or situated on, the bank of a river or other water body.
Runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
Run of mine	Raw coal production (unprocessed).
Sediment	Soil or other particles that settle to the bottom of lakes, rivers, oceans and other waters.
Strata	Geological layers below the ground surface.
Stream order	Stream classification system, where order 1 is for headwater (new) streams at the top of a catchment. Order number increases downstream using a defined methodology related to the branching of streams.
Subsidence	The vertical difference between the pre-mining surface level and the post-mining surface level at a point.
Surface water	Water that is derived from precipitation or pumped from underground and may be stored in dams, rivers, creeks and drainage lines.

Topography	Representation of the features and configuration of land surfaces.
Tributary	A stream or river that flows into a main river or lake.
Turbidity	A measure of clarity (turbidity) of water. Turbidity in excess of 5 NTU is just noticeable to the average person.

Abbreviations

AHD	Australian Height Datum
ARI	Average recurrence interval
bgl	Below ground level
BOD	Biochemical oxygen demand
BOM	Bureau of Meteorology
BSAL	Biophysical strategic agricultural land
c/t	Cut through
Centennial	Centennial Coal Company Limited
Centennial Mandalong	Centennial Mandalong Pty Limited
CES	Cooranbong Entry Site
CRD	Cumulative rainfall departure
DES	Delta Entry Site
DGV	Default guideline value
DPIW	Department of Primary Industries – Water
EC	Electrical conductivity
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPA	Environment Protection Authority
EPL	Environment protection licence
GDE	Groundwater dependent ecosystem
GHB	General head boundary
HARTT	Hydrograph Analysis: Rainfall and Time Trends
HUA WSP	Hunter Unregulated and Alluvial Water Sources Water Sharing Plan
km	Kilometre
L/s	Litre per second
LDP	Licensed discharge point
LOR	Limit of reporting
m	Metre
m/mm	Metre per millimetre
m/month	Metre per month

m/s	Metre per second
m/year	Metre per year
mg/L	Milligram per litre
MHRDC	Maximum harvestable right dam capacity
ML	Megalitre
ML/day	Megalitre per day
ML/year	Megalitre per year
mm	Millimetre
mm/day	Millimetre per day
MMAS	Mandalong Mine Access Site
MSSS	Mandalong South Surface Site
Mtpa	Million tonnes per annum
NCFPR WSP	North Coast Fractured and Porous Rock Groundwater Sources Water Sharing Plan
NTU	Nephelometric turbidity unit
NWQMS	National Water Quality Management Strategy
POEO Act	*Protection of the Environment Operations Act 1997*
ROM	Run of mine
SEE	Statement of Environmental Effects
SILO	Scientific Information for Land Owners
SSGV	Site-specific guideline value
t/year	Tonne per year
TARP	Trigger action response plan
TDS	Total dissolved solids
TKN	Total Kjeldahl nitrogen
TOC	Top of casing
TSS	Total suspended solids
Umwelt	Umwelt (Australia) Pty Limited
VWP	Vibrating wire piezometer
WAL	Water access licence
WM Act	*Water Management Act 2000*

WRIA	Water Resources Impact Assessment
WSP	Water sharing plan
µS/cm	Microsiemens per centimetre

1. Introduction

GHD Pty Ltd (GHD) was commissioned by Centennial Mandalong Pty Limited (Centennial Mandalong), a wholly owned subsidiary of Centennial Coal Company Limited (Centennial), to prepare a Water Resources Impact Assessment (WRIA) for the Mandalong Longwall Panel 22 to 23 Modification (the Project). This assessment forms part of a Statement of Environmental Effects (SEE) to support a development application under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

1.1 Background

Mandalong Mine is an underground coal mine located approximately 35 km south-west of Newcastle on the western side of Lake Macquarie. Centennial Mandalong acquired Mandalong Mine in 2002, with mining operations commencing in 2005.

Mandalong Mine consists of underground mine workings and surface facilities located at three sites: Mandalong Mine Access Site (MMAS), Mandalong South Surface Site (MSSS) and Delta Entry Site (DES). The location of the surface sites and the Project Application Area are shown in Figure 1-1.

Mandalong Mine currently operates under development consent SSD-5144, granted by the Planning Assessment Commission on 12 October 2015 for the Mandalong Southern Extension Project. The development consent provides for an extension of the mining area within the West Wallarah and Wallarah-Great Northern seams.

1.2 Project description

An igneous sill exists to the west of approved longwall panels 22 to 24. Due to historical uncertainty associated with the extent of the igneous sill, longwall panels 22 to 24 were shortened as a conservative measure to mitigate the sill's impact on the mine's production. In recent times through ongoing geological exploration and the successful extraction of adjacent longwall panels below the igneous sill, its extent and condition has become better understood. This has resulted in the proposed extension of longwall panels 22 and 23 within the development consent boundary of SSD-5144. Figure 1-2 illustrates the proposed extension of longwall mining within these two panels.

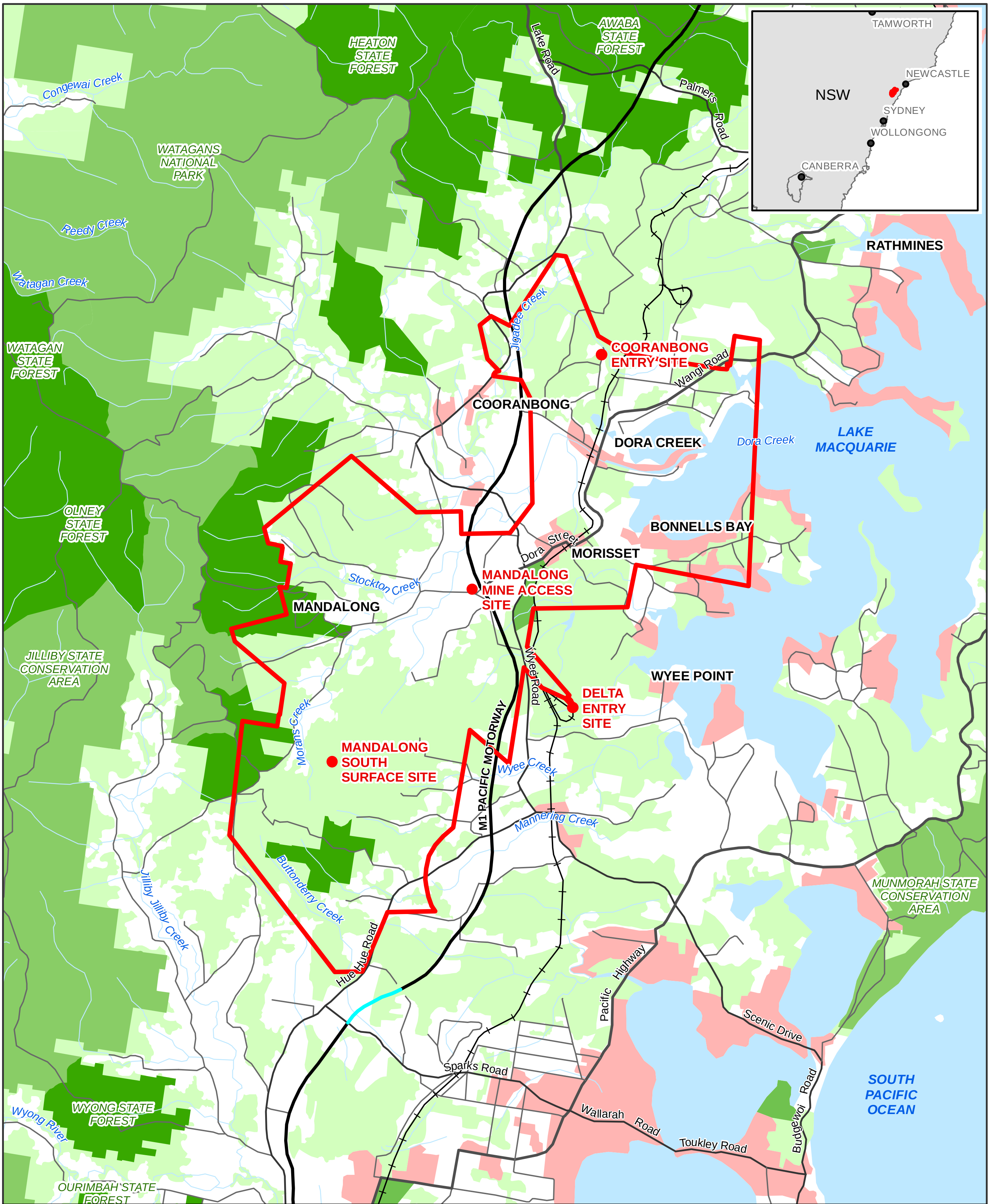
Centennial Mandalong has prepared a SEE to support an application seeking to modify development consent SSD-5144 under Part 4 of the EP&A Act. The modification is seeking to undertake the secondary extraction of extended longwall panels 22 and 23 within the development consent boundary of SSD-5144 as illustrated on Figure 1-1.

The primary components of the Project are:

- Extension of Longwall 22 from 1,630 m to 2,212 m. This yields 617,381 additional tonnes beyond 1,793,842 tonnes already approved.
- Extension of Longwall 23 from 1,631 m to 2,392 m. This yields 799,933 additional tonnes beyond 1,799,425 tonnes already approved.

1.3 Study area

The study area for the WRIA primarily encompasses the 26.5 degree angle of draw around the secondary extraction areas of longwalls 22 and 23, as shown in Figure 1-2. The WRIA also considers impacts on mine water inflows, underground water storages and groundwater bores that extend beyond the study area.



1:150,000 for A4

0 0.5 1 2 3 4
Kilometers

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

LEGEND

- Site location
- Project application area
- Existing rail
- Motorway
- Principal road
- Secondary road
- Minor road
- Watercourse
- Watercourse area
- Built up area
- Recreation areas
- Nature conservation
- State forest
- Forest or shrub

LOCATION	Mandalong
DRAWN	K.S
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23
Modification
Water Resources Impact Assessment

Locality Plan

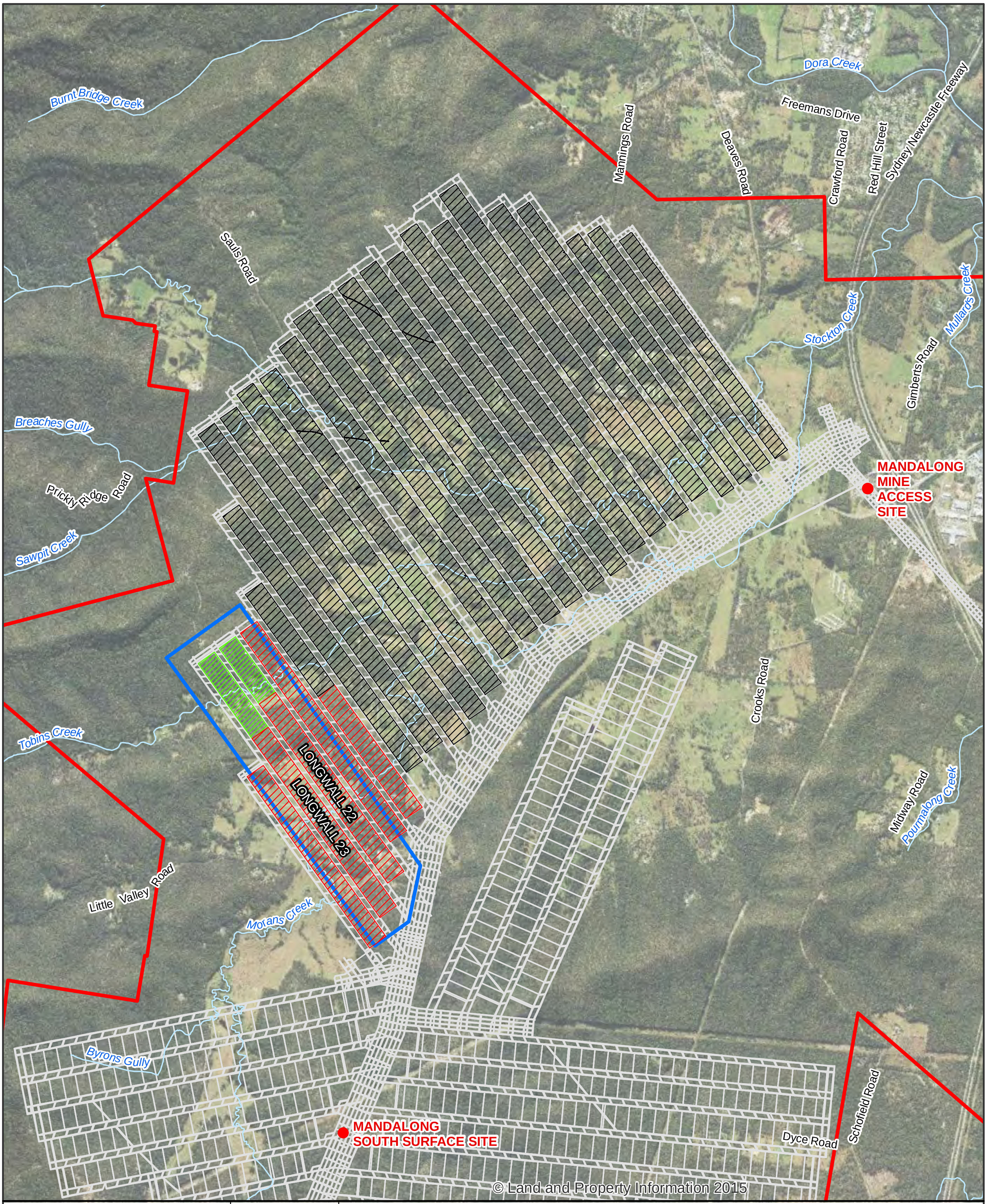
Centennial Coal
Mandalong

DATE 5/10/2016

Figure 1-1

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\WRIA\LW22_23_MOD\2218510_WRIA001_Locality_0.mxd

Data source: Commonwealth of Australia (Geoscience Australia): 250K Topographic Data Series 3, 2006; Centennial: Holdings Boundary, 2016. Created by: smacdonald, kpsroba



1:40,000 for A4

0 150 300 600 900 1,200

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

GHD

LEGEND

- Site location
- Proposed secondary extraction area
- Approved secondary extraction
- Existing extraction area
- Study area
- Project application area
- Approved Mine Workings
- Waterway

LOCATION	Mandalong
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

Mine Plan

Centennial Coal
Mandalong

DATE 5/10/2016

Figure 1-2

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\WRIA\LW22_23_MOD\2218510_WRIA002_MinePlan_0.mxd

Data source: LPI:DCDB/Imagery, 2012/2015. Centennial: Mine workings, Extraction area, consent boundary, 2016. Created by: smacdonald, kpsroba

1.4 Overview of site operations

The currently approved Mandalong Mine comprises the underground workings and surface infrastructure of the following:

- MMAS, encompassing underground workings and associated surface infrastructure near Morisset.
- Delivery of run of mine (ROM) coal from the underground workings to the Cooranbong Entry Site (CES). The CES coal handling and processing facilities are approved under the Northern Coal Logistic Project (SSD-5145).
- Delivery of ROM coal from the underground workings to the DES, located near Wyee at the Vales Point Rail Unloader Facility. The coal handling facility is approved under DA35-2-2004.
- MSSS, which is yet to be constructed, encompassing ventilation shafts, ventilation fans and underground delivery boreholes located approximately 6 km south-west of the MMAS.

1.5 Objectives of the Water Resources Impact Assessment

The primary objective of the WRIA is to determine the potential impacts of the Project on the surface and groundwater environments within the vicinity of the Project and the broader regional environment. The specific objectives of the WRIA and where these have been addressed are provided in Table 1-1. These are based on the water resources components of the Director General's Environment Assessment Requirements for the Mandalong Southern Extension Project (SSD-5144). In broad terms, this involves an assessment of surface and groundwater in terms of hydrology, hydrogeology, geomorphology, water quality and impacts on water users.

Table 1-1 Objectives of the Water Resources Impact Assessment

Element	Where addressed in this report
Detailed assessment of potential impacts on the quality and quantity of existing surface and groundwater resources, including: • Detailed modelling of potential groundwater impacts. • Impacts on riparian, ecological, geomorphological and hydrological values of watercourses, including environmental flows.	Section 4.2.2 Section 6
A detailed assessment of potential impacts of the Project on: • The quantity and quality or regional water supplies, and in particular the supply of water to the Gosford-Wyong Water Supply Scheme. • Regional water supply infrastructure. • Impacts on affected licensed water users and basic landholder rights.	Section 5.5 Section 6.4
A detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply infrastructure and water storage structures.	Section 4.3.1 Section 5.4.1 Section 6.3.1

Element	Where addressed in this report
An assessment of proposed water discharge quantities quality/ies against receiving water quality and, if relevant, flow objectives.	Section 6.3.4
Identification of any licensing requirements or other approvals under the *Water Act 1912* and/or *Water Management Act 2000* (WM Act).	Section 2.1.3 Section 6.3.1
Demonstration that water for the construction and operation of the development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant water sharing plan (WSP).	Section 2.1.3 Section 6.1
A description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo.	Section 2.1.3 Section 6.4
A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts.	Section 5.2 Section 6.1 Section 7
A detailed flood impact assessment, taking into consideration: • Predicted subsidence effects and identification of impacts on local and regional flood regimes. • Resultant impacts on agricultural land use, transport, services, habitability, public safety and other environmental consequences, including any measures proposed to mitigate potential flood impacts.	Umwelt (2016) Section 4.3.2 Section 5.4.2 Section 6.3.2

1.6 Scope of work

The scope of work for the WRIA includes:

- Review existing assessments and data relevant to the Project.
- Review relevant statutory requirements.
- Establish the existing conditions for groundwater and surface water systems.
- Identify components of the Project with the potential to impact groundwater and surface water environments.
- Undertake an assessment of the potential impacts of the Project on:
  – Groundwater levels and quality.
  – Water and salt balance.
  – Flooding.
  – Waterway geomorphology.
  – Surface water quality.
  – Downstream water users, including licensed water users and basic landholder rights.
- Develop measures to avoid, minimise and mitigate potential impacts of the Project and provide recommended management, monitoring and reporting requirements.

2. Legislation, policies and guidelines

2.1 Legislation

2.1.1 Environmental Planning and Assessment Act 1979

The EP&A Act, administered by the NSW Department of Planning and Environment, is the core legislation relating to planning and development activities in NSW and provides the statutory framework under which development proposals are assessed. The EP&A Act aims to encourage the proper management, development and conservation of resources, environmental protection and ecologically sustainable development.

The WRIA forms part of a SEE to support an application to modify SSD-5144 under Part 4, Division 7, Section 96(2) of the EP&A Act for the Project. The Minister for Planning (or delegate, such as the NSW Planning Assessment Commission) is the determining authority for the Project.

2.1.2 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (POEO Act) is administered by the NSW Environment Protection Authority (EPA), which is an independent statutory authority and the primary environmental regulator for NSW. The objectives of the POEO Act are to protect, restore and enhance the quality of the environment. Some of the mechanisms that can be applied under the POEO Act to achieve these objectives include programs to reduce pollution at the source and monitoring and reporting on environmental quality. The POEO Act regulates and requires licensing for environmental protection, including for waste generation and disposal and for water, air, land and noise pollution.

Under the POEO Act, an Environment Protection Licence (EPL) is required for premises at which a 'scheduled activity' is conducted. Schedule 1 of the POEO Act lists activities that are scheduled activities for the purpose of the act. Licence conditions relate to pollution prevention and monitoring and can control the air, noise, water and waste impacts of an activity.

Currently Mandalong Mine holds EPL 365 which covers coal mining to a scale of greater than 5 Mtpa and coal works to a scale of greater than 5 Mtpa. EPL 365 permits the discharge of surface water, mine water and runoff from the nearby CES via two licenced discharged points (LDPs – LDP001 and LDP002) into an unnamed drainage path that reports to Muddy Lake on the western side of Lake Macquarie. EPL 365 does not include any LDPs within the study area. No changes to this licence are proposed as part of the Project.

2.1.3 Water Management Act 2000

The *Water Act 1912* has historically been the main legislation for managing water resources in NSW, however is currently being progressively phased out and replaced by WSPs under the WM Act. Once a WSP commences, existing licences under the *Water Act 1912* are converted to water access licences (WALs) and to water supply works and use approvals under the WM Act.

The aim of the WM Act, which is administered by Department of Primary Industries – Water (DPIW), is to ensure that water resources are conserved and properly managed for sustainable use benefiting both present and future generations. It is also intended to provide formal means for the protection and enhancement of the environmental qualities of waterways and in-stream uses as well as to provide for protection of catchment conditions.

Water sharing plans

Fresh water sources throughout NSW are managed via WSPs under the WM Act. Provisions within WSPs provide water to support the ecological processes and environmental needs of groundwater dependent ecosystems (GDEs) and waterways. WSPs also regulate how the water available for extraction is shared between the environment, basic landholder rights, town water supplies and commercial uses. Key rules within the WSPs specify when licence holders can access water and how water can be traded.

The study area is covered by two WSPs made under Section 50 of the WM Act. Each WSP consists of several water sources that are regulated by a water extraction entitlement. The boundaries of the applicable groundwater and surface water WSPs are shown in Figure 2-1 and Figure 2-2 respectively.

<u>North Coast Fractured and Porous Rock Groundwater Sources</u>

The WSP for the North Coast Fractured and Porous Rock Groundwater Sources Water Sharing Plan (NCFPR WSP) commenced on 1 July 2016 and regulates the interception and extraction of groundwater from the fractured and porous rock aquifer within the WSP boundary.

Centennial Mandalong currently holds one WAL (WAL 39767) to extract up to 1,825 ML/year of flooded mine working water from the existing Cooranbong void. No changes to this licence are proposed as part of the Project.

<u>Hunter Unregulated and Alluvial Water Sources Water Sharing Plan</u>

The study area is located within the Hunter Unregulated and Alluvial Water Sources Water Sharing Plan (HUA WSP), which commenced in August 2009. The HUA WSP covers unregulated rivers and creeks and alluvial groundwater within the Hunter region. The HUA WSP includes four extraction management units which are further broken down into water sources. The area covered by the HUA WSP includes 39 surface water and alluvial groundwater sources.

Basic landholder rights

Under the WM Act, extraction of water for basic landholder rights is protected by allocating and prioritising water for basic landholder rights. There are three types of basic landholder rights in NSW under the WM Act:

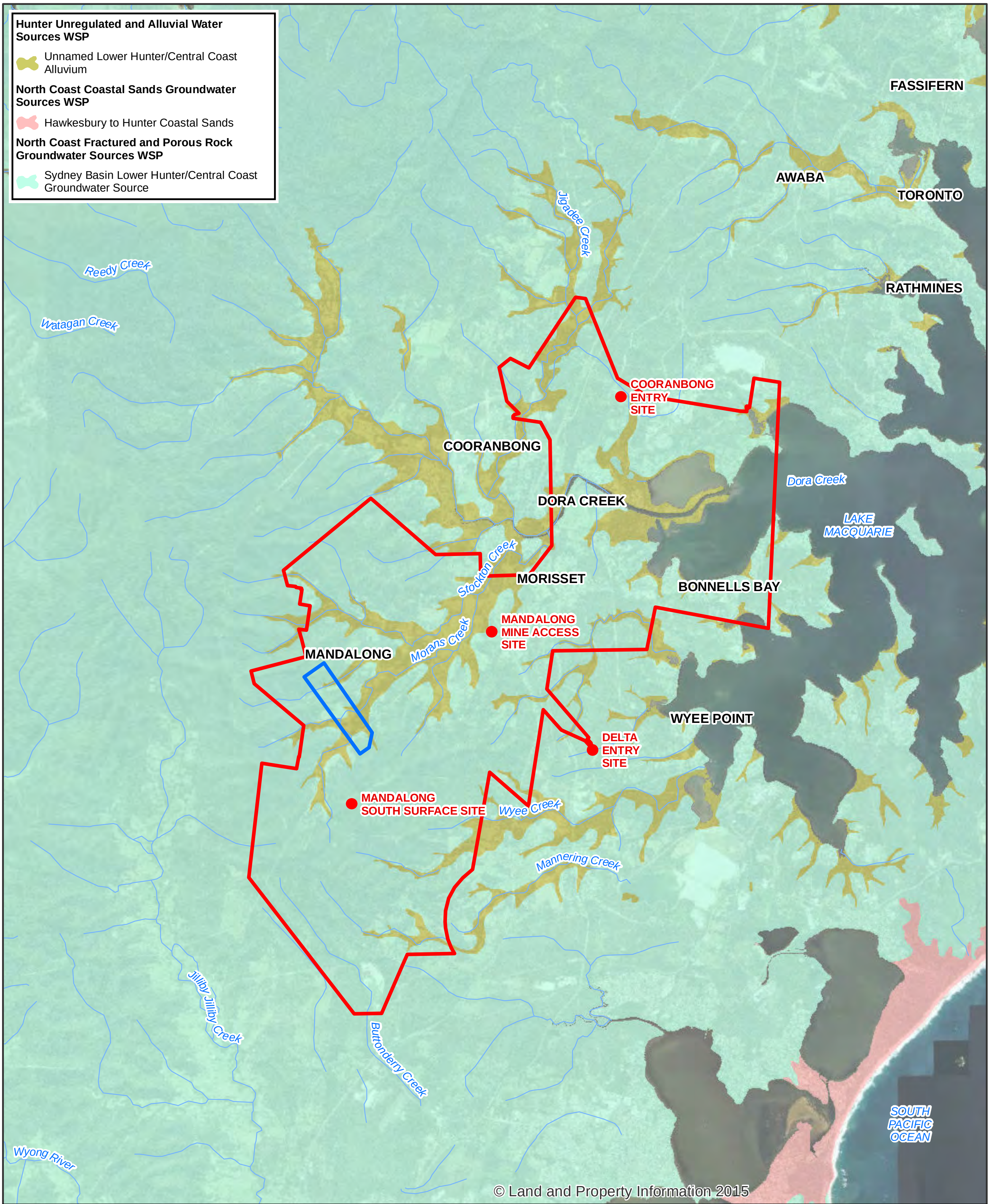
- Domestic and stock rights.
- Native title rights.
- Harvestable rights.

<u>Domestic and stock rights</u>

Landholders are entitled to take water from a river, estuary or lake which fronts their land or from an aquifer which is underlying their land for domestic consumption and stock watering, without the need for a licence. However, a water supply work approval is required to construct a dam or a groundwater bore.

<u>Native title rights</u>

Anyone who holds native title with respect to water, as determined by the *Native Title Act 1993*, can take and use water for a range of purposes, including personal, domestic and non-commercial communal purposes. There are no native title rights in the HUA WSP and therefore this type of basic landholder rights has not been considered in the WRIA.



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Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

LEGEND
- Site location
- Study area
- Project application area
- Watercourse

LOCATION	Mandalong
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

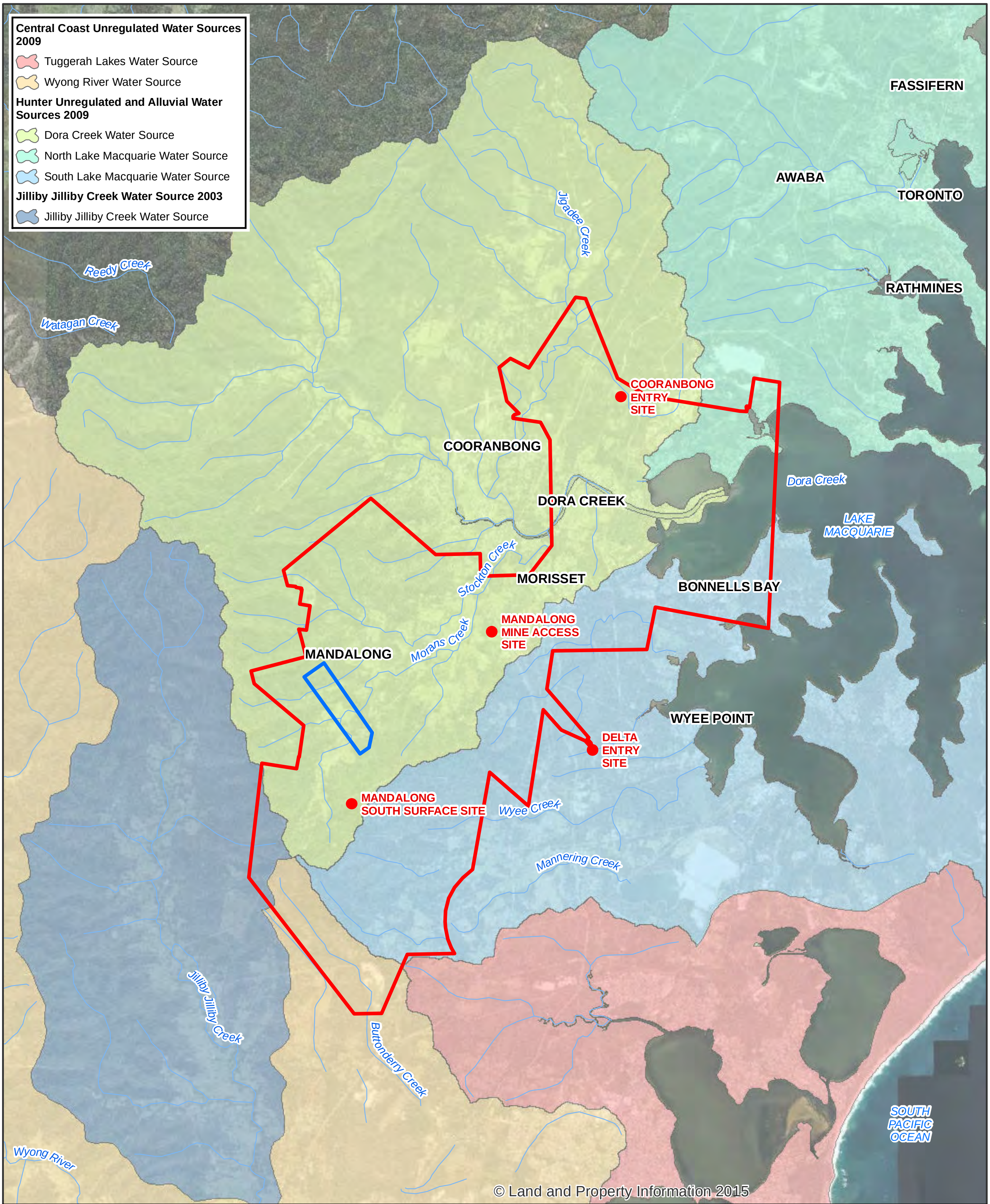
Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment
Water Sharing Boundaries - Groundwater

Centennial Coal
Mandalong

DATE 5/10/2016

Figure 2-1

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\WRIA\LW22_23_MOD\2218510_WRIA015_GW_SharingBoundaries_0.mxd
Data source: LP: Imagery, 2015. Commonwealth of Australia (Geoscience Australia): 250K Topographic Data Series 3, 2006. Centennial: Mine workings, Extraction area, consent boundary, 2016. OOW: Pinneena, WSP, 2012.
Created by: smacdonald, kpsroba



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0 625 1,250 2,500 3,750 5,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

LEGEND
- Site location
- Study area
- Project application area
- Watercourse

LOCATION	Mandalong
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment
Water Sharing Boundaries - Surface Water

Centennial Coal
Mandalong

DATE 5/10/2016

Figure 2-2

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\WRIA\LW22_23_MOD\2218510_WRIA016_SW_SharingBoundaries_0.mxd

Data source: LPI:DCDB/Imagery, 2012/2015. Centennial: Mine workings, Extraction area, consent boundary, 2016. OOW: Pinneena, WSP, 2012. Created by: smacdonald, kpsroba

Harvestable rights

Landholders are entitled to collect a portion of runoff from their property and store it in one or more dams up to a certain size, known as a ‘harvestable right’, which is determined from the total contiguous area of land ownership. In the Central and Eastern Divisions of NSW (where the Project is located), landholders may capture and use up to 10% of the average regional rainfall runoff for their property without requiring a licence under the WM Act. The maximum harvestable right is the total volume of rainfall runoff that a landholder is entitled to use without requiring a licence. If the maximum harvestable right for a site is exceeded, licensing for the volume of water extracted from the surface water source exceeding the harvestable right is required under the WM Act.

The guidelines for determining the maximum harvestable right dam capacity (MHRDC) indicate that the following dams are exempt from the calculation of the MHRDC and do not require a licence (NOW, 2010):

- Dams for the control or prevention of soil erosion.
- Dams for the capture, containment and recirculation of drainage.
- Dams without a catchment.

Exemption from requirement for access licence

As specified by Clause 31 of the *Water Management (General) Regulation 2011*, dams solely for the capture, containment and recirculation of drainage and/or effluent, consistent with best management practice to prevent the contamination of a water source, are considered to be ‘excluded works’ and are exempt from the requirement for water supply works approval. The use of water from such dams is also exempt from the requirement for a WAL under Clause 18 of the Regulation.

Water used in mining activities

An amendment to the WM Act (Section 60I) came into effect 1 March 2013. This amendment provides that a WAL is required to take, remove or divert water from a water source (whether or not water is returned to that water source) or to relocated water from one part of an aquifer to another part of an aquifer in the course of carrying out a mining activity. Various activities are captured by the amendment including mining, mineral exploration and petroleum exploration.

Activity approvals

Section 91 of the WM Act details activity approvals to be considered with regards to developments proposed within a WSP. The two activity approvals stipulated under Section 91, namely controlled activity approvals and aquifer interference approvals, will not be required for the Project.

Any works proposed within the defined riparian zone of a creek are to be carried out in accordance with the WM Act. Works undertaken on waterfront land (i.e. adjacent to a river, lake or estuary) require a controlled activity approval, unless defined as exempt. Controlled activity approvals are not required for projects that are defined as state significant developments. As such no controlled activity approvals will be required for any aspect of the Project. However, DPIW may be consulted in relation to proposed activities within existing riparian corridors, such as rehabilitation works following subsidence, which would provide a means of determining the suitability of engineering controls and general mitigation measures.

2.2 Policies

2.2.1 NSW Aquifer Interference Policy

The NSW Aquifer Interference Policy (DPI, 2012a) was finalised in September 2012 and clarifies the water licensing and approval requirements for aquifer interference activities in NSW, including the taking of water from an aquifer in the course of carrying out mining. Many aspects of this policy will be given legal effect through an Aquifer Interference Regulation. Stage 1 of the Aquifer Interference Regulation commenced on 30 June 2011.

The Policy outlines the water licensing requirements under the *Water Act 1912* and WM Act. A water licence is required whether water is taken for consumptive use or whether it is taken incidentally by the aquifer interference activity (such as groundwater filling a void), even where that water is not being used consumptively as part of the activity's operation. Under the WM Act, a water licence gives its holder a share of the total entitlement available for extraction from the groundwater source. The WAL must hold sufficient share component and water allocation to account for the take of water from the relevant water source at all times.

Sufficient access licences must be held to account for all water taken from a groundwater or surface water source as a result of an aquifer interference activity, both for the life of the activity and after the activity has ceased. Many mining operations continue to take water from groundwater sources after operations have ceased. This take of water continues until an aquifer system reaches equilibrium and must be licensed.

The NSW Aquifer Interference Policy requires that potential impacts on groundwater sources, including their users and GDEs, be assessed against minimal impact considerations, outlined in Table 1 of the Policy. If the predicted impacts are less than the Level 1 minimal impact considerations, then these impacts will be considered as acceptable. The Level 1 minimal impact considerations relevant to the Project are defined in Section 6.2.1.

2.2.2 NSW State Groundwater Policy

The objective of the NSW State Groundwater Policy Framework Document is to manage the State's groundwater resources so that they can sustain environmental, social and economic uses for the people of NSW. The NSW groundwater policy has three parts:

- NSW Groundwater Quantity Protection Policy.
- NSW Groundwater Quality Protection Policy.
- NSW Groundwater Dependent Ecosystems Policy.

NSW Groundwater Quantity Protection Policy

The principles of this policy include:

- Maintain total groundwater use within the sustainable yield of the aquifer from which it is withdrawn.
- Groundwater extraction shall be managed to prevent unacceptable local impacts.
- All groundwater extraction for water supply shall be licensed. Transfers of licensed entitlements shall be allowed depending on the physical constraints of the groundwater system.

NSW Groundwater Quality Protection Policy

The objective of this policy is the ecologically sustainable management of the State's groundwater resources so as to:

- Slow, halt or reverse any degradation in groundwater resources.
- Direct potentially polluting activities to the most appropriate geological setting so as to minimise the risk to groundwater.
- Establish a methodology for reviewing new developments with respect to their potential impact on water resources that will provide protection to the resource commensurate with both the threat that the development poses and the value of the resource.
- Establish triggers for the use of more advanced groundwater protection tools such as groundwater vulnerability maps or groundwater protection zones.

NSW Groundwater Dependent Ecosystems Policy

This policy was designed to protect 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.

2.3 Guidelines

2.3.1 Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales

The document *Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales* (DEC, 2004) provides the sampling and analysis methods to be used when acquiring water samples for compliance with environmental protection legislation, a relevant licence or relevant notice.

2.3.2 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The National Water Quality Management Strategy (NWQMS) provides a national framework for improving water quality in Australia's waterways. The main policy objective of the NWQMS is to achieve sustainable use of the nation's water resources, protecting and enhancing their quality, while maintaining economic and social development.

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000) is a benchmark document of the NWQMS which provides a guide for assessing and managing ambient water quality in a wide range of water resource types and according to specified environmental values, such as aquatic ecosystems, primary industries, recreation and drinking water. ANZECC (2000) provide a framework for determining appropriate guideline values or performance criteria to evaluate the results of water quality monitoring programs.

The ANZECC (2000) guidelines adopt a risk-based approach to assessing ambient water quality by providing the framework to tailor water quality guidelines to local environmental conditions. Guideline values provided by ANZECC (2000) can be modified into regional, local or site-specific guideline values (SSGVs) by taking into account factors such as the variability of the particular ecosystem, soil types, rainfall and level of exposure to contaminants. It should be noted that guideline values are applied to the receiving environment at the edge of the mixing zone and do not apply to mine water discharges.

2.3.3 Managing Urban Stormwater

Managing Urban Stormwater: Soils and Construction Volume 1 (The 'Blue Book'; Landcom, 2004) outlines the basic principles for the design, construction and implementation of sediment and erosion control measures to improve stormwater management and mitigate the impacts of land disturbance activities on soils and receiving waters.

This document relates particularly to urban development sites; however, it is relevant to the Project as it provides guidance on the configuration of erosion and sedimentation controls required during construction.

Additional guidelines on specific aspects of development and erosion and sediment control are also available. The relevant guidelines relating to the Blue Book are:

- *Managing Urban Stormwater: Soils and Construction – Volume 2E Mines and Quarries* (DECC, 2008) provides specific guidelines, principles and minimum design standards for good management practice in erosion and sediment control during the construction and operation of mines and quarries.
- *Managing Urban Stormwater: Source Control* (EPA, 1998) provides guidance to local and state government agencies and developers, as well as community and business groups, on a range of source control (water quantity and quality) techniques that can be adopted to minimise impacts of works on surface water environments.

2.3.4 Leading Practice Sustainable Development Program for the Mining Industry: Water Management

Leading Practice Sustainable Development Program for the Mining Industry: Water Management (DRET, 2008) provides a discussion of several matters relating to water management at mine sites. The topics discussed broadly include the drivers for needing to improve water management, features of management and reporting systems and the document discusses technical and community requirements for site water management. The Project has been developed to be consistent with this guideline document.

2.3.5 Controlled activities on waterfront land

As discussed in Section 2.1.3, works undertaken on water front land (i.e. near a river, lake or estuary) require a controlled activity approval, unless they are defined as exempt. DPIW has developed *Guidelines for Instream Works on Waterfront Land* (NOW, 2012a) and *Guidelines for Riparian Corridors on Waterfront Land* (NOW, 2012b), which provide recommendations for the design and construction of instream works and an indication of the width of riparian zones to be considered. The guidelines focus on the following key requirements:

- Maintaining the natural geomorphic processes through the accommodation of the existing waterway, allow for natural movement of sediment, woody debris and not allowing for an increase or the creation of scour and erosion within the existing waterway.
- Maintain the existing waterway's hydrologic function through accommodation of low flows and not altering the natural bank full or flood flows.
- The use of scour protection when required for the protection of existing banks, using placed rock.
- Visual inspections and maintenance on the waterway during the works.

2.3.6 Guidelines for Groundwater Protection in Australia

The *Guidelines for Groundwater Protection in Australia* (ANZECC, 1995) are part of the NWQMS. The objective of these guidelines is to provide a national framework for the protection of groundwater from contamination. The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000) are identified as a reference for identifying water quality criteria for developing a strategy for protecting groundwater and the aquatic ecosystem to meet a desired end point.

Protection of groundwater is generally easier when the source of contamination is concentrated at a point rather than spread over a broad area. Additionally, environmental protection measures have been developed to manage and minimise pollution from production of waste. These measures for protecting groundwater include waste avoidance, waste reuse, recycling and waste treatment.

Other groundwater protection strategies can include monitoring and review of performance of protection measures.

2.3.7 NSW Government Water Quality and River Flow Objectives

The *NSW Government Water Quality and River Flow Objectives* (DEC, 2006) are the agreed environmental values and long-term goals for NSW's surface waters. Water quality objectives have been agreed for fresh and estuarine surface waters and are consistent with the agreed national framework for assessing water quality set out in the ANZECC (2000) guidelines and uses these guidelines for strategic planning and assessing impacts of developments at a local level. From this assessment risks and threats to water quality can be identified and prioritised for management plans and on-ground investment to manage water quality ‘hot-spots’.

The river flow objectives are the agreed high-level goals for surface water flow management. They identify the key elements of the flow regime that protect river health and water quality for ecosystems and human uses.

The water quality objectives are consistent with and complementary to the state-wide targets developed by the Natural Resources Commission and Catchment Management Authorities for managing natural resources and to work towards long-term improvement goals. The *NSW Government Water Quality and River Flow Objectives* (DEC, 2006) refers stakeholders to booklet summarising the components in the ANZECC (2000) guidelines which is designed for technical practitioners applying the guidelines in NSW.

3. Site description

3.1 Topography

The terrain within the vicinity of the Project is characterised by the floodplains of Morans Creek and Tobins Creek and the bounding valley slopes and elevated ridgelines. Rural residential areas around the floodplain are bordered by densely timbered ridgelines. Elevations within the vicinity of the Project range from less than 30 m Australian Height Datum (AHD) along floodplains of drainage lines, to over 100 m AHD along the ridgelines.

3.2 Soils

Soil landscape mapping (Murphy, 1993) indicates that the soil types within the study area are typically sandy loams of moderate erodibility. Figure 3-1 presents the soil landscapes in the vicinity of the Project, with a summary of the soil types, typical terrain and erodibility provided in Table 3-1.

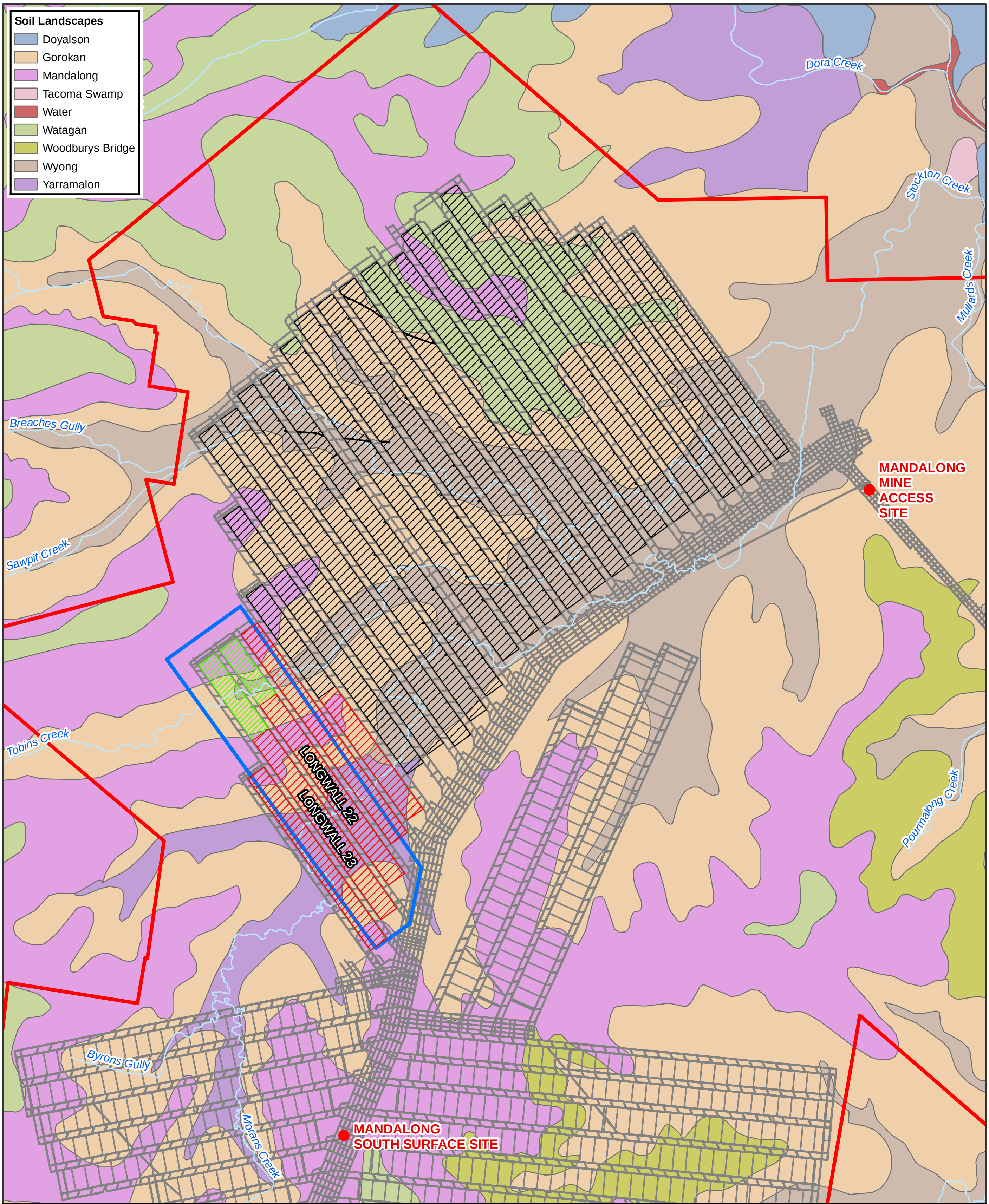
Table 3-1 Typical soils landscapes and erodibility (Murphy, 1993)

Soil landscape group	Landscape	Typical terrain of landscape	Dominant topsoil	Erodibility
Colluvial	Mandalong	Upper slopes	Hard setting stony brown sand clay loam	Very high
Erosional	Gorokan	Foot slopes	Fine sandy loam to a sandy clay loam	Very high erosion hazard*
Alluvial	Yarramalong	Floodplains	Loose brown sands	Moderate to high
			Brown pedal loam	Moderate
	Wyong	Floodplains	Yellow and brown duplex soils	Moderate

* Murphy (1993) indicates that the Gorokan landscape includes moderate erodibility, however the assessment undertaken by GSSE (2013) indicates very high erosion hazard in this soil landscape.

Areas of very high to extreme erodibility were identified within the Gorokan landscape. GSSE (2013) identified both the top soil and subsoil within the Gorokan landscape as being sodic (i.e. high in sodium) with a poor structure. As the soil profile deepens, the sodic nature increased (based on exchangeable sodium percentage) (GSSE, 2013).

The Gorokan landscape is typically located within the foot slope areas of the study area. These areas are typically cleared of taller vegetation (trees) as part of the rural land use of the Morans Creek floodplain areas. The clearing establishment of pasture within these areas typically results in an increase in the interaction between the groundwater and subsoil and topsoil layers. This increased groundwater interaction has the potential to increase the occurrence of tunnel erosion within the sodic soils of the Gorokan landscape. Other potential contributing factors to the occurrence of tunnel erosion include landowner activities and livestock.



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Metres

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Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

LEGEND
- Site location
- Proposed secondary extraction area
- Approved secondary extraction
- Existing extraction area
- Study area
- Approved Mine Workings
- Waterway
- Project application area

LOCATION	Mandalong
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

Soil Landscapes

Centennial Coal
Mandalong

DATE 5/10/2016

Figure 3-1

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\WRIA\LW22_23_MOD\2218510_WRIA004_SoilMapping_0.mxd

Data source: LPI:DCDB, 2012. Centennial: Mine workings, Extraction area, consent boundary, 2016. DECC: Soil Landscapes, 2008. Created by: smacdonald, kpsroba

3.3 Climate

3.3.1 Rainfall

Annual rainfall

Daily rainfall data was obtained from the Scientific Information for Land Owners (SILO) database operated by the Queensland Department of Science, Information Technology and Innovation. SILO patched point data is based on historical data from a particular Bureau of Meteorology (BOM) station with missing data 'patched in' with interpolations from nearby stations.

For this assessment, SILO data was obtained for Cooranbong (Avondale) Station (station number 61012), which is located approximately 3 km north of the MMAS. Figure 3-2 presents the historical SILO patched point daily rainfall data from the Cooranbong (Avondale) Station between 1889 and 2015.

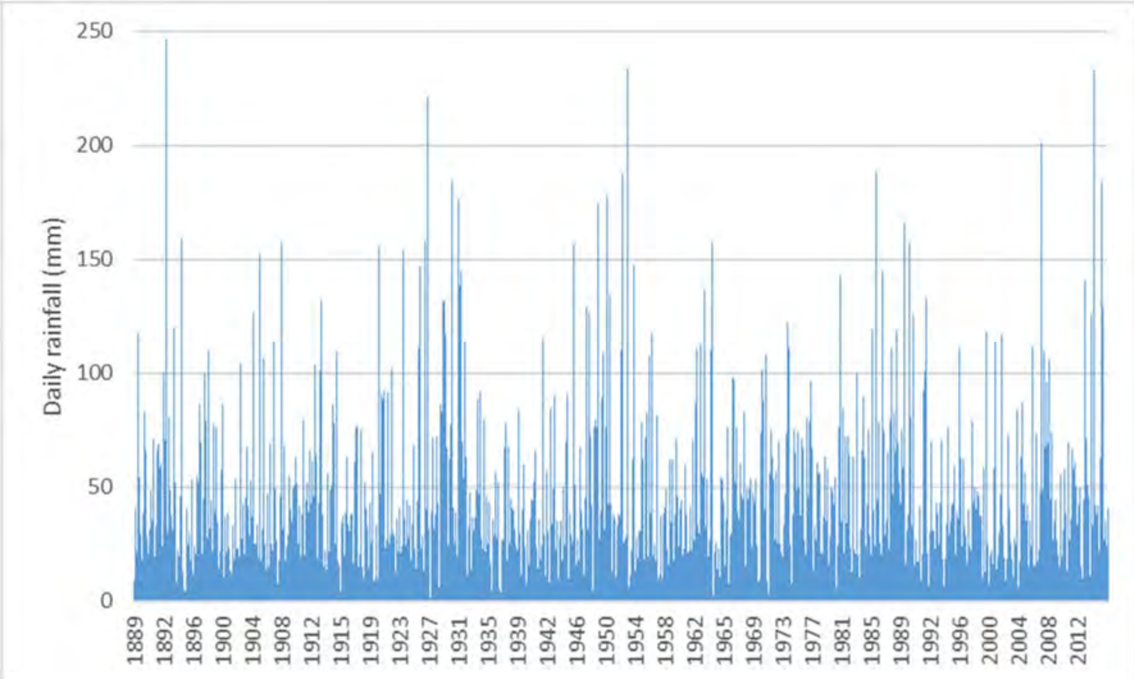


Figure 3-2 Historical daily rainfall at Cooranbong (Avondale) Station

The annual statistics associated with Figure 3-2 are:

- Minimum rainfall total – 531 mm in 1944.
- Average rainfall total – 1,124 mm.
- Median rainfall total – 1,076 mm.
- Maximum rainfall total – 2,040 mm in 1990.

Cumulative rainfall departure

The SILO patched point data from the Cooranbong (Avondale) Station was also used to generate a cumulative rainfall departure (CRD) curve, presented in Figure 3-3. A CRD curve is a monthly accumulation of the difference between the observed monthly rainfall and long-term average monthly rainfall. Any increase in the CRD curve reflects above average rainfall while a decrease in CRD curve reflects below average rainfall. The CRD curve only deviates from zero due to atypical (above and below average) rainfall.

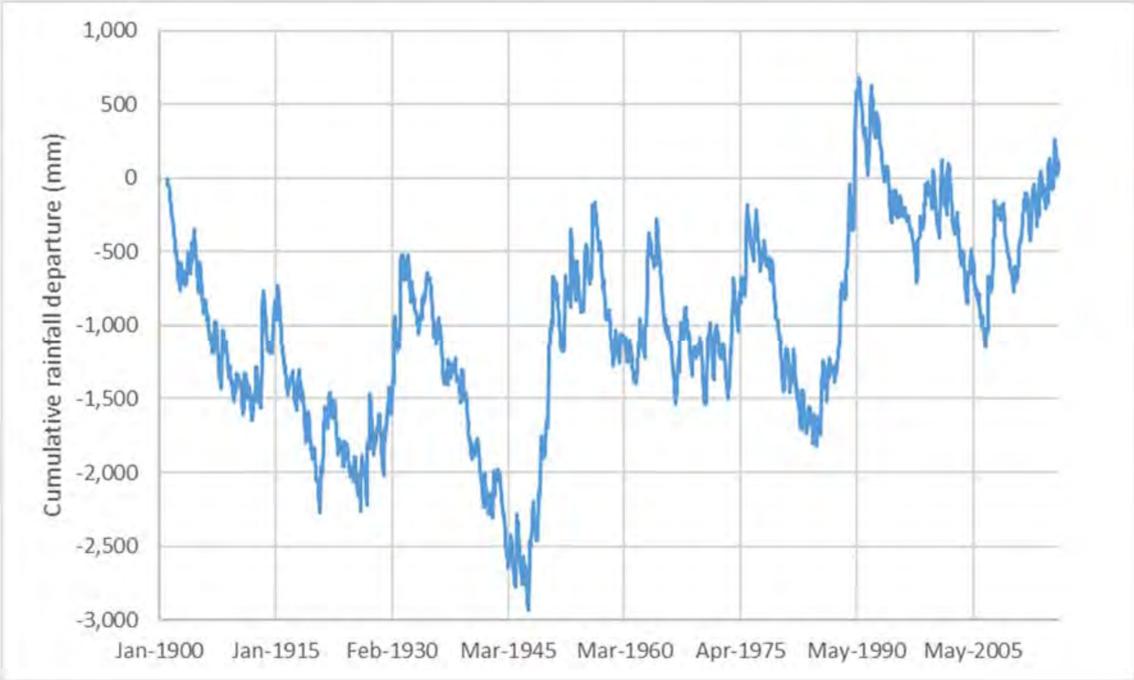


Figure 3-3 Cumulative rainfall departure curve

3.3.2 Evaporation

Information provided at the closest BOM station which records evaporation, Peats Ridge (Waratah Road) Station (station number 61351), was reviewed and average monthly evaporation rates were determined. The average daily evaporation is presented in Figure 3-4, based on 31 years of data from 1981 to 2012.

The total average annual evaporation is approximately 1,172 mm, compared to the annual average rainfall total of approximately 1,124 mm. This gives an annual deficit (difference between annual rainfall and annual evaporation) of approximately 48 mm.

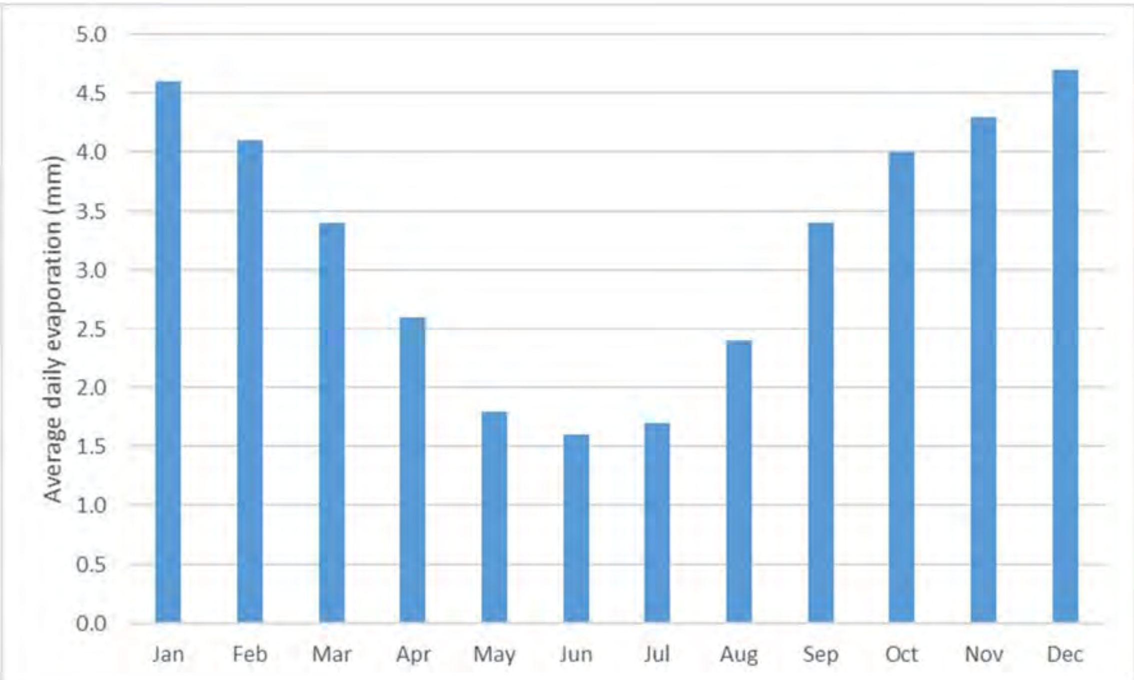


Figure 3-4 Average daily evaporation from Bathurst Agricultural Station

3.4 Geology

Mandalong Mine is located in the Newcastle Coalfield, which occupies the north-eastern portion of the Sydney Basin. The area in the vicinity of Mandalong Mine is underlain by Triassic claystone, sandstone and conglomerate, as well as Quaternary alluvial sediments along watercourses. The Triassic rocks are underlain by the Permian Newcastle Coal Measures, which regionally dips to the south at approximately 1 to 2 degrees.

The stratigraphy at Mandalong Mine is summarised in Table 3-2. This information has been sourced from the Newcastle Coalfields Regional Geology 1:100,000 map (DMR, 1995) and exploration logs for Mandalong Mine.

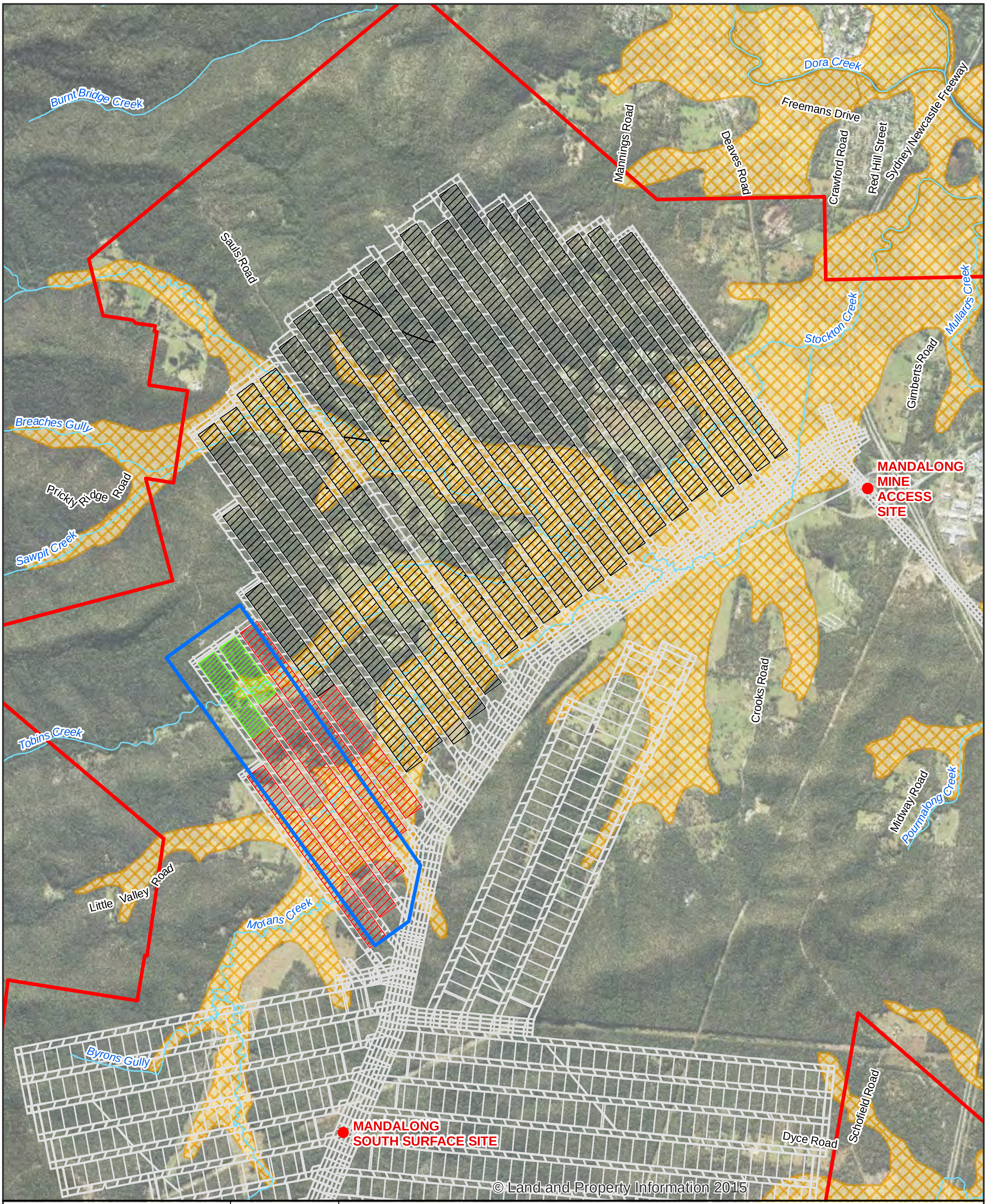
Table 3-2 Stratigraphic sequence

Period	Stratigraphy		Formation	Lithology
	Group	Subgroup		
Quaternary				Alluvium
Triassic	Narrabeen	Clifton	Patonga Claystone Tuggerah Formation Munmorah Conglomerate Dooralong Shale	Conglomerate, sandstone, siltstone, claystone
Permian	Newcastle Coal Measures	Moon Island Beach	West Wallarah Seam	Conglomerate, sandstone, siltstone, tuff, coal
		Awaba Tuff		Tuff

The approximate boundaries of the Quaternary alluvial sediments in the vicinity of Mandalong Mine are shown in Figure 3-5 and have been derived from the Soil Landscapes of the Newcastle 1:100,000 Sheet (Matthei, 1995) and the Soil Landscapes of the Gosford-Lake Macquarie 1:100,000 Sheet (Murphy, 1993).

The Newcastle Coal Measures are overlain by the Triassic Narrabeen Group. The Narrabeen Group comprises variable sequences of interbedded claystones, siltstones and fine to coarse grained sandstones. The Munmorah Conglomerate is a sandstone-dominated formation within the Narrabeen Group which typically occurs between 60 m and 140 m above the Newcastle Coal Measures (or a depth of approximately 40 m to 340 m below ground level (bgl)). The Munmorah Conglomerate at Mandalong Mine has been found to contain a thick pebbly sandstone/conglomerate layer which is geotechnically important in reducing surface subsidence impacts over longwall panels.

Depth of cover to the target seam (West Wallarah) ranges from approximately 250 m to 300 m in the vicinity of longwall panels 22 and 23. This is similar to the depth of cover above the existing Mandalong Mine workings (approximately 150 m to 350 m depth of cover above the existing Mandalong Mine workings and greater than the depth of cover above the Cooranbong workings (generally less than 100 m depth of cover above the Cooranbong workings). Depth of cover contours are shown in Figure 3-6.



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Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

GHD

LEGEND

- Site location
- Proposed secondary extraction area
- Study area
- Approved secondary extraction
- Existing extraction area
- Project application area
- Approved Mine Workings
- Alluvium
- Waterway

LOCATION	Mandalong
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

Location of Alluvium

Centennial Coal
Mandalong

DATE 5/10/2016

Figure 3-5

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\WRIA\LW22_23_MOD\2218510_WRIA010_Alluvium_0.mxd

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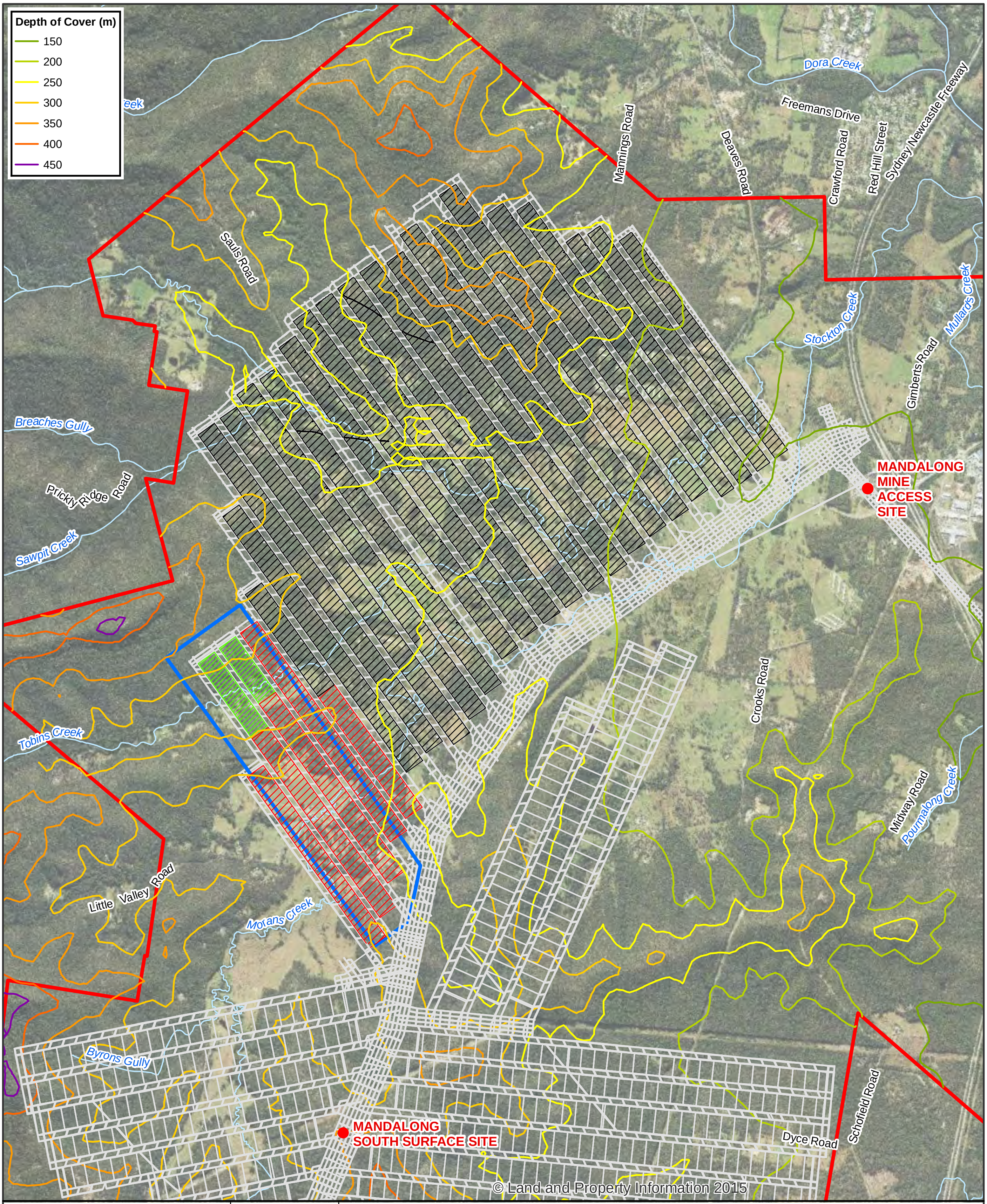

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Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
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GHD

LEGEND
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- Approved secondary extraction
- Existing extraction area
- Study area
- Project application area
- Approved Mine Workings
- Waterway

LOCATION	Mandalong
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

Depth of Cover Above Target Seam

Centennial Coal
Mandalong

DATE 5/10/2016

Figure 3-6

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\WRIA\LW22_23_MOD\2218510_WRIA011_DepthofCover_0.mxd

Data source: LPI:DCDB/Imgery, 2012/2015. Centennial: Mine workings, Extraction area, consent boundary, 2016. Created by: smacdonald, kpsroba

3.5 Hydrogeology

The groundwater sources in the Mandalong Mine area are generally low yielding and predominantly weathered and/or fractured sandstone, coal seams and clayey quaternary alluvium.

3.5.1 Alluvial groundwater sources

The alluvium throughout the study area forms an unconfined shallow aquifer with a water table typically ranging in depth from less than 1 m and up to about 3 m bgl and aquifer thickness less than 20 m. The alluvial water sources within the study area are covered under the HUA WSP.

3.5.2 Fractured and porous rock groundwater sources

Coal seam

The piezometric head within the Permian coal seams tends to reflect the natural topography and the orientation and dip of the seams, with reduced pressures at major surface drainage areas and in areas of coal extraction. Where coal seam groundwater has not been depressurised, the groundwater head generally tends to be in the order of 0 m AHD due to the coastal environment.

Permeability testing undertaken in 1996 and 1997 on the West Wallarah Seam and overburden strata in the existing Mandalong Mine area is reported in Pacific Power International (1997). Results indicate a variable hydraulic conductivity for the seam, ranging from 10^{-9} m/s to 10^{-5} m/s (0.03 m/year to 300 m/year). Areas of higher hydraulic conductivity coincide with areas where the coal is more intensively jointed or fractured, although the majority of the seam was generally found to be of lower hydraulic conductivity.

Recent permeability testing of the West Wallarah and Wallarah/Great Northern seams (at depths of 285 m to 300 m bgl) undertaken in 2011 as part of the Mandalong Southern Extension exploration program measured hydraulic conductivities ranging from approximately 0.75 m/year to 35 m/year (Sigra, 2011).

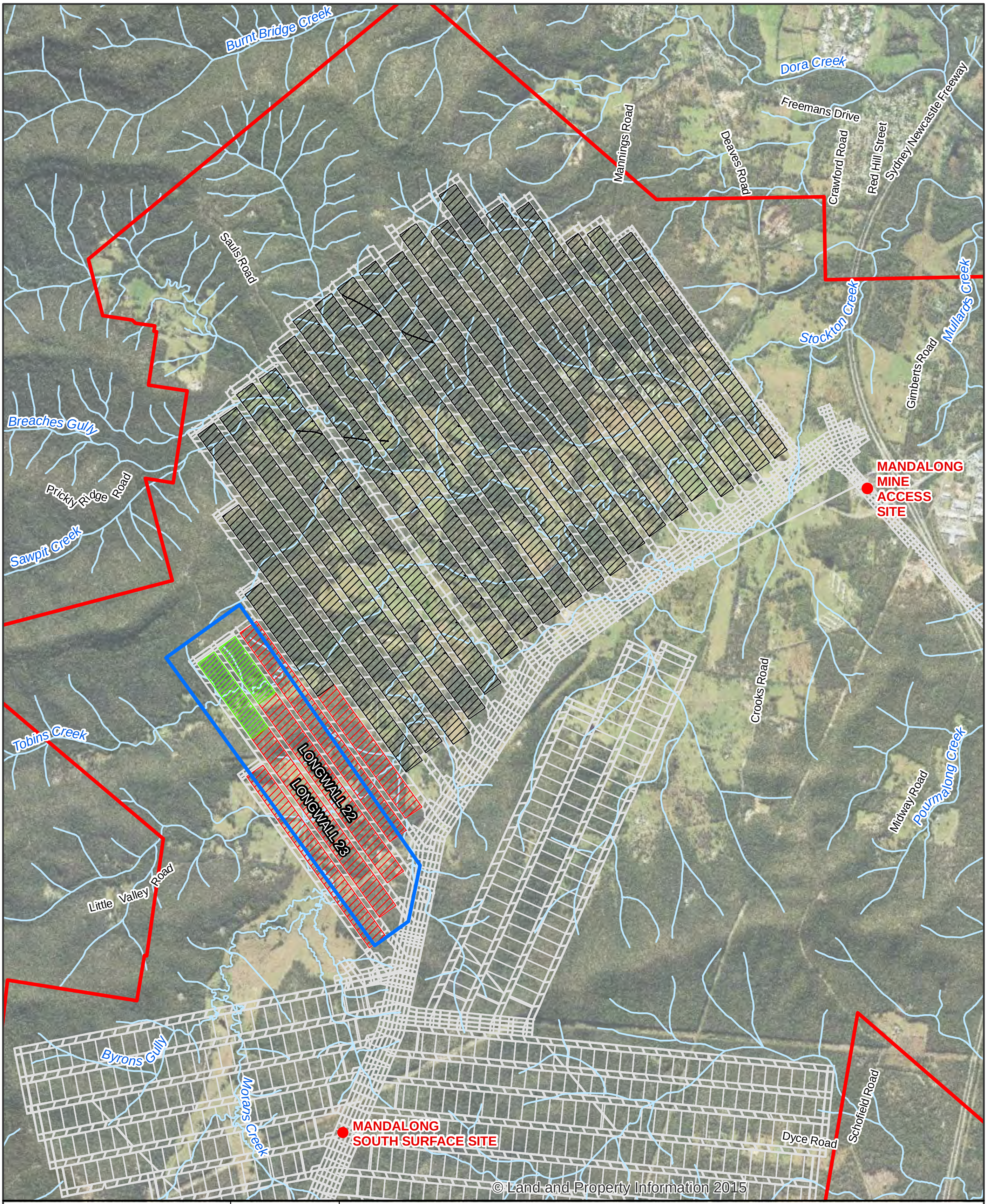
Groundwater inflows into the existing Cooranbong and Mandalong workings from the coal seam and adjacent strata are reported by Centennial Mandalong to be relatively low. Further details on the underground water management can be found in Section 5.1.1.

Overburden rock

The overburden and interseam strata within the Newcastle Coalfield tend to have very low hydraulic conductivities (in the order of 0.0003 m/year to 0.03 m/year), unless joints or fracturing creates a secondary permeability (Pacific Power International, 1997). Groundwater within the overburden rock above the West Wallarah Seam primarily occurs within weathered or fractured Triassic sandstone. There is generally a downward vertical hydraulic gradient within the Triassic and Permian strata that overlay the West Wallarah Seam.

3.6 Hydrology

The study area is located within the upper reaches of Morans Creek and Tobins Creek and includes several unnamed tributaries, as shown in Figure 3-7. Both Morans Creek and Tobins Creek are north-easterly flowing tributaries of Stockton Creek, which discharge into the estuarine reach of Dora Creek approximately 8 km north east of the study area. Both creeks are ephemeral, with periods of limited or no flow during low rainfall.



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0 150 300 600 900 1,200

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

GHD

LEGEND

- Site location
- Proposed secondary extraction area
- Study area
- Approved secondary extraction
- Existing extraction area
- Project application area
- Approved Mine Workings
- Waterway

LOCATION	Mandalong
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

Watercourses

Centennial Coal
Mandalong

DATE 5/10/2016

Figure 3-7

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\WRIA\LW22_23_MOD\2218510_WRIA009_Watercourse_0.mxd

Data source: LPI:DCDB/Imagery, 2012/2015. Centennial: Mine workings, Extraction area, consent boundary, 2016. Created by: smacdonald, kpsroba

4. Methodology

4.1 Potential impacts

The objective of the WRIA is to determine the potential impact of the Project on the groundwater and surface water environments. The identification of potential impacts will enable the development of measures to avoid or mitigate impacts or provide the framework of monitoring programs that may be required for the Project. The following potential impacts to groundwater and surface water systems were identified through review of the report objectives, adopted from the relevant DGRs for the Mandalong South Extension Project

- Changes to the local water cycle.
- Changes to regional catchment flows.
- Altered groundwater and surface water quality downstream of the Project.
- Altered availability of groundwater and surface water to downstream of the Project.

4.2 Groundwater environment

Potential groundwater impacts from the proposed extensions to longwalls 22 and 23 have been predicted by two methods:

- Review of groundwater quality and quantity data within the existing Mandalong Mine area to identify groundwater impacts from previous longwall development.
- Utilising the existing hydrogeological model developed for Mandalong Mine as part of the Mandalong Southern Extension Project (GHD, 2013a) and recalibrated as part of the Mandalong Tonnage Production Project (GHD, 2016a).

4.2.1 Review of existing data

Groundwater levels

Alluvial water sources

Groundwater hydrographs were plotted for each of the alluvium bores in and compared to the CRD curve for the rainfall dataset (as shown in Figure 3-3) to establish the relationship between groundwater levels and rainfall, and to identify whether natural or other anthropocentric factors have been influencing these groundwater levels.

Where possible, a statistical comparison was undertaken using HARTT (Hydrograph Analysis: Rainfall and Time Trends) statistical methodology, to reduce the uncertainty inherent with visual interpretation of the time series graphs. HARTT is an Excel based regression model developed by the West Australian Department of Agriculture and Food that involves establishing an underlying time trend in groundwater level by separating the effect of above and below average rainfall. In this way, the relationship between groundwater change and atypical rainfall is established and it is possible to identify whether other factors are influencing groundwater level. Where conventional linear regression trend analysis is carried out for groundwater hydrographs, it is not possible to determine to what degree trends are associated with rainfall or other factors.

The HARTT analysis is based on the following regression equation (Ferdowsian et al., 2000):

$$D = c + a\mathrm{CRD}_{t\text{-}L} + bt$$

Where D is the depth to groundwater in an unconfined aquifer, CRD is the Cumulative Rainfall Departure (mm), t is time (months), L is the time lag (months) between rainfall and its impact on groundwater, and *a*, *b* and *c* are constants estimated from the multiple regression analysis.

Constant *a* represents the effect of non-average rainfall on groundwater level in m/mm. The value of constant *a* cannot be negative, since this would imply that rainfall recharge results in a fall in groundwater level. Constant *b* is the underlying rate of groundwater change in m/month without the effect of rainfall. The constant *c* represents the steady state groundwater level with no rainfall effects and no time trends. The best fit regression line is the non-linear approximation of the observed hydrograph with the highest R^2 value.

The HARTT analysis also determines the statistical significance of the rainfall and time variables. A *p*-value of less than 0.05 suggests that there is a statistically significant relationship between the depth to groundwater and the variable.

Generally, when the constant *b* is negative and the *p*-value for time is less than 0.05, this suggests that there is a statistically significant decreasing trend in groundwater level that is independent of rainfall. To assess how mining may be related to this trend, it is necessary to investigate how trends vary spatially and over different time periods (i.e. pre- and post-mining).

Note that there are a number of limitations to the HARTT regression model:

- The model assumes that average monthly rainfall does not change over the analysis period (e.g. due to climate change) and that the rainfall dataset selected for the analysis is appropriate.
- The method is generally limited to shallow groundwater in unconfined aquifers.
- The model assumes linear time trends.

<u>Deep groundwater sources</u>

According to Ferdowsian et al. (2000), the HARTT method is generally limited to the analysis of relatively shallow groundwater from unconfined aquifers. Therefore, it was necessary to make a visual assessment of hydrographs from deeper bores in to identify potential impacts from longwall mining, which commenced in 2005.

Groundwater quality

Groundwater pH and electrical conductivity (EC) has been summarised to analyse the beneficial use category of the groundwater source. The environmental value or beneficial use category of the groundwater sources at Mandalong Mine is at best ‘primary industry’ (specifically stock watering) with most of the groundwater only suitable for stock watering. Based on ANZECC (2000) guidelines, the groundwater pH should be in the range 6 to 8.5 and the EC generally should not exceed approximately 3,000 µS/cm for poultry, 3,700 µS/cm for dairy cattle and about 6,000 µS/cm for horses.

4.2.2 Hydrogeological model

Hydrogeological modelling was undertaken to estimate groundwater seepage into the Mandalong Mine workings and determine groundwater drawdown associated with Mandalong Mine and the proposed workings. A hydrogeological model was previously developed for Mandalong Mine as part of the Mandalong Southern Extension Project (GHD, 2013a). The hydrogeological model developed for the Mandalong Southern Extension Project reflected the most likely schedule of mining at Mandalong Mine. The hydrogeological model was recalibrated for updated groundwater inflow estimates as part of the Mandalong Tonnage Production Project (GHD, 2016a).

As discussed by GHD (2016a), observed groundwater inflow was calculated by GHD (2014) for the period from June 2013 to May 2014 and by GHD (2015) for the period from May 2014 to June 2015. The observed groundwater inflow was calculated through a water budget for the underground Cooranbong storage. The observed groundwater inflow was lower than the groundwater inflow modelled as part of the approved Mandalong Southern Extension Project (GHD, 2013a). The hydrogeological model was recalibrated to observed groundwater inflows (GHD, 2016a). The recalibrated hydrogeological model was updated and re-run for this assessment to reflect the proposed extension to longwalls 22 and 23. As part of the Mandalong Tonnage Production Project the recalibrated hydrogeological model was run for a mining schedule that reflected mining at a constant rate of 6.5 Mtpa. An overview of the revisions of the hydrogeological model is provided in Table 4-1.

Table 4-1 Overview of hydrogeological modelling

Project	Calibration target	Mining schedule
Mandalong Southern Extension Project (GHD, 2013a)	Calculated groundwater inflow between December 2011 and June 2012 (GHD, 2013a)	Most likely schedule of mining defined by Centennial Mandalong
Mandalong Tonnage Production Project (GHD, 2016a)	Re-calibrated model to observed groundwater inflow calculated by GHD (2014) and GHD (2015)	Schedule that reflected mining at a constant rate of 6.5 Mtpa
Mandalong Longwall Panel 22 to 23 Modification	Utilised calibrated model from Mandalong Tonnage Production Project (GHD, 2016a)	Updated most likely schedule of mining defined by Centennial Mandalong

4.3 Surface water environment

4.3.1 Water and salt balance assessment

A water and salt balance assessment was undertaken to quantify the water and salt budgets, including inflows, outflows and net change in storage, in relation to the groundwater and surface water management systems for Mandalong Mine. A site water and salt balance was previously developed in GoldSim for the Mandalong Southern Extension Project (GHD, 2013b), which is revised on an annual basis to assist in the management and reporting of water use at the site (GHD, 2016b). This water and salt balance was also used to assess the Mandalong Tonnage Project (GHD, 2016a).

The water and salt balance model was updated to reflect the groundwater inflows into the underground workings predicted by hydrogeological modelling. The Project does not propose any changes to the surface water management at MMAS, MSSS or DES and as such, these elements have not been presented.

The water management system for Mandalong Mine was modelled for the projected life of the mine, from current conditions in 2016 to 2037. The model was created by representing the water and salt cycle as a series of elements, each containing pre-set rules and data, that were linked together to simulate the interaction of these elements within the water and salt cycle. The water and salt cycle was simulated over time in GoldSim and selected outputs from the modelled system were statistically summarised.

To assess the impact of rainfall on the site, modelling was completed by using a historical time series of daily rainfall data extending over 127 years, from January 1889 to December 2015 (refer Section 3.3.1). A total of 127 simulations were applied with each simulation modelling a different rainfall pattern.

The salt balance model was developed as an extension of the water balance model, with expected concentrations of salt applied to water inflows into the system. Transfers of the resulting salt loads were modelled throughout the site. The mass and concentration of salt within particular storages was established such that a mass balance was achieved after allowing for salt discharged via extraction and overflows.

4.3.2 Flood assessment

Umwelt (Australia) Pty Limited (Umwelt) has prepared a flood assessment (Umwelt, 2016) to determine the impact on the flooding regime in the Mandalong Valley as a result of underground mining of longwalls 22 and 23 at Mandalong Mine. The flood assessment also considers longwalls 1 to 21 to allow for consideration of the cumulative impacts of underground mining. The flood assessment completed by Umwelt (2016) is provided in Appendix A, with relevant results provided in Section 5.4.2 and 6.3.2.

4.3.3 Waterway geomorphology

Desktop assessment

A desktop assessment of existing information (GIS data and aerial imagery) was undertaken to identify and preliminarily map in GIS the waterway types (river style), geomorphic condition and stream order of waterways potentially impacted by the Project.

Stream ordering followed the Strahler stream classification system where waterways are given an 'order' according to the number of additional tributaries associated with each waterway (Strahler, 1952). Figure 4-1 indicates the Strahler stream ordering process for a generic catchment. Numbering begins at the top of a catchment with headwater ('new') flow paths being assigned the number one. Where two flow paths of order one join, the section downstream of the junction is referred to as a second order stream. Where two second order streams join, the waterway downstream of the junction is referred to as a third order stream, and so on. Where a lower order stream (e.g. first order) joins a higher order stream (e.g. third order), the area downstream of the junction will retain the higher stream order.

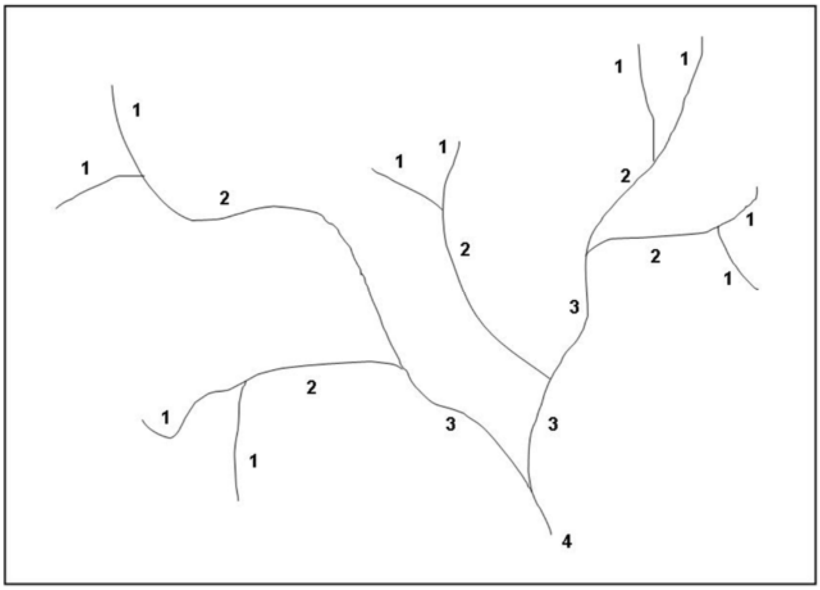


Figure 4-1 Stream order for a generic catchment using Strahler (1952) method

The assessment of stream physical form and function is broadly based on the methods and principles of the River Styles framework (Brierley and Fryirs, 2005). This is the primary framework used in NSW for the geomorphic characterisation of waterways.

Determination of stream types is largely based on the following parameters:

- Degree of valley confinement and bedrock influences.
- Presence and continuity of a channel.
- Channel planform (number of channels, sinuosity).
- Channel and floodplain geomorphic features.
- Nature of channel and floodplain sediments.

Site investigation

A site investigation was undertaken on 2 September 2016 to identify the current physical characteristics of the waterways potentially impacted by the Project. The investigation focused on assessing the higher Strahler order waterways. Information recorded during the field investigation included:

- Geomorphic type and condition of waterways.
- Nature, location and extent of existing waterway instabilities.
- Nature and location of waterway controls (e.g. bedrock, logs).
- Nature of channel and bedload materials.

General site data was recorded using a hand held GPS with other measurements being undertaken including valley widths and channel widths and depths during the site investigation. The inspection area is shown on Figure 4-2.

Condition assessment

The assessment of geomorphic condition was based on Outhet and Cook (2004) who describe a rapid method of condition assessment that frames geomorphic condition in the context of natural and human induced variability. The characteristics of each condition category are described in Table 4-2. These categories provide an indication of the degree of alteration a reach has experienced from its expected natural form.

Table 4-2 Geomorphic condition categories

Indicative geomorphic condition	Characteristics
Good	Geomorphic structure is largely unchanged from the pre-disturbance state such that only minor cases of localised instability occur. Relatively intact and effective vegetation coverage dominated by native species, giving resistance to natural disturbance and accelerated erosion. There is minimal alteration to catchment controls such as sediment supply and the hydrological regime allowing fast recovery from natural disturbance. There is also a high potential for ecological diversity.

Indicative geomorphic condition	Characteristics
Moderate	Geomorphic structure is moderately altered such that a reduced diversity of river features exists and floodplain connectivity is somewhat limited. Localised degradation of river character and behaviour, typically marked by modified patterns of geomorphic units. Patchy effective vegetation coverage allowing some localised accelerated erosion. The river has not fully adjusted to prevailing conditions and is experiencing ongoing changes.
Poor	Considerable geomorphic alteration to the functioning and structure of the system when compared with the pre-disturbance condition. Type, extent and rate of processes are radically altered. Floodplain connectivity may be significantly altered. Abnormal or accelerated geomorphic instability (reaches are prone to accelerated and/or inappropriate patterns or rates of planform change and/or bank and bed erosion). Excessively high volumes of sediment inputs which blanket the bed, reducing flow diversity. Absent or geomorphologically ineffective coverage by vegetation (allowing most locations to have accelerated rates of erosion).

4.3.4 Surface water quality

A surface water quality assessment was undertaken for the existing site conditions in order to establish baseline water quality for Morans Creek and Tobins Creek prior to proposed undermining. This water quality assessment has been undertaken in accordance with the assessment framework and methodologies outlined by ANZECC (2000).

Data requirements

ANZECC (2000) recommend that, for the purpose of deriving ambient concentrations and SSGVs, a sufficient amount of data needs to be collected and that it should characterise seasonal variations:

"A minimum of two years of continuous monthly data at the reference site is required before a valid trigger value can be established."

The datasets currently available for the Project span over two years of monthly monitoring results.

Guideline values

To characterise the existing waterway quality, threshold guideline values may be derived from:

- ANZECC (2000) default values (consistent with water quality objectives).
- Limits specified in relevant EPLs and development consents.
- SSGVs derived or recommended using site-specific water quality monitoring data.

- Local ecotoxicity testing.

ANZECC (2000) define guideline values as:

"…the concentrations (or loads) of the key performance indicators measured for the ecosystem, below which there exists a low risk that adverse biological (ecological) effects will occur. They indicate a risk of impact if exceeded and should 'trigger' some action, either further ecosystem specific investigations or implementation of management/remedial actions."

Water quality objectives

Environmental values associated with the waterways and water sources within the area surrounding the Project include primary industry, aquatic ecosystems, recreational users, irrigation and stock watering. In this assessment, the guideline values from the ANZECC (2000) guidelines for the protection of 95% of aquatic species have been used, as they are considered to be the most sensitive and, regardless of the current water quality present within the receiving environment, foster an improved water quality standard in the future.

Ecosystem condition

The ANZECC (2000; Section 3.1.3.1) guidelines recognise the following three categories of ecosystem condition, with a level of protection assigned to each:

- High conservation/ecological value systems.
- Slightly to moderately disturbed systems.
- Highly disturbed systems.

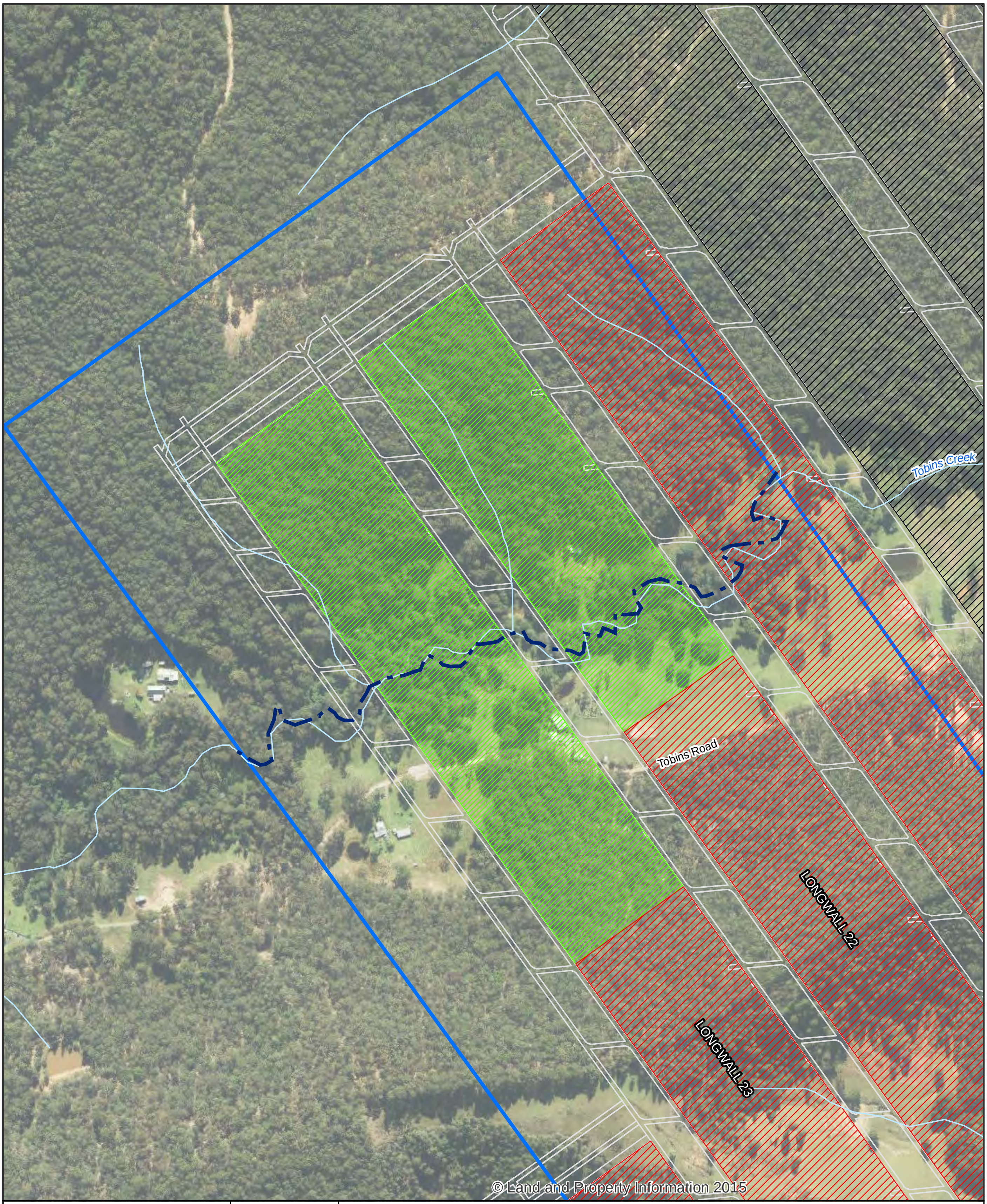
Morans Creek and Tobins Creek are considered to be a 'slightly to moderately disturbed' systems, as the waterways have been adversely affected by human activities by a small to measureable degree.

Reference site

Monitoring sites SWMP06 and SWMP07 on Morans Creek have been selected as the most appropriate reference site to provide background data to derive SSGVs. These sites are located upstream of the study area and are not measurably impacted by mining activities.

Default guideline values

Guideline values for many parameters are recommended by ANZECC (2000), which are usually derived from background assessments (physicochemical parameters and nutrients) and ecotoxicity studies (toxicants) and are not specific to the site studied. These guideline values should be considered as default guideline values (DGVs) and their suitability should be verified by establishing local background conditions. DGVs were selected from the ANZECC (2000) guidelines, with state derived guideline values preferred to regionally derived guideline values.



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Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

GHD

LEGEND

- Site location
- Proposed secondary extraction area
- Approved secondary extraction
- Existing extraction area
- Study area
- Project application area
- Approved Mine Workings
- Waterway
- Ground-truthed waterway centreline

LOCATION	Mandalong
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

Geomorphic Assessment

Centennial Coal
Mandalong

DATE 5/10/2016

Figure 4-2

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Data source: LPI:DCDB/Imagery, 2012/2015. Centennial: Mine workings, Extraction area, consent boundary, 2016. Created by: smacdonald, kpsroba

Within the ANZECC (2000) guidelines, Morans Creek falls into two different categories of ecosystem protection depending on the parameter reviewed, as identified in Table 4-3.

Table 4-3 ANZECC (2000) protection categories

Parameter	Category
Physicochemical parameters and nutrients	NSW lowland river (ANZECC, 2000; Table 8.2.2 to 8.2.12)
Metals and toxicants	Freshwater category (ANZECC, 2000; Table 3.4.1), with 95% species protection for slightly-moderately disturbed ecosystems

A list of the DGVs recommended by ANZECC (2000) to assess water quality in the absence of adequate reference site monitoring data is presented in Table 4-4.

Table 4-4 Default guideline values for assessment of water quality (ANZECC, 2000)

Parameter	Units	Guideline value	Comments
Physicochemical parameters			
EC	µS/cm	200	NSW coastal lowland river (Table 8.2.9).
pH	pH units	6.5–9.0	NSW lowland river (Table 8.2.8).
Total suspended solids (TSS)	mg/L	6	NSW coastal lowland river (Table 8.2.12).
Turbidity	NTU	6	NSW coastal lowland river (Table 8.2.11).
Nutrients			
Ammonia	mg/L	0.9	Freshwater guideline for 95% species protection (Table 3.4.1).
Total nitrogen	mg/L	0.35	NSW lowland river (Table 8.2.2).
Total phosphorus	mg/L	0.025	NSW lowland river (Table 8.2.3).
Dissolved metals			
Aluminium	mg/L	0.055	Freshwater guideline for 95% species protection (Table 3.4.1). Applies for pH>6.5.
Arsenic	mg/L	0.024	Freshwater guideline for 95% species protection for As(V) (Table 3.4.1).
Boron	mg/L	0.37	Freshwater guideline for 95% species protection (Table 3.4.1).
Cadmium	mg/L	0.0002	Freshwater guideline for 95% species protection (Table 3.4.1).

Parameter	Units	Guideline value	Comments
Chromium	mg/L	0.001	Freshwater guideline for 95% species protection (Table 3.4.1).
Cobalt	mg/L	0.0025	Environment Canada (2013).
Copper	mg/L	0.0014	Freshwater guideline for 95% species protection (Table 3.4.1).
Iron	mg/L	0.3	Canadian guideline as recommended by ANZECC (2000; Section 8.3.7.1).
Lead	mg/L	0.0034	Freshwater guideline for 95% species protection (Table 3.4.1).
Manganese	mg/L	1.9	Freshwater guideline for 95% species protection (Table 3.4.1).
Mercury	mg/L	0.0006	Freshwater guideline for 99% species protection (Table 3.4.1).
Nickel	mg/L	0.011	Freshwater guideline for 95% species protection (Table 3.4.1).
Selenium	mg/L	0.011 [1]	Freshwater guideline for 99% species protection (Table 3.4.1).
Silver	mg/L	0.00005	Freshwater guideline for 95% species protection (Table 3.4.1).
Zinc	mg/L	0.008	Freshwater guideline for 95% species protection (Table 3.4.1).
Other parameters			
Cyanide (total)	mg/L	0.004	Freshwater guideline for 95% species protection (Table 3.4.1).

1. Guideline value for total selenium.

Derivation of site-specific guideline values

SSGVs were derived on the basis of the methodology outlined by ANZECC (2000) by calculating the 80th percentile of data collected at the reference site (and 20th percentile for parameters reported as a range, for example pH). These values were then compared with the DGVs recommended by ANZECC (2000) as shown in Table 4-4.

Data below the limit of reporting

When the analytical result was below the limit of reporting (LOR) for a particular parameter, then the detection limit was included in the calculation. This is one of the approaches recommended by ANZECC (2000; Section 6.2.1). Table 4-5 identifies the LOR for each water quality parameter.

It is understood that this approach has limitations, in particular when over 25% of data is below the detection limit. Where greater than 25% of values for a parameter in the reference site dataset were below the LOR, the lowest detection limit reported for that dataset has been used in establishing the guideline values.

Table 4-5 Limit of reporting for water quality parameters

Parameter	Units	Limit of reporting
Physicochemical parameters		
EC	µS/cm	1
pH	pH units	0.1
Total dissolved solids (TDS)	mg/L	1
TSS	mg/L	5
Turbidity	NTU	1
Nutrients		
Ammonia	mg/L	0.01
Biochemical oxygen demand (BOD)	mg/L	2
Total Kjeldahl nitrogen (TKN)	mg/L	0.1
Total nitrogen	mg/L	0.1
Total phosphorus	mg/L	0.01
Anions		
Alkalinity (total)	mg/L	1
Chloride	mg/L	1
Sulfate	mg/L	1
Cations		
Calcium	mg/L	1
Magnesium	mg/L	1
Potassium	mg/L	1
Sodium	mg/L	1
Metals		
Aluminium	mg/L	0.01
Arsenic	mg/L	0.001
Barium	mg/L	0.001

Parameter	Units	Limit of reporting
Boron	mg/L	0.05
Cadmium	mg/L	0.0001
Chromium	mg/L	0.001
Cobalt	mg/L	0.001
Copper	mg/L	0.001
Iron	mg/L	0.05
Lead	mg/L	0.001
Manganese	mg/L	0.001
Mercury	mg/L	0.0001
Nickel	mg/L	0.001
Selenium	mg/L	0.01
Silver	mg/L	0.001
Zinc	mg/L	0.005
Other parameters		
Cyanide (total)	mg/L	0.004
Fluoride (total)	mg/L	0.1
Oil and grease	mg/L	2

4.4 Downstream water users

The potential impacts of the Project on downstream water users were assessed by identifying sensitive groundwater and surface water receptors within the potential area of impact. The potential area of impact was estimated conservatively based on the results of the assessments on groundwater level and quality, water and salt balance, flooding, waterway geomorphology and surface water quality.

Groundwater users were identified by searching the NSW groundwater bore database (DPIW, 2016a) for registered groundwater bores. Licensed surface water users and domestic and stock rights users with a water supply work approval were identified by searching for all lots within the potential area of impact in the *NSW Water Register* (DPIW, 2016b).

5. Existing conditions

5.1 Water management

5.1.1 Underground water management

Overview

The underground water management system receives water from the Mandalong, Cooranbong and Delta underground workings. This water is transferred to a goaf (the Cooranbong underground storage area) via a series of collection points and pumps from various working areas underground. The goaf has a large volume and provides a filtration and sediment settlement function prior to being pumped to the Borehole Dam at the CES.

The inputs to the underground water management system consist of the following:

- Groundwater seepage from the coal seam and adjacent strata.
- Supply of potable water to mining equipment within the Mandalong workings (approximately 0.7 ML/day) and subsequent transfer of dirty mine water to the Cooranbong underground storage area (approximately 0.4 ML/day to 0.7 ML/day).
- Transfer of surface water from Sediment Dams 1 and 2 at the CES (approximately 80 ML/year).
- Transfer of surface water from the 5 ML Dam at the CES (approximately 50 ML/year).
- Transfer of water from the Gross Pollutant Trap at the CES (also referred to as Coal Handling Plant Settlement Tank).

As shown in Figure 5-1, dirty water from the Mandalong workings is pumped at a rate of approximately 0.4 ML/day from the 69 cut through (c/t) area into the Cooranbong underground storage area. It is understood that some of the water within the Mandalong workings (originating from potable supply and groundwater seepage) remains within the longwall goaf areas.

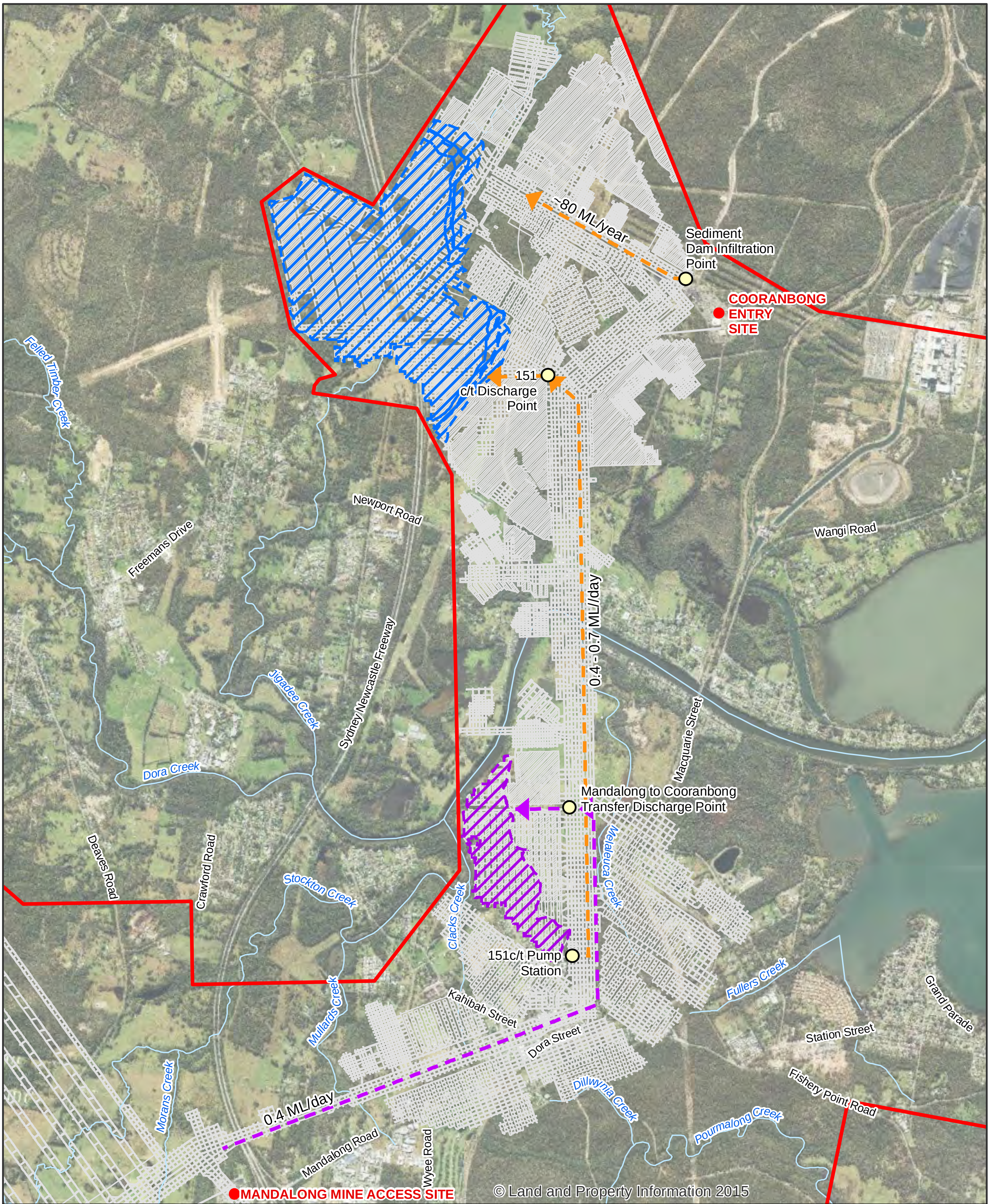
The water transferred from the Mandalong workings is first allowed to settle at the Cooranbong settlement area shown in Figure 5-1. This water is then pumped at a rate of approximately 0.4 ML/day to 0.7 ML/day from the 151 c/t pump station to the Cooranbong underground storage dam. A dewatering bore extracts water from this underground storage dam, which is transferred to the Borehole Dam at the CES.

Water that is transferred from the CES enters the Cooranbong underground storage area via a series of passive infiltration bores. The location of this transfer point is shown in Figure 5-1. This water then drains under gravity to the Cooranbong underground storage dam.

Underground water levels

Water levels in the Cooranbong underground storage area have been monitored by Centennial Mandalong since December 2011. The measured water levels (corrected to AHD) between December 2011 and June 2016 are shown in Figure 5-2. The following observations have been made over this period:

- For the period prior to March 2013, the average rate of dewatering of the Cooranbong underground storage dam was 1.5 ML/day and the water level rose by approximately 5 m over this period.



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Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
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LEGEND
- Site location
- Project application area
- Approved Mine Workings
- Waterway
- Cooranbong Transfer Locations
- Cooranbong Goaf
- Cooranbong Settling Area
- Mandalong Mine Dirty Water Pump Transfer
- Water Transfer

LOCATION	Mandalong
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment
Current Cooranbong Underground Water Management

Centennial Coal
Mandalong

DATE 5/10/2016

Figure 5-1

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\WRIA\LW22_23_MOD\2218510_WRIA014_CooranbongUnderground_0.mxd

Data source: LPI:DCDB/Imagery, 2012/2015. Centennial: Mine workings, Extraction area, consent boundary, 2016. Created by: smacdonald, kpsroba

- Over the period March to August 2013, the underground water level rose by a further 4 m since the pump was not in operation for most of this time.
- Between mid-August 2013 and February 2014, the average extraction rate was approximately 2.6 ML/day and the water level reduced by 6 m.
- Between February and September 2014, there was no extraction of water from the Cooranbong underground storage and the water level rose by approximately 11 m.
- Between October 2014 and January 2015, the average extraction rate was approximately 1.9 ML/day and the water level reduced by 1 m.
- Between January and March 2015 there was no pumping for most of this time and the water level rose 2 m.
- Between March and May 2015, the average extraction rate was approximately 2 ML/day and the water level dropped 0.15 m.
- Between June 2015 and November 2015, the average extraction rate was 3.0 ML/day and the water level reduced by 8.83 m.
- During December 2015 and January 2016, the average extraction rate was 2.7 ML/day and the water level reduced by 0.22 m.
- Between February 2016 and May 2016, the average extraction rate was 1.6 ML/day and the water level rose 1.6 m. This included a period where pumping ceased between April to May 2016 for LDP001 upgrade at CES.
- During June 2016, the average extraction rate was 3.3 ML/day and the water level reduced by 1.12 m.

Based on an assessment of the floor contours of the Cooranbong workings, the underground water storage area has a capacity of approximately 4,200 ML (assuming void height of 3 m and void ratio of 0.4). Once the underground water storage reaches full capacity, the water spills to the south back towards the active Mandalong workings.

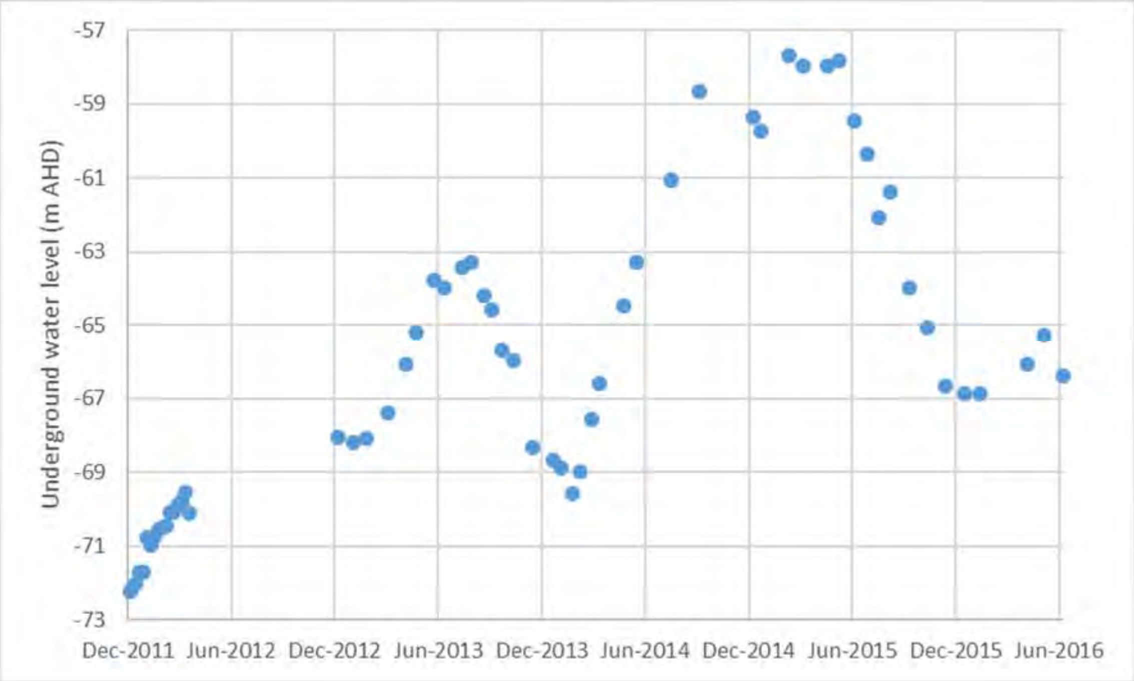


Figure 5-2 Recorded Cooranbong underground storage water levels

5.1.2 Surface water management

Overview

Sources of water at the Mandalong Mine surface sites include potable water supply, rainfall, runoff and groundwater inflow into the underground mine workings. The primary water demands are for underground operations, machinery washdown, fire-fighting storage and staff amenities.

Surface water runoff from areas where there is no coal storage, transportation, handling or processing or any disturbance is considered to be clean water, as it is unlikely to be contaminated with coal fines or sediment. Runoff is diverted around dirty water and coal-contact catchments to avoid mixing with clean water runoff. Clean water runoff is typically from natural and impervious catchments such as areas of vegetation, sealed roads and sealed carparks.

Dirty water is runoff from disturbed areas and areas likely to contain suspended sediment, oils, grease and hydrocarbons. This typically includes workshop and fuel storage areas. Coal-contact water is runoff from catchments where coal storage, transportation, handling or processing occurs and is managed within the dirty water management systems.

Mandalong Mine has site-specific water management objectives that include:

- Maximise the separation of clean and dirty surface water systems.
- Manage water discharge from the sites, in terms of volume and quality, to a level that is acceptable for environmental management and community expectations.
- Minimise water discharges from the premises by maximising, where practicable, opportunities for the reuse and recycling of water on site.
- Manage discharge to natural waterways in accordance with the relevant EPL conditions or as agreed with the EPA.

Mine water management

The Cooranbong dewatering bore extracts water from the Cooranbong underground storage area. The extracted water is transferred by overland pipe to the CES to the east and discharges into the Borehole Dam before discharging through LDP001 at CES. It should be noted that the Borehole Dam located upslope of the main CES is considered to be part of Mandalong Mine.

The approved extraction volume of 1,825 ML/year for the Cooranbong dewatering bore (WAL 39767) enables Mandalong Mine to sustainably manage the accumulation of water in the underground workings and align discharge volumes with LDP001 at CES which has a volumetric limit of 5 ML/day.

LDP001 at CES is located at the end of the discharge pipeline adjacent to an unnamed tributary of Muddy Lake. The pipeline receives mine water from the Borehole Dam and surface water from sediment dams at CES.

Potable water

Potable water is provided via connections to Hunter Water Corporation’s reticulated potable water supply system. From the surface, potable water is transferred underground, where it is used for process water.

5.2 Monitoring network

5.2.1 Groundwater monitoring network

A groundwater monitoring network has been progressively established at Mandalong Mine since 1997 and consists of mostly standpipe monitoring bores installed in alluvial and fractured and porous rock groundwater sources, as well as a series of five vibrating wire piezometers (VWP) installed in an exploration hole in the Mandalong South area. The bores and VWPs are monitored monthly for groundwater levels and quality (pH and EC) while some bores contain water level loggers for continuous monitoring of groundwater levels. There are currently no accessible private landholder bores within the monitoring program.

The locations of groundwater monitoring bores at Mandalong Mine are shown in Figure 5-3. Details of the groundwater bores are summarised in . As indicated in , there are some bores that are now dry or blocked, monitoring has ceased or the bore has been decommissioned.

Table 5-1 Groundwater monitoring bore details

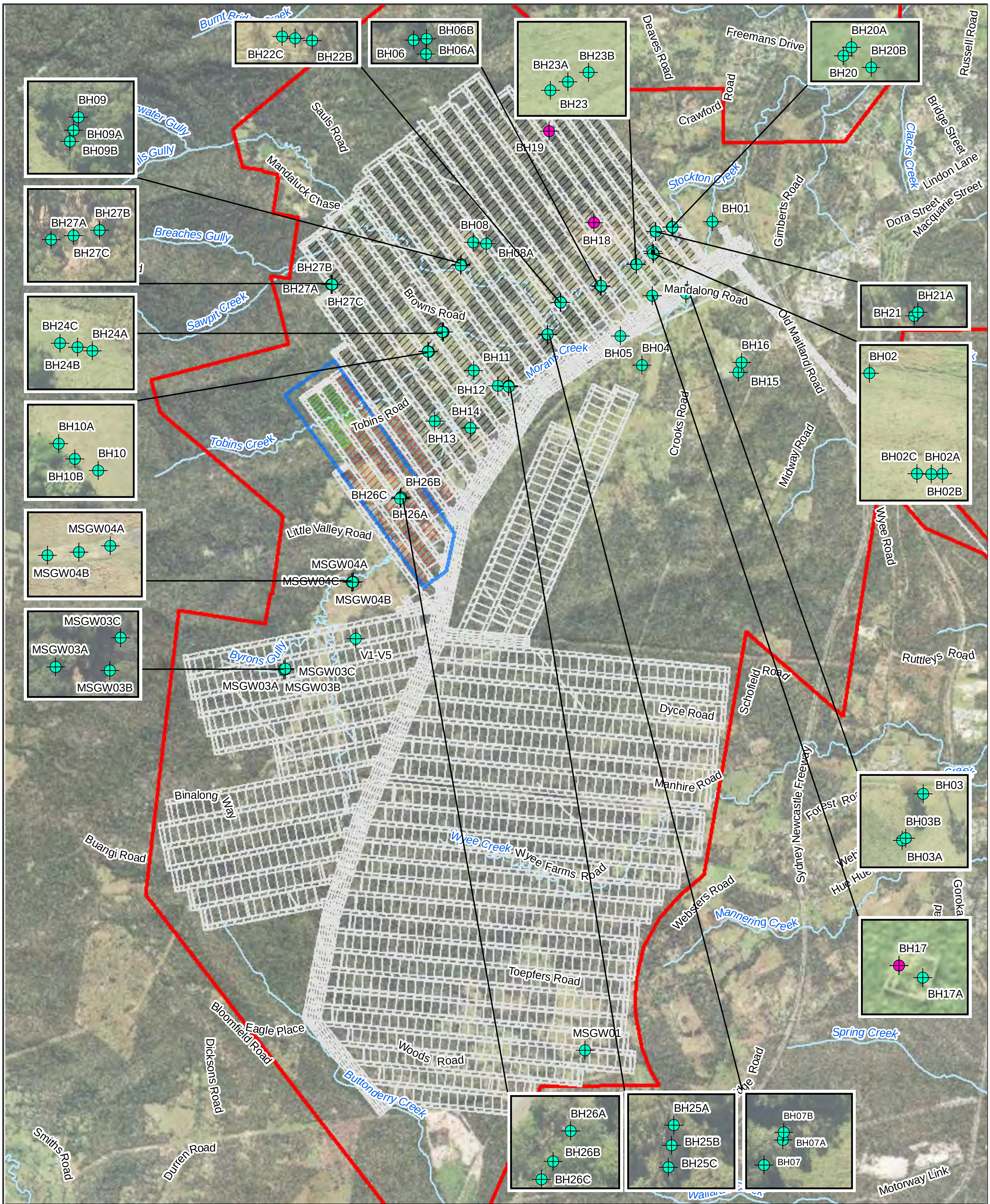
Bore	Monitoring period	Lithology	Longwall area
BH01	Aug 1997 – present	Alluvium	–
BH02	Aug 1997 – present	Alluvium	LW3
BH02A	Oct 2005 – present [1]	Sandstone	LW3
BH02B	Dec 2005 – present [1]	Alluvium	LW3
BH02C	Dec 2005 – present [1]	Alluvium	LW3
BH03	Aug 1997 – present	Alluvium	–
BH03A	Nov 2005 – present	Alluvium	–
BH03B	Dec 2005 – present	Sandstone	–
BH04	Aug 1997 – present	Alluvium	–
BH05	Aug 1997 – present	Alluvium	–
BH06	Aug 1997 – present [1]	Alluvium	LW7
BH06A	Nov 2005 – present [1]	Sandstone	LW7
BH06B	Dec 2005 – May 2009 [1] (dry since June 2009)	Sandstone	LW7
BH07	Aug 1997 – present [1]	Alluvium	LW10/11
BH07A	Dec 2005 – present [1] (bore blocked)	Conglomerate	LW10/11
BH07B	Jan 2006 – present [1]	Siltstone	LW10/11
BH08	Aug 1997 – present [1]	Alluvium	LW11
BH08A	No data – blocked [1]	Sandstone	LW11

Bore	Monitoring period	Lithology	Longwall area
BH09	Aug 1997 – present	Alluvium	LW12
BH09A	Jun 2010 – present	Mudstone/sandstone	LW12
BH09B	July 2010 – present	Mudstone/sandstone	LW12
BH10	Aug 1997 – present	Alluvium	LW16
BH10A	Jun 2010 – present	Mudstone/sandstone	LW16
BH10B	Jun 2010 – present	Sandstone	LW16
BH11	Aug 1997 – present	Alluvium	LW15
BH12	Aug 1997 – present	Alluvium	LW14/15
BH13	Aug 1997 – present	Alluvium	LW18
BH14	Aug 1997 – present	Alluvium	LW17
BH15	Sep 2003 – February 2015 (bore blocked since Oct 2013)	Fassifern Seam	–
BH16	No data – dry	Great Northern Seam	–
BH17	Apr 2003 – Apr 2008 (now decommissioned)	Conglomerate	LW5
BH17A	Oct 2005 – present [1]	Alluvium	LW5
BH18	Apr 2003 – Oct 2007 (now decommissioned)	Conglomerate	LW5
BH19	Apr 2003 – Nov 2006 (now decommissioned)	Conglomerate	LW4
BH20	Dec 2003 – present [1]	Conglomerate	LW1
BH20A	Dec 2003 – present [1]	Alluvium	LW1
BH20B	Oct 2004 – present [1]	Siltstone	LW1
BH21	Dec 2003 – present [1]	Conglomerate	LW2
BH21A	Dec 2003 – present [1]	Alluvium	LW2
BH22A	Dec 2005 – present [1]	Alluvium	LW9
BH22B	Dec 2005 – present [1]	Sandstone	LW9
BH22C	Dec 2005 – Oct 2008 [1] (now blocked)	Conglomerate	LW9
BH23	Jan 2006 – present [1]	Conglomerate	LW4/5
BH23A	Jan 2006 – present [1]	Mudstone	LW4/5

Bore	Monitoring period	Lithology	Longwall area
BH23B	Jan 2006 – present [1]	Alluvium	LW4/5
BH24A	Jun 2010 – present	Alluvium	LW15
BH24B	Jun 2010 – present	Sandstone	LW15
BH24C	Jun 2010 – present	Mudstone/sandstone	LW15
BH25A	Jun 2010 – present	Alluvium	LW14
BH25B	Jun 2010 – present	Sandstone	LW14
BH25C	Jun 2010 – present	Mudstone/sandstone	LW14
BH26A	Oct 2011 – present	Alluvium	LW22
BH26B	Oct 2011 – present	Sandstone	LW22
BH26C	Oct 2011 – present	Conglomerate	LW22
BH27A	Oct 2011 – present	Alluvium	LW18/19
BH27B	Oct 2011 – present	Sandstone	LW18/19
BH27C	Oct 2011 – present	Conglomerate	LW18/19
MSGW01	September 2011 – present	Mannering Creek alluvium	–
MSGW03A	September 2011 – present	Morans Creek alluvium	–
MSGW03B	September 2011 – present	Sandstone (Tuggerah)	–
MSGW03C	September 2011 – present	Conglomerate (Munmorah)	–
MSGW04A	September 2011 – present	Morans Creek alluvium	–
MSGW04B	September 2011 – present	Sandstone (Tuggerah)	–
MSGW04C	September 2011 – present	Conglomerate (Munmorah)	–
V1	October 2011 – present	West Wallarah Seam	–
V2	October 2011 – present	West Wallarah Seam	–
V3	October 2011 – present	Shale (Dooralong)	–
V4	October 2011 – present	Conglomerate (Munmorah)	–
V5	October 2011 – present	Conglomerate (Munmorah)	–

1. Monitoring to cease pending approval from DPIW.

Note: V1 – V5 are VWPs.



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Meters

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

LEGEND

- Groundwater Monitoring Bore
- Decomissioned Groundwater Monitoring Bore
- Approved Mine Workings
- Proposed secondary extraction area
- Approved secondary extraction
- Existing extraction area
- Project application area
- Study area
- Waterway

LOCATION	Mandalong
SEAM	West Wallarah
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

Groundwater Monitoring Bore Locations

Centennial Coal Mandalong

DATE 5/10/2016

Figure 5-3

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5.2.2 Surface water monitoring network

Surface water quality

Sporadic surface water quality monitoring commenced at the Mandalong Mine in 1996. A formal surface water quality monitoring program commenced in 1999, with monthly and quarterly surface water quality monitoring occurring at ten locations. Five of these locations are located within the Stockton Creek catchment area and cover the upper, mid and lower reaches of Stockton Creek; the convergence of Stockton Creek and Morans Creek; and downstream of the convergence prior to discharging into Dora Creek.

Surface water quality monitoring has been undertaken on Morans Creek since 2011 at SWMP06 and SWMP07, located upstream of the study area, as shown in Figure 5-4.

Flow monitoring

There exists two public watercourse stream gauges located on Jilliby Creek (ID 211010) and Wyee Creek (ID 211001). Both are not continuously monitored sites and the data is considered to be unreliable. Centennial Mandalong installed a flow and level gauge on Morans Creek in 2006 and recorded data up until 2009. The gauge is located approximately 4.8 km downstream of longwalls 22 to 23, as shown in Figure 5-4.

5.3 Groundwater environment

5.3.1 Review of existing data

Groundwater levels

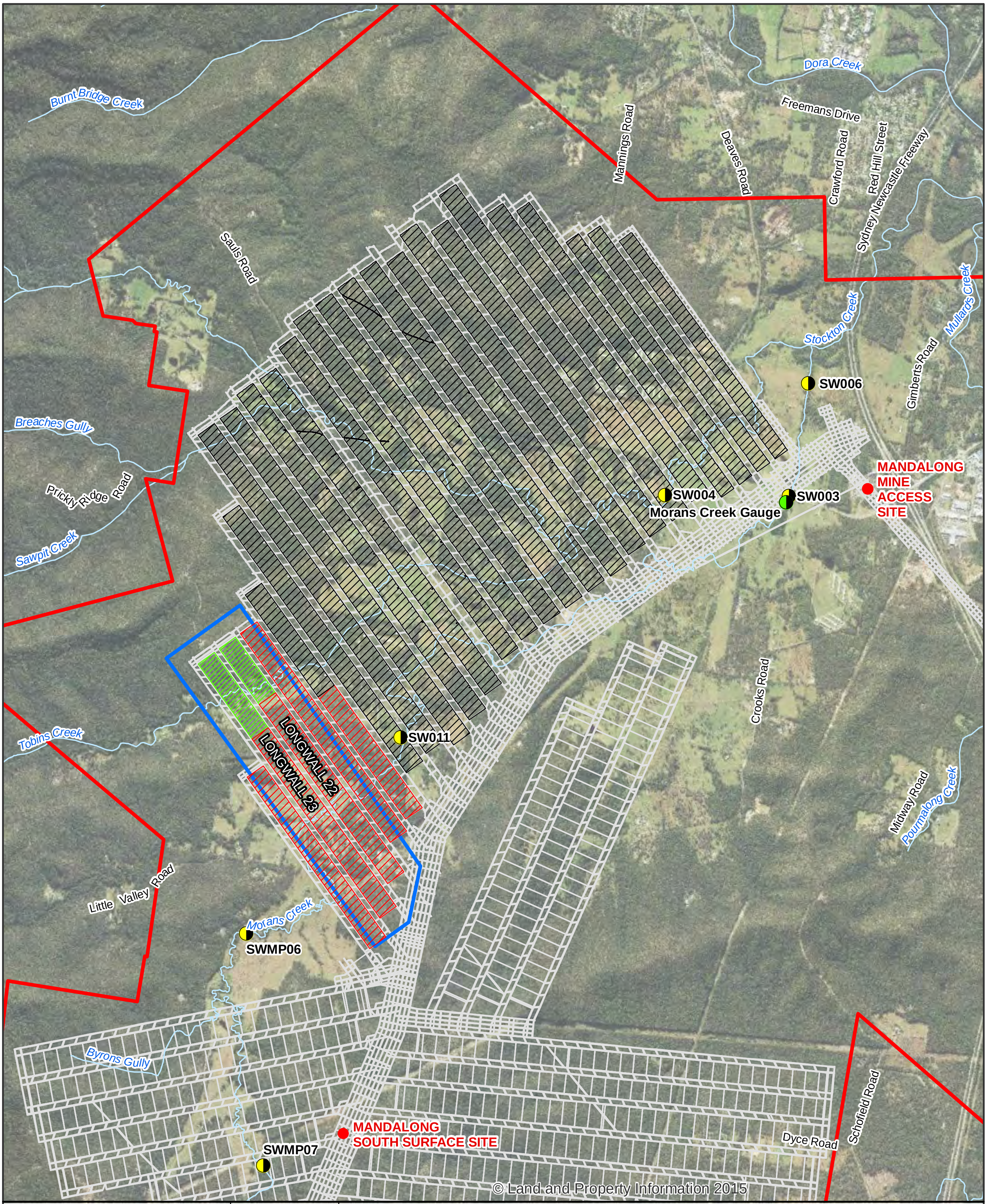
<u>Alluvial groundwater sources</u>

Groundwater hydrographs for each of the alluvial monitoring bores at Mandalong Mine listed in have been plotted and compared to the CRD curve. These hydrographs are shown in Appendix B.

The recorded groundwater elevations for each alluvial monitoring bore are shown in black in each hydrograph in Appendix B. Groundwater elevation at each monitoring location has generally fluctuated over time within a range of 2 m to 3 m bgl.

It should be noted that groundwater levels at Mandalong Mine have been recorded manually and that the limit of reading of the measuring tape is 10 mm. When considering the accuracy achievable by the field technician, the limit of accuracy of an individual measurement may be up to ± 50 mm. Therefore, groundwater monitoring is unlikely to detect changes in groundwater level of less than 10 mm at a particular bore from one monthly monitoring round to the next. When water pressure loggers have been used to monitor groundwater levels, the limit of accuracy for corrected levels is also 10 mm since this is the accuracy of the top of casing (TOC) elevation measurement.

The CRD curve is shown in blue in each hydrograph in Appendix B. HARTT analysis has been undertaken for each alluvial dataset to establish the relationship between groundwater levels and rainfall and detect underlying trends in groundwater levels that are independent of rainfall. The best fit HARTT regression line is shown in red in each hydrograph. The HARTT statistical output for each alluvial hydrograph is shown in Table 5-2.



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Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

GHD

LEGEND

- Morans Creek Gauge
- Surface water monitoring location
- Site location
- Proposed secondary extraction area
- Approved secondary extraction
- Existing extraction area
- Study area
- Approved Mine Workings
- Project application area
- Waterway

LOCATION	Mandalong
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

Surface Water Monitoring Locations

Centennial Coal
Mandalong

DATE 5/10/2016

Figure 5-4

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\WRIA\LW22_23_MOD\2218510_WRIA003_SWMonitoring_0.mxd

Data source: LPI:DCDB/Imagery, 2012/2015. Centennial: Mine workings, Extraction area, consent boundary, 2016. Created by: smacdonald, kpsroba

Table 5-2 HARTT analysis results for alluvial monitoring bores

Bore	R^2	Rainfall coefficient *a* (m/mm)	*p*-value (rain)	Time coefficient *b* (m/month)	*p*-value (time)	*c* (m)
BH01	0.493	0.001	0.000	-0.002	0.000	3.075
BH02	0.503	0.001	0.000	0.000	0.238	6.840
BH02B	0.549	0.002	0.000	-0.008	0.000	6.920
BH02C	0.587	0.002	0.000	-0.005	0.000	7.126
BH03	0.749	0.001	0.000	-0.003	0.000	6.129
BH03A	0.532	0.001	0.000	-0.004	0.001	6.185
BH04	0.339	0.001	0.000	-0.001	0.002	9.213
BH05	0.214	0.001	0.000	-0.004	0.000	10.227
BH06	0.252	0.001	0.000	-0.001	0.001	9.977
BH07	0.371	0.001	0.000	-0.003	0.000	12.399
BH08	0.630	0.001	0.000	0.000	0.529	15.760
BH09	0.330	0.001	0.000	0.001	0.184	16.240
BH10	0.369	0.001	0.000	0.002	0.000	18.162
BH11	0.187	0.001	0.000	0.000	0.931	15.531
BH12	0.290	0.001	0.000	-0.002	0.000	14.349
BH13	0.132	0.001	0.000	-0.002	0.007	16.049
BH14	0.339	0.001	0.000	0.001	0.155	15.510
BH17A	0.651	0.001	0.000	0.000	0.702	6.995
BH20A	0.501	0.001	0.000	-0.002	0.033	5.285
BH21A	0.496	0.002	0.000	-0.003	0.019	5.770
BH22A	0.327	0.002	0.000	-0.008	0.001	12.059
BH23B	0.584	0.001	0.000	-0.002	0.106	6.989
BH24A	0.785	0.002	0.000	-0.053	0.000	18.439
BH24A (post-August 2014)	0.213	0.0004	0.341	0.008	0.281	14.769
BH25A	0.306	0.003	0.000	-0.025	0.000	15.089

Bore	R^2	Rainfall coefficient *a* (m/mm)	*p*-value (rain)	Time coefficient *b* (m/month)	*p*-value (time)	*c* (m)
BH26A	0.062	0.001	0.068	-0.007	0.101	20.325
BH27A	0.941	0.024	0.387	-0.251	0.297	64.168
MSGW01	0.427	0.002	0.000	-0.017	0.000	42.486
MSGW03A	0.123	0.008	0.265	-0.020	0.691	34.479
MSGW04A	0.295	0.001	0.000	-0.011	0.000	25.210

The R^2 value of the HARTT regression line gives a measure of the quality of fit of the non-linear regression line to the observed hydrograph. This value was greater than 50% for 11 of the 29 alluvial hydrographs analysed, indicating that almost half the hydrographs can be reasonably modelled by the HARTT variables (CRD and linear time trends) alone. A lower R^2 value indicates that the bore is situated at a location where the hydrograph cannot be modelled by the HARTT variables alone and that other factors are affecting groundwater levels.

The *p*-value for the rainfall variable *a* is less than 0.05 for all bores except BH24A (post-August 2014 dataset), BH26A, BH27A and MSGW03A indicating that there is a significant relationship between groundwater level and CRD at most alluvial monitoring locations. The rainfall coefficient suggests that alluvial groundwater levels respond by 1 mm to 2 mm per mm of CRD (or atypical rainfall), which is less than the limit of accuracy of groundwater level measurements. Due to this strong relationship it is difficult to identify the underlying trend visually.

The *p*-value for the time variable *b* is less than 0.05 for 19 of the 30 alluvial bores, indicating statistically significant linear time trends (independent of rainfall) in groundwater levels. Where the *p*-value is greater than 0.05, time trends are statistically insignificant and the time coefficient *b* cannot be relied upon to describe historical trends or predict future groundwater levels. The magnitudes of the statistically significant temporal trends (both increasing and decreasing) were below the limit of reading of groundwater level measurements (i.e. 0.01 m) for all bores except BH24A, BH25A, MSGW01 and MSGW04A. Decreasing trends are evident at each of these locations.

Visual inspection of the hydrograph for BH24A indicated that groundwater levels fell after undermining at BH24A from approximately 16.8 m AHD in January 2014 to 14.8 m AHD in August 2014. Analysis of the post-August 2014 hydrograph indicates that levels at this monitoring location have shown a statistically insignificant increasing trend (independent of rainfall) with levels responding to CRD.

Visual inspection of the hydrograph for BH25A indicated that the decreasing trend in groundwater level at this location is not completely attributable to mining. The visual inspection of the hydrograph indicated that post-mining groundwater levels have remained within the observed range of pre-mining levels and post-mining groundwater levels have continued to respond to CRD. Visual review of the hydrograph did indicate some temporary, short-term variation in groundwater levels following mining.

The variation in groundwater levels at BH24A and BH25A are assumed to be a result of the development of shallow tensile and compressive cracks resulting in localised increases in hydraulic conductivity and porosity. It is expected that these cracks would fill over time and the hydraulic conductivity and porosity should return to pre-mining values.

This has been observed at other alluvial bores that had a temporary reduction in groundwater levels post mining, such as BH22A. The depth of cover above the coal seam at monitoring bores BH24A and BH25A is approximately 170 m to 200 m.

MSGW01 and MSGW04A are located in the vicinity of the future Mandalong South longwalls. Visual inspection of hydrographs indicates that groundwater levels at MSGW01 have consistently fluctuated between 41 m AHD and 42.5 m AHD while groundwater levels at MSGW04A have generally fluctuated between 24 m AHD and 25.2 m AHD. It is assumed that the decreasing time trends (independent of rainfall) in groundwater level at MSGW01 and MSGW04A are not mining related, but are due to groundwater levels remaining within these historical range of levels despite a general increasing trend in CRD over the past 18 months.

Fractured and porous rock groundwater sources

According to Ferdowsian et al. (2000), the HARTT method is generally limited to the analysis of relatively shallow groundwater from unconfined aquifers. Therefore, it was necessary to make a visual assessment of hydrographs from deeper bores to identify existing impacts on fractured and porous rock groundwater sources. Hydrographs for deeper monitoring bores at Mandalong Mine are shown in Appendix B.

At the time of this assessment, all deeper monitoring bores had been directly undermined by longwall panels with the exception of BH26B, BH26C, MSGW03B, MSGW03C, MSGW04B, MSGW04C and the VWPs (V1 to V5). These bores are screened within Triassic sandstone and conglomerate. The VWP monitoring locations are installed between the Triassic conglomerate and the West Wallarah Seam of the Permian Newcastle Coal Measures.

There appears to be some variation in groundwater levels at MSGW03B that coincide with changes in CRD. Additionally, there was a decreasing trend in groundwater levels (not tested statistically) at MSGW03B between September 2011 and January 2013. This decreasing trend at MSGW03B may be related to monthly sampling of the bore between October 2011 and February 2013. After this period MSGW03B has been sampled once every three months. The frequency of sampling (in conjunction with rainfall trends) may explain the decreasing trend in groundwater levels between September 2011 and January 2013.

Groundwater levels at MSGW03C were consistently around 25 m AHD between September 2011 and June 2012. Purging of bore MSGW03C for sampling in June 2012 resulted in groundwater levels falling. Groundwater levels recovered over a number of months to return to pre-sampling levels. Since June 2014 groundwater levels at MSGW03C have been gradually falling, with the groundwater level decreasing from 24.759 m AHD in June 2014 to 22.734 m AHD in June 2016.

Groundwater levels at MSGW04B were relatively consistent at around 22.5 m AHD for the first 12 months of monitoring between September 2011 and September 2012. Following this period of monitoring groundwater levels at MSGW04B have been decreasing with groundwater levels reaching 11.861 m AHD in June 2016.

Groundwater levels at MSGW04C were relatively constant at around 20 m AHD for the first 12 months of monitoring. Following this initial period of monitoring groundwater levels have shown a large amount of variability. This variability in groundwater levels is due to purging of the bore for sampling. MSGW04C was most recently sampled in November 2014 and November 2015. Following sampling of the bore groundwater levels recovered over a number of months.

Groundwater pressures at monitoring locations installed in the West Wallarah Seam show increasing or relatively constant groundwater pressure. Monitoring locations at the VWPs in the overburden show a relatively constant decrease in groundwater pressure. As there is no response to mining at the VWPs in the coal seam, it is considered that the observed decrease in groundwater pressure in the overburden is not related to mining.

Groundwater levels at BH26B have been relatively constant with observed groundwater levels between 20 m AHD and 21.5 m AHD. Groundwater levels at BH26C decreased between October 2011 and December 2014. In December 2014 the bore was purged for sampling resulting in a sudden drop in observed groundwater levels. Since purging of the bore for sampling purposes groundwater levels at BH26C have been recovering towards pre-purging levels.

Monitoring bores BH02A, BH03B, BH06A, BH07B, BH09A, BH09B, BH10A, BH10B, BH20B, BH22B, BH23A, BH24B, BH24C, BH25B, BH25C and BH27B screened within the sandstone and siltstone of the Tuggerah Formation, have been directly undermined by existing workings. By visual assessment, following undermining there appeared to be a consistent drop in groundwater elevation at most of these locations (with the exception of BH20B, BH07B and BH27B). The gradual drop in groundwater pressure suggests that discontinuous fractures may have developed in the rock overlying the mine workings at these locations. At most locations the fractured and porous rock groundwater sources monitored by these bores are approximately 120 m to 230 m above the coal seam.

At a number of these locations (including BH02A, BH03B, BH07B, BH09A, BH09B and BH23A), groundwater levels have re-stabilised to between 2 m AHD and -12 m AHD or have shown slight increases towards pre-mining levels at approximately three to five years post-undermining.

At BH20B, levels have shown some response to CRD, while at BH07B groundwater levels fell suddenly following undermining with groundwater levels soon beginning to recover with levels re-stabilising at approximately 2 m AHD. At BH27B groundwater levels displayed a sudden increase at the time of undermining with levels now decreasing towards pre-mining levels.

Monitoring bores BH07A, BH20, BH21, BH22C, BH23 and BH27C screened within the Munmorah Conglomerate have been undermined by existing longwalls and groundwater elevations at all locations have dropped over the monitoring period. Groundwater elevations at BH20, BH21 and BH23 initially dropped suddenly and have fluctuated between approximately -40 m AHD and -50 m AHD over the past number of years, while groundwater pressure at BH07A decreased at a rate of approximately 4 m to 5 m per year for approximately three years following undermining before levels stabilised at approximately -70 m AHD. Groundwater levels at BH27C showed a decreasing pre-mining trend including a sudden drop in levels in November 2014 related to purging of the bore for sampling. BH27C was undermined in July 2015, resulting in the bore becoming dry. The lack of observed groundwater at BH27C post-mining may be due to shifting of the strata which resulted in the bore becoming damaged. Shifting of strata may explain the temporary increase in groundwater level at adjacent bore BH27B following undermining. At BH22C there is a lack of data following undermining and therefore it is difficult to identify mining related trends. The fractured and porous rock groundwater sources monitored by these bores are approximately 100 m to 120 m above the coal seam with the exception of BH27C which is approximately 170 m above the coal seam.

The only coal seam bore (not including the VWPs) is BH15 in the Fassifern Seam, underlying the West Wallarah Seam and Awaba Tuff. Monitoring of this bore ceased in November 2014 due to bore damage. Groundwater elevations at this location have fluctuated between 12 m AHD and 14 m AHD over the monitoring period. By visual assessment there appears to be some degree of response to CRD in groundwater elevations reported at BH15 but no depressurisation is evident.

Overall, analysis of deeper groundwater monitoring data indicates that depressurisation of fractured and porous rock groundwater sources (by greater than 2 m) occurs up to 230 m above the Mandalong longwall panels. The greatest depressurisation tends to occur up to 120 m above the longwalls. At a number of monitoring locations that have shown depressurisation due to mining, groundwater levels have stabilised or started to gradually increase towards pre-mining levels approximately three to five years after undermining occurring. It is also noted that groundwater levels/pressures have reduced in recent years at locations not yet affected by mining.

Groundwater quality

Alluvial groundwater sources

Previous assessment of alluvial groundwater quality (GHD, 2013c) indicated that at most alluvial bores the groundwater pH is consistently within the range of 5 to 8 and groundwater EC varies considerably within the alluvium across the mining area, ranging from less than 1,000 µS/cm to over 10,000 µS/cm.

As discussed in the Mandalong Southern Extension Project response to submissions, there is variability in groundwater EC at a number of alluvial monitoring bores at Mandalong Mine. As part of the response to submissions process it was identified that this variability in EC was attributable to sampling of bores by bailing without initial purging. Since January 2015, alluvial monitoring bores at Mandalong Mine have been sampled using low flow techniques where possible (i.e. peristaltic pump or Micro-purge pump) with initial purging until pH and EC stabilise. Additionally, bores that were identified as being regularly submerged by surface water have been regularly purged to remove potential influence of surface water on monitoring results. Following the update of the groundwater monitoring methodology, variability in observed EC has reduced.

Groundwater pH and EC reported at alluvial monitoring bores at Mandalong Mine is summarised in Appendix C. The groundwater pH and EC indicates that current alluvial groundwater quality is generally within the range reported by GHD (2013c) and no change in groundwater pH or EC resulting in a lowering of the beneficial use category is evident since longwall mining began in 2005.

Fractured and porous rock groundwater sources

Review of groundwater quality data by GHD (2013c) indicated that there is considerable spatial variability in groundwater pH within the fractured and porous rock groundwater source. However, at some monitoring locations the pH is consistently in the moderately to highly alkaline range. The review of groundwater quality data indicated that groundwater pH generally remained within the pre-mining range during and after undermining (GHD, 2013c).

GHD (2013c) also reports that groundwater EC within the fractured and porous rock water sources typically ranges from about 6,000 µS/cm to over 10,000 µS/cm. The review of groundwater quality data by GHD (2013c) indicated that groundwater EC generally remains within the pre-mining range during and after undermining or reduces over time.

As discussed above, as part of the response to submissions process it was identified that variability in monitoring results for EC was occurring at a number of monitoring bores at Mandalong Mine and this variability was attributable to sampling of bores by bailing without initial purging. Since January 2015, deeper monitoring bores at Mandalong Mine have also been sampled using low flow techniques where possible (i.e. peristaltic pump or Micro-purge pump). Additionally, bores that were identified as being regularly submerged by surface water have been regularly purged to remove potential influence of surface water on monitoring results.

Following the update of the groundwater monitoring methodology, variability in observed EC has reduced.

Groundwater pH and EC reported at fractured and porous rock monitoring bores at Mandalong Mine is summarised in Appendix C. The groundwater pH and EC indicates that current fractured and porous rock groundwater quality is generally within the range reported by GHD (2013c) and no change in groundwater pH or EC resulting in a lowering of the beneficial use category is evident since longwall mining began in 2005.

5.3.2 Hydrogeological model predictions

The MODFLOW flow budget results for transient run 24 of the recalibrated hydrogeological model (best calibration under transient conditions) as reported in GHD (2016a) for current conditions in 2016 are presented in Table 5-3. This flow budget incorporates the entire model domain, which extends well beyond the footprint of Mandalong mine as outlined in GHD (2013a).

Table 5-3 Hydrogeological model predictions for existing conditions

	Alluvium and outcropping rock [1] (ML/year)	Rock (ML/year)
INPUTS		
Recharge	4,055	0
GHB [2]	1,326	351
Storage	7	313
Other zones	536	574
TOTAL INPUTS (rounded)	**5,924**	**1,238**
OUTPUTS		
Drains [3]	3,580	326
GHB [2]	228	27
Storage	1,542	349
Other zones	574	536
TOTAL OUTPUTS (rounded)	**5,924**	**1,238**
BALANCE		
Inputs – outputs	**0**	**0**

1. Layer 1 of MODFLOW model.

2. General head boundary.

3. Transfer from alluvium and outcropping rock to drains is baseflow. Transfer from fractured and porous rock to drains is inflow to mine workings.

The flow budget indicates that the inflow of groundwater into mine workings is 0.89 ML/day in 2016, which comes from fractured and porous rock groundwater source.

5.4 Surface water environment

5.4.1 Water and salt balance assessment

Water balance results

The water management system for Mandalong Mine was modelled based on the current conditions in 2016, using a historical time series of daily rainfall data extending over 127 years. A total of 127 simulations were applied with each simulation modelling a different rainfall pattern (refer Section 4.3.1). As a result, 127 annual totals were available for each element within the water balance model, thereby representing a wide range of possible rainfall conditions.

Water balance modelling estimated the annual volumetric transfers between the water cycle components under existing conditions, as shown in Figure 5-5. Note that as the Project does not propose any changes to the surface water management at MMAS, MSSS or DES, these elements of the water cycle have not been presented.

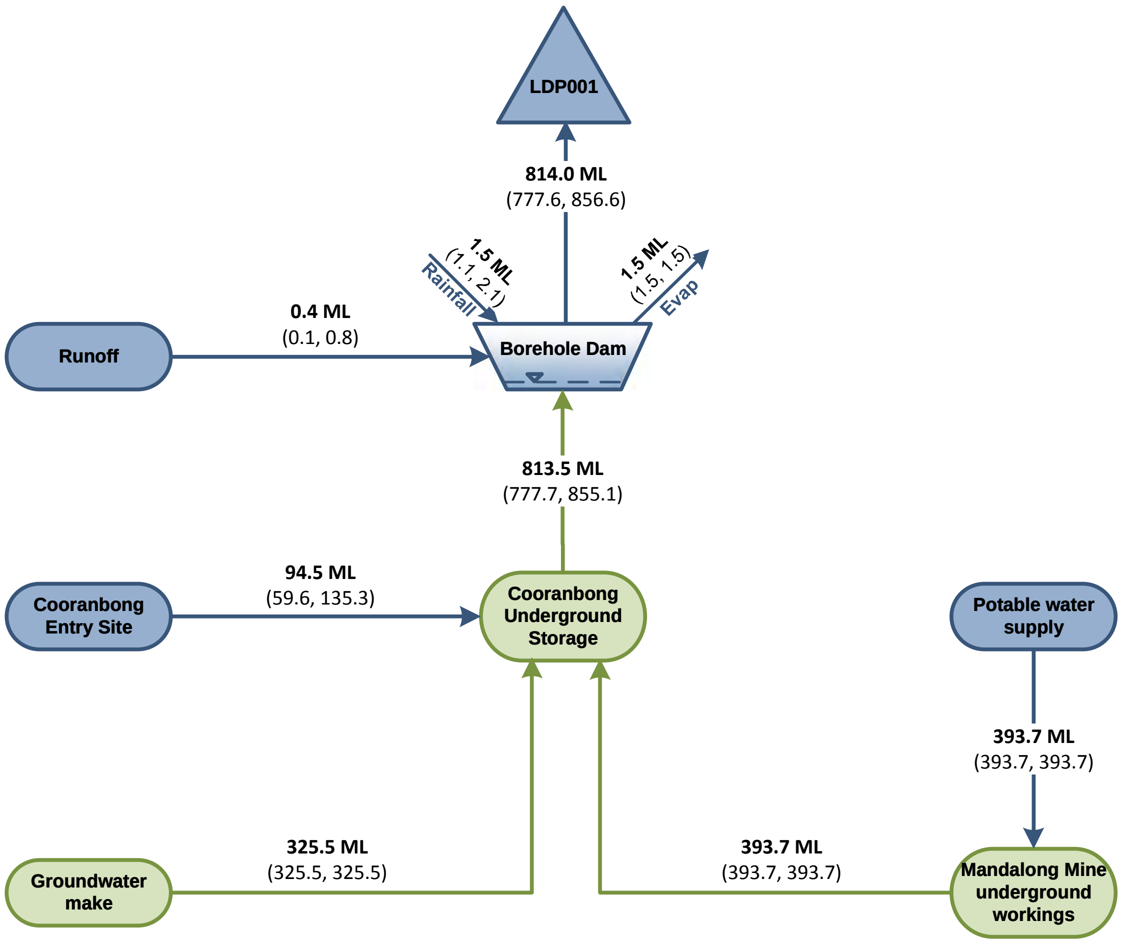
The results present the average annual transfers between water management elements as well as the 10th percentile and 90th percentile values. The purpose of displaying the three results for each water transfer is to show the average transfer volume and an indication of the range of values expected due to possible variation in rainfall.

The 10th percentile represents the value at which 10% of the modelled outputs were less than this value. Similarly, the 90th percentile represents the value at which 90% of the modelled outputs were less than this value. The 10th and 90th percentile values have been used (rather than minimum and maximum values) to remove the impact of skewing by infrequent to extreme wet and dry conditions.

From the results provided in Figure 5-5, average annual inputs and outputs for the water balance under existing conditions in 2016 were summarised, as shown in Table 5-4.

As seen in Table 5-4, the largest source of water into the water cycle under existing conditions in 2016 was potable water supply for underground mining activities, which accounted for approximately 394 ML/year on average. This was followed by groundwater inflows to the underground workings, which was modelled to be approximately 326 ML/year in 2016.

Discharge from the Borehole Dam to LDP001 at CES was modelled to represent the largest output from the site. The average annual contribution from the Borehole Dam to LDP001 was predicted to be 814 ML/year on average. It should be noted that overflows from Sediment Dam 2 at the CES also contributes to LDP001, which have not been presented in Figure 5-5 or Table 5-4. However, the majority of LDP001 discharge is comprised of groundwater make, with less than 15 ML/year predicted to be discharged from Sediment Dam 2 (GHD, 2016a).



GHD

Surface Water Transfer

Underground Water Transfer

Storage

LOCATION	Cooranbong
SEAM	N/A
DRAWN	SM
CHECKED	TD
APPROVED	LH
SCALE	NTS

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

Annual water transfers
Existing conditions (2016)

Centennial Coal

DATE Sep 2016

Figure 5-5

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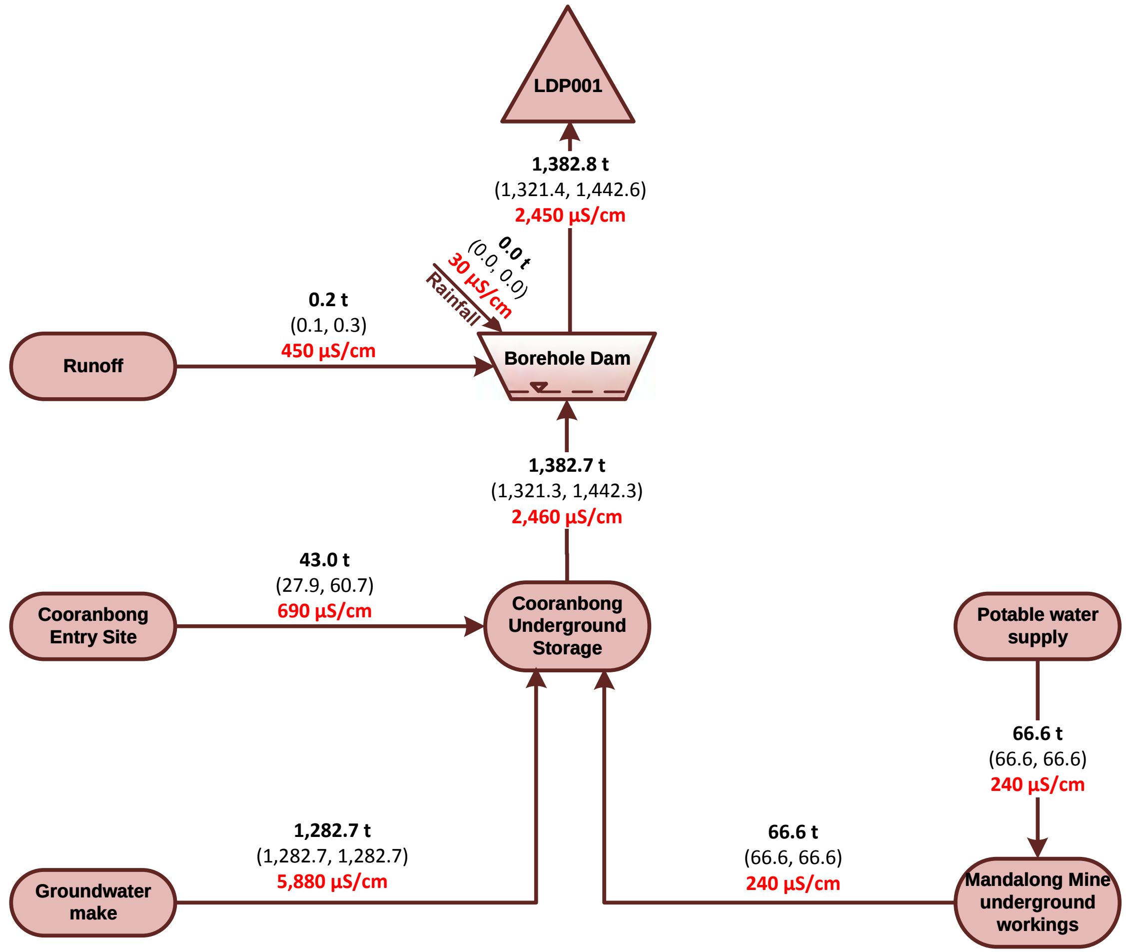
Table 5-4 Summary of average annual water inputs and outputs under existing conditions

	Volume (ML/year)
INPUTS	
Rainfall and catchment runoff	1.9
Transfer from CES to underground workings	94.5
Potable water supply	393.7
Groundwater inflow into underground workings	325.5
TOTAL INPUTS (rounded)	**816**
OUTPUTS	
Evaporation	1.5
Discharge to LDP001 from Borehole Dam	814.0
TOTAL OUTPUTS (rounded)	**816**
CHANGE IN STORAGE	
Borehole Dam	0.0
Cooranbong underground storage	0.2
TOTAL CHANGE IN STORAGE (rounded)	**0**
BALANCE	
Inputs – outputs – change in storage	0

Salt balance results

As discussed in Section 4.3.1, the salt balance model was developed as an extension of the water balance model with expected concentrations of salt applied to water inflows into the system. Similar to the water balance, salt balance modelling provided 127 possible annual totals of salt transfers between the water cycle components of Mandalong Mine under existing conditions, as shown in Figure 5-6. As with the water balance results, the salt balance results present the average annual salt transfers as well as the 10th percentile and 90th percentile values to provide an indication of the range of values expected due to possible variation in rainfall. In addition to the salt transfer quantities, the average salinity of each transfer is also displayed on the figure.

From the results provided in Figure 5-6, average annual inputs and outputs for the salt balance under existing conditions in 2016 were summarised, as shown in Table 5-5.



Salt Transfer

Storage

LOCATION	Cooranbong
SEAM	N/A
DRAWN	SM
CHECKED	TD
APPROVED	LH
SCALE	NTS

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

Annual salt transfers
Existing conditions (2016)

Centennial Coal

DATE Sep 2016

Figure 5-6

Table 5-5 Summary of average annual salt inputs and outputs under existing conditions

	Mass (t/year)
INPUTS	
Rainfall and catchment runoff	0.1
Transfer from CES to underground workings	43.5
Potable water supply	62.2
Groundwater inflow into underground workings	1,282.7
TOTAL INPUTS (rounded)	**1,389**
OUTPUTS	
Discharge to LDP001 from Borehole Dam	1,564.1
TOTAL OUTPUTS (rounded)	**1,564**
CHANGE IN STORAGE	
Borehole Dam	-0.2
Cooranbong underground storage	-175.4
TOTAL CHANGE IN STORAGE (rounded)	**-176**
BALANCE	
Inputs – outputs – change in storage	0

As seen in Table 5-5, the sources and sinks for the salt balance were broadly similar to the water balance. The largest source of salt under existing conditions was modelled to be associated with groundwater inflows into the underground workings, which accounts for approximately 1,283 tonnes of salt on average annually. The average salinity of groundwater inflows was estimated to be 5,880 µS/cm.

The second largest annual salt inputs under existing conditions was modelled to be associated with the potable water supply for underground mining activities, which is estimated to input an average of approximately 62 tonnes of salt into the water management system annually.

Approximately 1,564 tonnes of salt on average was predicted to be output from the water management system at Mandalong Mine from the Borehole Dam to LDP001 at CES for 2016. The average salinity of discharges from the Borehole Dam to LDP001 were modelled to be approximately 2,870 µS/cm under existing conditions.

5.4.2 Flood assessment

The flooding assessment for the Project prepared by Umwelt (2016; refer Appendix A) provides the pre-mining flood predictions for the 1 year and 100 year average recurrence interval (ARI) storm events. The results for Morans Creek indicate a flow width of between 500 m to 750 m across in a 100 year ARI storm event, at longwalls 22 and 23. Tobins Creek was modelled to have flow widths in the 100 year ARI storm event between 75 m to 200 m.

Flow paths within Morans Creek consist of a three channel system at longwalls 22 and 23, with two channels indicating high flood hazard. The flow depths for the 100 year ARI storm event were up approximately 1 m outside of the main channel within Morans Creek under the existing conditions.

The 1 year ARI storm event predictions clearly identify the three main flow paths present within Morans Creek. Flow paths in Morans Creek are typically of widths less than 50 m at longwalls 22 and 23. Tobins Creek model predictions indicate flooding in a 1 year ARI storm event is limited to a single channel of relatively narrow width.

Flood hazards were found by Umwelt (2016) to vary between Morans Creek and Tobins Creek. Tobins Creek was limited to a high hazard category (vehicles and wading unsafe) within the channel extent. Flow outside of the main channel of Morans Creek varied from low hazard (vehicles unstable but wading safe) increasing to high hazard (damage to light structures).

5.4.3 Waterway geomorphology

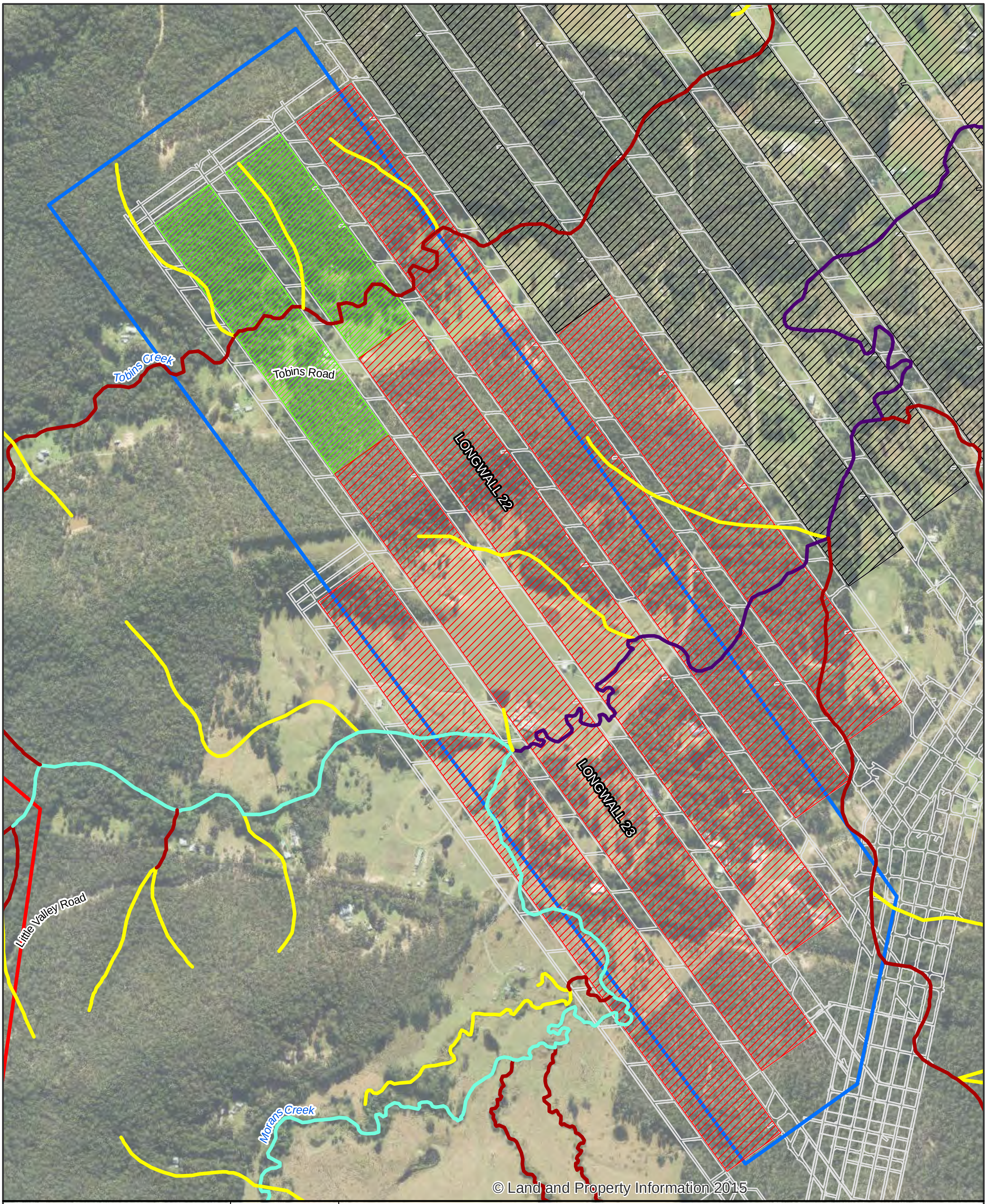
Geomorphic characteristics

A desktop assessment and site visit were undertaken to assess the existing geomorphic characteristics of the reaches of watercourses that may be affected by the Project. The geomorphic assessment included characterising streams by stream order, watercourse types and watercourse condition. The proposed extension to longwalls 22 and 23 will undermine the upper reach of Tobins Creek, which has not been previously undermined. Stream ordering for waterways in the vicinity of the Project are shown in Figure 5-7. Through the study area, Tobins Creek is a third order streamline while Morans Creek is a fourth order streamline.

Under the River Styles framework (Brierley and Fryirs, 2005), the morphology of both Morans Creek and Tobins Creek is classified as fine-grained meandering systems. This watercourse type exhibits a moderately sinuous channel set within continuous floodplains composed of alluvial sandy silt. The channels are symmetrical to asymmetrical on bends and have low to moderate width/depth ratios. Banks are typically well-vegetated with a range of native and exotic species, as shown in Figure 5-8. As a result, in combination with relatively cohesive bank sediments, the occurrence and rates of bank erosion are low.

Channel beds are dominated by fine-grained sediments with occasional bank attached sand bars. The channels have a relatively low longitudinal gradient of approximately 0.035%. Bed controls are dominated by timber accumulations and there is no bedrock influencing channel stability. As a result, the channel beds have the potential to incise through headcuts. A low headcut in the order of 0.2 m was observed along Tobins Creek, as shown in Figure 5-9, where it crosses the proposed extension of Longwall 23.

The floodplain zone exhibits oxbows and back swamps or wetlands and typically cleared for grazing. The channels are of relatively low capacity and sections of the floodplains can become inundated in the 1 year ARI storm event (Umwelt, 2016).



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Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

GHD

LEGEND

- Site location
- Proposed secondary extraction area
- Approved secondary extraction
- Existing extraction area
- Study area
- Approved Mine Workings
- Project application area

STREAM ORDER

- 1st Order
- 2nd Order
- 3rd Order
- 4th Order

LOCATION	Mandalong
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment
Stream Order of Waterwys
in the Vicinity of the Project

Centennial Coal
Mandalong

DATE 5/10/2016

Figure 5-7

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Data source: LPI:DCDB/Imagery, 2012/2015. Centennial: Mine workings, Extraction area, consent boundary, 2016. Created by: smacdonald, kpsroba

Figure 5-8 View of Tobins Creek displaying typical vegetation associations

Figure 5-9 View of headcut along Tobins Creek

Hydrology

As discussed in Section 5.2.2, a flow and level gauge was installed on Morans Creek in 2006 and recorded data up until 2009. Figure 5-10 presents the level recorded by the gauge between 2006 and 2008. Table 5-6 presents the statistics of the flow monitoring data.

Table 5-6 Flow monitoring data for Morans Creek

Statistic	Year		
	2006	2007	2008
Percentage of year monitored	100%	46.7%	69.6%
Annual rainfall total	828 mm	1508 mm	1,577 mm
Volume recorded*	2,542 ML	2,296 ML	N/A

* Estimated from data provided. Gauge rating data to be confirmed.

Water levels within Morans Creek indicate a general creek response of up to 0.5 m to rainfall greater than 50 mm/day. Due to the inconsistent gauging recordings a reliable correlation between rainfall and level was not possible.

5.4.4 Surface water quality

A statistical summary of the surface water quality at monitoring sites SWMP06 and SWMP07 is provided in Table 5-7. The median (50th percentile) results provided are representative of the ambient water conditions. Time series graphs for selected water quality parameters monitored are provided in Appendix D.

Physicochemical parameters

EC generally ranged between 150 µS/cm and 1,000 µS/cm, indicating fresh waters. Median concentrations of 583 µS/cm and 510 µS/cm were reported for SWMP06 and SWMP07 respectively. The majority of EC levels were found to exceed the ANZECC (2000) DGV of 200 µS/cm.

The pH levels reported for SWMP06 and SWMP07 indicated neutral to slightly acidic conditions, with samples typically ranging between 6 and 7. The majority of pH levels were within the ANZECC (2000) DGVs of 6.5 and 9.0.

Results for TSS generally exceeded the ANZECC (2000) DGV of 6 mg/L at both locations, with increased concentrations at SWMP06 compared to SWMP07.

The majority of turbidity results have been below the ANZECC (2000) DGV of 6 NTU; however, elevated results were reported for late 2011, with a maximum of 269 NTU recorded for SWMP06 in October 2011.

Nutrients

The majority of recorded ammonia concentrations have ranged between the LOR of 0.01 mg/L and 0.2 mg/L. All results have been below the ANZECC (2000) DGV of 0.9 mg/L.

Total nitrogen concentrations ranged between a minimum of 0.1 mg/L up to a maximum of 3.2 mg/L. The majority of total nitrogen results have exceeded the ANZECC (2000) DGV of 0.35 mg/L, with the exception of one result in January 2012 recorded at 0.1 mg/L.

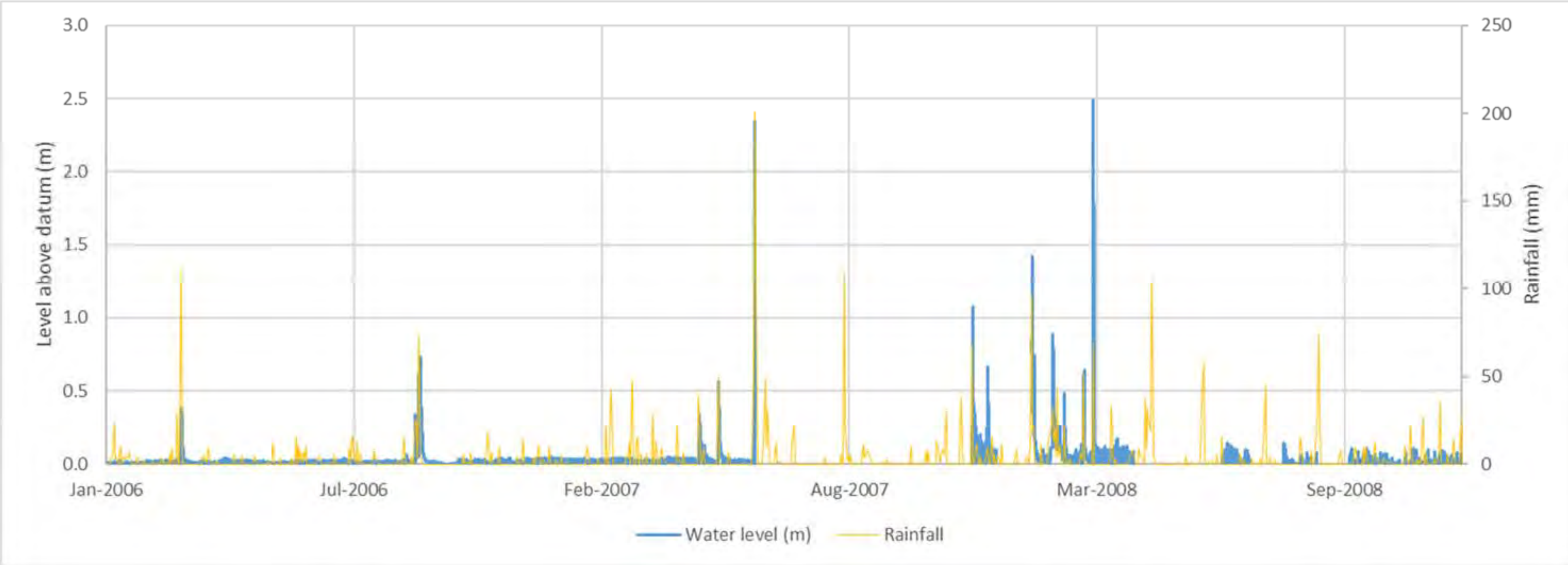


Figure 5-10 Level gauging within Morans Creek from 2006 to 2008

Table 5-7 Statistical summary of surface water quality

Parameter	Units	SWMP06		SWMP07	
		Count	Median	Count	Median
Physicochemical parameters					
EC	µS/cm	32	583	33	510
pH	pH units	32	6.5	33	6.8
TDS	mg/L	32	383	33	308
TSS	mg/L	32	25	33	8
Turbidity	NTU	32	32	33	28
Nutrients					
Ammonia	mg/L	32	0.03	32	0.05
BOD	mg/L	32	2	33	2
TKN	mg/L	32	0.7	33	0.8
Total nitrogen	mg/L	32	0.7	33	0.9
Total phosphorus	mg/L	32	0.04	33	0.06
Anions					
Alkalinity (total)	mg/L	32	26	33	40
Chloride	mg/L	32	147	33	119
Sulfate	mg/L	32	12	33	10
Cations					
Calcium	mg/L	32	5	33	5
Magnesium	mg/L	32	12	33	10
Potassium	mg/L	32	3	33	4
Sodium	mg/L	32	84	33	76
Dissolved metals					
Aluminium	mg/L	32	0.29	33	0.32
Arsenic	mg/L	32	0.001	33	0.001
Barium	mg/L	32	0.065	33	0.050
Boron	mg/L	32	0.05	33	0.05
Cadmium	mg/L	32	0.0001	33	0.0001

Parameter	Units	SWMP06		SWMP07	
		Count	Median	Count	Median
Chromium	mg/L	32	0.001	33	0.001
Cobalt	mg/L	32	0.004	33	0.001
Copper	mg/L	32	0.001	33	0.001
Iron	mg/L	31	2.55	32	2.29
Lead	mg/L	32	0.001	33	0.001
Manganese	mg/L	31	0.312	32	0.369
Mercury	mg/L	32	0.0001	33	0.0001
Nickel	mg/L	32	0.005	33	0.003
Selenium	mg/L	32	0.01	33	0.01
Silver	mg/L	32	0.001	33	0.001
Zinc	mg/L	32	0.005	33	0.005
Other parameters					
Cyanide (total)	mg/L	32	0.004	33	0.004
Fluoride (total)	mg/L	32	0.1	33	0.1
Oil and grease	mg/L	32	2	33	2

Concentrations of dissolved phosphorus were typically below 0.1 mg/L. Maximum concentrations of 0.46 mg/L in December 2011 and 0.2 mg/L in March 2015 have been recorded for SWMP06 and SWMP07 respectively. Over 80% of all total phosphorus concentrations were found to exceed the ANZECC (2000) DGV of 0.025 mg/L.

Metals

The majority of concentrations for dissolved arsenic, boron, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, silver and zinc were reported to be below relevant ANZECC (2000) DGVs, as shown in Table 4-4.

Dissolved aluminium results generally ranged between 0.1 mg/L and 0.8 mg/L, with the maximum result of 1.45 mg/L recorded at SWMP07 in June 2012. All results exceeded the ANZECC (2000) DGV of 0.055 mg/L, with the exception of two results recorded at SWMP06.

Concentrations of dissolved cobalt varied between the LOR of 0.001 mg/L and a maximum of 0.016 mg/L. Results reported for SWMP06 were generally higher than SWMP07, with the majority of results at SWMP06 exceeding the DGV of 0.0025 mg/L (Environment Canada, 2013).

Reported dissolved iron concentrations were found to range between the 1 mg/L and 4 mg/L in general. A maximum of 7.65 mg/L of dissolved iron has been recorded at SWMP07 in December 2013. All results for SWMP06 and SWMP07 were found to be above the ANZECC (2000) DGV of 0.3 mg/L.

Other parameters

Reported concentrations of total cyanide, total fluoride and oil and grease have generally been at or below the LOR.

5.5 Downstream water users

5.5.1 Groundwater users

The search of the NSW groundwater bore database (DPIW, 2016a) identified 127 bores in a 5 km radius of the existing, approved and proposed Mandalong Mine workings. The majority (64 bores) registered as monitoring/test bores, one bore registered for monitoring/town water supply and the remainder (62 bores) being registered for domestic, irrigation and/or stock use. Approximate bore locations are shown in Figure 5-11 and bore details are outlined in Appendix E.

The registered domestic and stock bores that were identified primarily extract groundwater from the Triassic sandstone and conglomerate formations with yields generally less than 1 L/s.

The search identified two private bores (GW078043 and GW105311) within 1 km of longwalls 22 and 23. Both of these bores are located within 250 m of longwall 23. The bore search indicated that GW105311 is an abandoned bore and GW078043 is a stock and domestic bore that is 33 m deep and is installed in the fractured and porous rock groundwater source.

5.5.2 Groundwater dependent ecosystems

The potential vegetation GDEs within the study area (RPS, 2016) include:

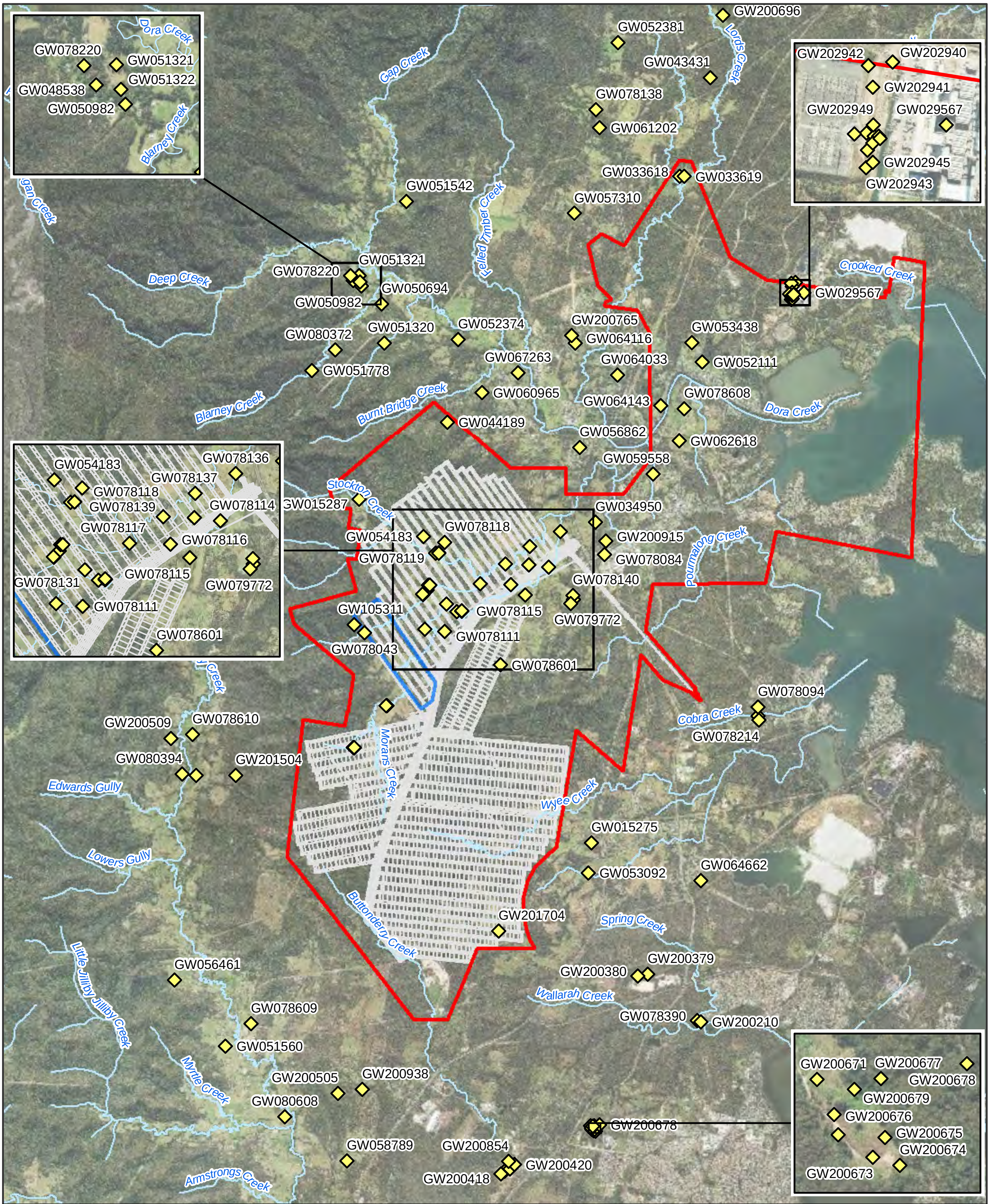
- Coastal Wet Gully Forest.
- Alluvial Tall Moist Forest.
- Alluvial Floodplain Cabbage Gum Forest.

Potential GDEs generally coincide with the creeks and drainage lines. The watercourses identified within the study area are the reaches of Morans Creek and Tobins Creek. Shallow unconfined alluvium has been identified along these two creek lines.

Ecological communities within the area are likely to be utilising shallow aquifers associated with ephemeral drainage lines and have therefore been considered as unlikely to be entirely groundwater dependent. This occurrence has been supported by the fact that the plant species within this vegetation community are not restricted to alluvial drainage lines; they can occur along moist sheltered gully areas, creek lines, as well as dry slopes. Therefore, they can be termed as facultative ecosystems.

Facultative ecosystems have been described as (DPI, 2012b):

"a GDE that is not entirely dependent on groundwater, and may rely on groundwater on a seasonal basis or only during extended drought periods. At other times, water requirements may be met by soil or surface water".



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Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

LEGEND

- Registered bore
- Study area
- Approved Mine Workings
- Waterway
- Project application area

LOCATION	Mandalong
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

Registered Bore Search

Centennial Coal
Mandalong

DATE 5/10/2016

Figure 5-11

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\WRIA\LW22_23_MOD\2218510_WRIA007_NSWBoreSearch_0.mxd

Data source: LPI:DCDB/Imagery, 2012/2015. Centennial: Mine workings, Extraction area, consent boundary, 2016. OOW: Pinneena, Registered Bore, 2010. Created by: smacdonald, kpsroba

5.5.3 Surface water users

As discussed in Section 3.6, watercourses within the study area are ephemeral with periods of limited or no flow. Due to the ephemeral nature of Morans Creek and Tobins Creek, the dependence of downstream water users on flows within these watercourses is not expected.

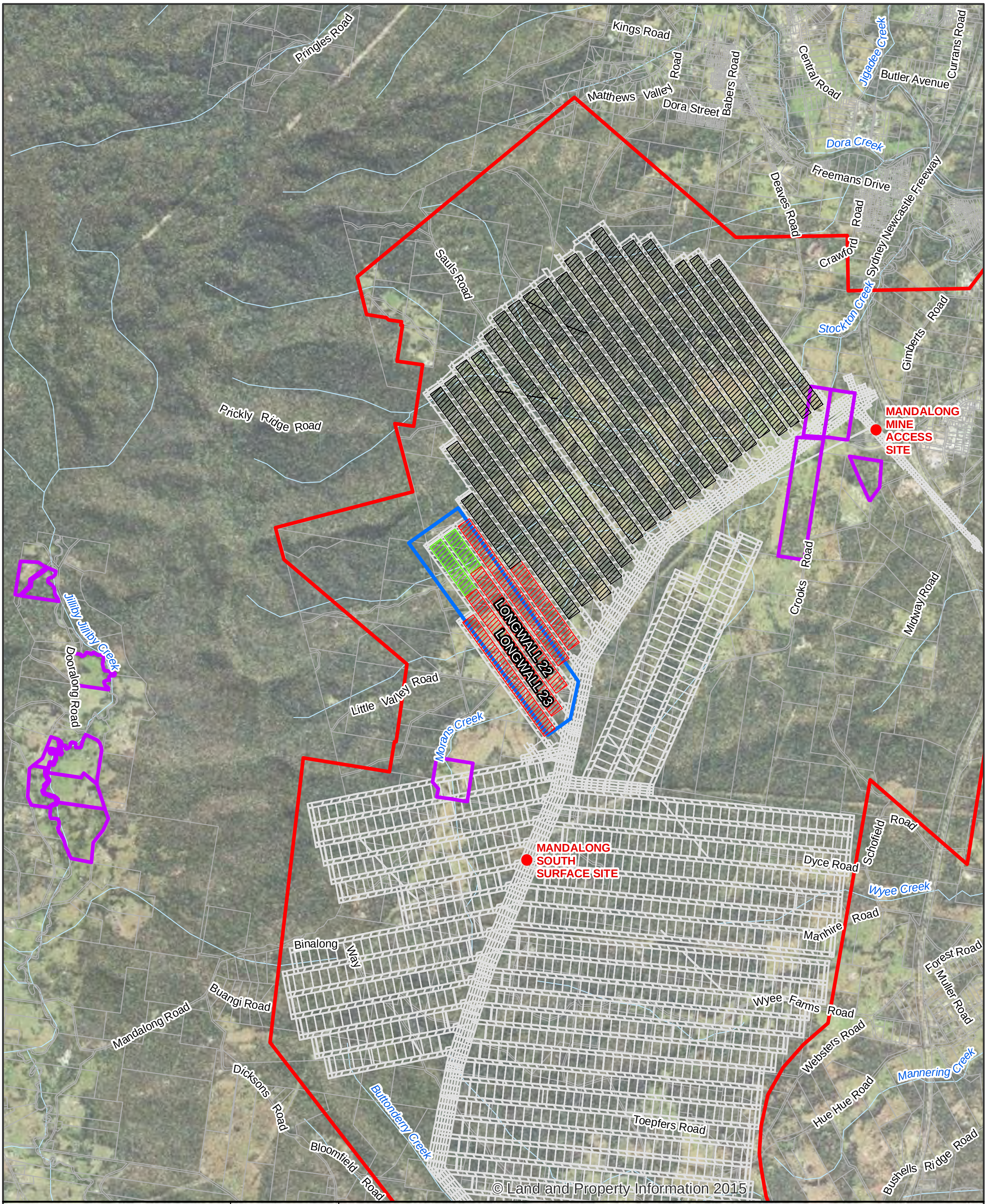
Figure 5-12 presents the property lots within a 5 km radius of the study area that were identified by searching the *NSW Water Register* (DPIW, 2016b). These lots are licensed for surface water extraction from the Dora Creek water source of the HUA WSP or the Jilliby Jilliby Creek Water Source WSP. The designated use or purpose of these licences includes irrigation, farming and industrial. Available information about the WALs identified is provided in Table 5-8.

Table 5-8 Details of licensed surface water users

WAL	Associated approval	Lot/DP	Annual allowance (ML)	Purpose
1422	20CA201926	1143/1037803	13	Irrigation
1426	20CA201941	310/832118	50	Irrigation
1429	20CA201949	310/832118	23	Irrigation
1431	20CA201959	1/748993	18	Irrigation
6585	20CA201934	311/832118	10	Irrigation
6586	20CA201957	1/748993	17	Industrial/ irrigation
6588	20CA201963	32/875601	6	Irrigation
7829	20CA201937	232/588261	6.5	Irrigation
7833	20CA201965	23/844203	30	Irrigation
17923	20CA207246	4/555891	6	Irrigation
17926	20CA207238	2/557230	88	Irrigation
17931	20CA207244	53/755238	78	Industrial/ irrigation
17935	20CA207224	A/110119	54	Irrigation
17937	20CA207242	55/9632	35	Industrial (low security)/ irrigation/farming

No approvals for basic landholder rights were identified from the search of the *NSW Water Register* (DPIW, 2016b).

Although part of the Wyong River catchment used to supply the Gosford-Wyong Water Supply Scheme lies within the Project Application Area, however the existing and approved surface sites all lie within the Lake Macquarie catchment. None of the proposed transfers of water, including underground transfers, will be within the Wyong River catchment. Therefore, the Project is not expected to have the potential to impact on the Wyong River catchment and the associated town water supply or infrastructure.



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Metres

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Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

GHD

LEGEND

- Site location
- Proposed secondary extraction area
- Approved Mine Workings
- Licensed surface water users
- Approved secondary extraction
- Existing extraction area
- Study area
- Project application area
- Cadastre
- Watercourse

LOCATION	Mandalong
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment
Licensed Surface Water Users in the Vicinity of the Project

Centennial Coal
Mandalong

DATE 5/10/2016

Figure 5-12

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Data source: Commonwealth of Australia (Geoscience Australia): 250K Topographic Data Series 3, 2008. LPI:DCDB/Imagery, 2012/2015. Centennial: Mine workings, 2016. DoPI: Water register, 2016. Created by: smacdonald, kpsroba

6. Impact assessment

6.1 Water management

As part of the Project, underground water will be managed by water transfers within the underground workings of Mandalong Mine including the Cooranbong underground storage area. Water extracted from the underground workings will be managed via the existing pumping system of Mandalong Mine.

The overall layout of the Mandalong Mine surface sites will remain unchanged, with no changes proposed to the approved infrastructure as part of this Project. The likely increases in underground water volume from existing conditions as a result of the Project will result in an increase in daily discharges from the Borehole Dam through LDP001 at CES. The volume of the Borehole Dam is expected to be able to cater for the predicted increase in groundwater volumes.

Potable water will continue to be serviced by the existing connections to Hunter Water Corporation's reticulated potable water system. There are not expected to be any appreciable increases in potable water usage as a result of the Project.

No changes to any licences held by Mandalong Mine are required by the Project.

6.2 Groundwater environment

6.2.1 Impact assessment criteria

The NSW Aquifer Interference Policy requires that potential impacts on groundwater sources, including their users and GDEs, be assessed against minimal impact considerations, outlined in Table 1 of the Policy. If the predicted impacts are less than the Level 1 minimal impact considerations, then these impacts will be considered as acceptable. The Level 1 minimal impact considerations for less productive fractured and porous rock water sources have been adopted for the assessment of potential groundwater impacts and are as follows:

- Water table: less than or equal to 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, at a distance of 40 m from any high priority groundwater dependent ecosystem or high priority culturally significant site listed in the schedule of the relevant WSP. A maximum of a 2 m water table decline cumulatively at any water supply work.
- If more than 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 m from any high priority GDE; or high priority culturally significant site; listed in the schedule of the relevant water sharing plan then appropriate studies (including the hydrogeology, ecological condition and cultural function) will need to demonstrate to the Minister for Land and Water's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than 2 m decline cumulatively at any water supply work then make good provisions should apply.
- Water pressure: a cumulative pressure head decline of not more than a 2 m decline at any water supply work.
- If the predicted pressure head decline is greater than the requirement above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.

- Water quality: any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.
- If the predicted change in water quality is greater than the requirement above, then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long term viability of groundwater ecosystems, significant sites or affected water supply works.

6.2.2 Hydrogeological model predictions

The MODFLOW flow budget results for transient run 24 of the recalibrated hydrogeological model (best calibration under transient conditions) for 2018 (end of mining of longwalls 22 and 23) and 2036 (predicted maximum groundwater inflow) are presented in Table 6-1. The MODFLOW flow budget for the best fit transient model developed as part of the Mandalong Southern Extension Project (GHD, 2013c) for the peak year of groundwater make (2035) are also presented in Table 6-1 for reference.

Note reported results for MODFLOW flow budget for the best fit transient model developed as part of the Mandalong Southern Extension Project (GHD, 2013c) for the peak year of groundwater make (2035) differ from the results presented in GHD (2016a) due to change in reporting of results for outcropping rock.

Table 6-1 Hydrogeological model predictions for proposed conditions

	2018		2036		2035 [1]	
	Alluvium and outcropping rock [2] (ML/year)	Rock (ML/year)	Alluvium and outcropping rock [2] (ML/year)	Rock (ML/year)	Alluvium and outcropping rock [2] (ML/year)	Rock (ML/year)
INPUTS						
Recharge	4,055	0	4,055	0	4,055	0
GHB [3]	1,326	351	1,323	349	1,466	628
Storage	5	368	1	733	82	2,291
Other zones	537	574	554	576	1,372	802
TOTAL INPUTS	**5,923**	**1,293**	**5,933**	**1,658**	**6,975**	**3,721**
OUTPUTS						
Drains [4]	3,606	384	3,835	752	5,944	2,246
GHB [3]	229	27	232	30	225	53
Storage	1,514	345	1,290	322	4	50
Other zones	574	537	576	554	802	1,372
TOTAL OUTPUTS	**5,923**	**1,293**	**5,933**	**1,658**	**6,975**	**3,721**

	2018		2036		2035 [1]	
	Alluvium and outcropping rock [2] (ML/year)	Rock (ML/year)	Alluvium and outcropping rock [2] (ML/year)	Rock (ML/year)	Alluvium and outcropping rock [2] (ML/year)	Rock (ML/year)
BALANCE						
Inputs – outputs	0	0	0	0	0	0

1. Results predicted as part of the approved Mandalong Southern Extension Project (GHD, 2013b).

2. Layer 1 of MODFLOW model.

3. General head boundary.

4. Transfer from alluvium to drains is baseflow. Transfer from fractured and porous rock to drains is inflow to mine workings.

Alluvial groundwater sources

Transient run 24 of the recalibrated hydrogeological model (best calibration under transient conditions) predicts that underground mining at Mandalong Mine (including the proposed extension to longwalls 22 and 23) is unlikely to result in a water table drop greater than 0.1 m within the alluvial groundwater throughout the period of mining. This prediction is based on no increase in the hydraulic conductivity of strata within the surface zone. Note that a head prediction of 0.1 m is considered to be the limit of accuracy of the model based on the limit of accuracy of observation groundwater level data used to calibrate the model.

The MODFLOW flow budget results, shown in Table 6-1, suggest that there is unlikely to be an increase in the movement of shallow groundwater within the surface strata (extending to a depth of 15 m bgl) to underlying aquifers as a result of the proposed and approved workings. The flow budget predicts a net gain of groundwater into alluvium from the fractured and porous rock strata. The flow budget indicates that recharge into alluvial sediments and groundwater flow from the fractured and porous rock aquifer will generally remain in storage within the alluvial sediments or discharge to creek lines or drainage lines as seepage. These modelled results are consistent with the EIS predictions (GHD, 2013a).

Fractured and porous rock groundwater sources

Figure 6-1 shows the total predicted groundwater inflows into the drained workings from transient run 24 (best fit from transient recalibration). Total groundwater inflows into the connected Cooranbong, Mandalong and Mandalong South workings are predicted to peak at approximately 2.1 ML/day in 2036. The peak predicted groundwater inflow is less than the peak groundwater inflow assessed as part of the approved Mandalong Southern Extension Project (GHD, 2013a), which is also presented in Figure 6-1. The predicted groundwater inflow is lower due to recalibration of the hydrogeological model as discussed in Section 4.2.2 and GHD (2016a).

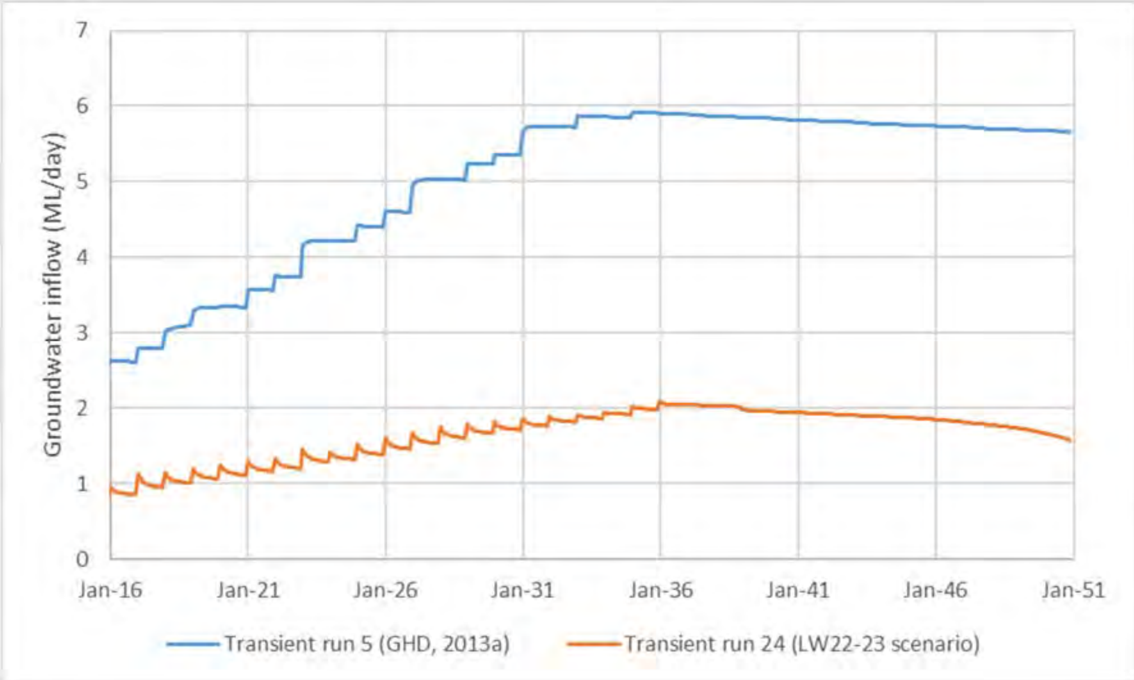


Figure 6-1 Modelled groundwater inflows into the Cooranbong, Mandalong and Mandalong South workings

The MODFLOW flow budget results for transient run 24 for current conditions (2016) (shown in Table 5-3), for end of mining of longwalls 22 and 23 (2018) and predicted maximum groundwater inflow (2036) indicate that between 2016 and 2036 modelled outputs into drains from fractured and porous rock aquifer increase. This increased output is due to an increase in groundwater inflows into the mine over time. The increase in groundwater inflows into the mine is offset by a decrease in net groundwater storage in the fractured and porous rock aquifer as shown in Table 6-1.

The hydrogeological model has been used to predict the depressurisation of fractured and porous rock groundwater sources overlying the proposed and approved Mandalong and Mandalong South workings.

Based on the results from transient run 24 of the recalibrated hydrogeological model, the predicted location of the 0.1 m drawdown contour within layer 6 of the hydrogeological model (overburden rock to a height of 50 m above the coal seam) at the completion of mining in 2037 is within approximately 3 km of the Mandalong workings. The predicted location of the 2 m drawdown contour within layer 6 of the hydrogeological model (overburden rock to a height of 50 m above the coal seam) at the completion of mining in 2037 is generally within 2 km of the Mandalong workings. The predicted 2 m drawdown contour is presented in Figure 6-2. The maximum predicted drawdown in the overburden within this zone of depressurisation is approximately 273 m which occurs at the southern extent of the Mandalong South workings.

Note that the drawdown predictions differ from the predictions presented as part of the approved Mandalong Southern Extension Project (GHD, 2013c), primarily due to recalibration of the model. The magnitude of drawdown also differs as the Mandalong Southern Extension Project presented the drawdown averaged over the 140 m of overburden directly above the mine workings. The predicted magnitude of drawdown presented as part of this assessment is focused on the 50 m of overburden directly above the workings. Compared to the groundwater drawdown predictions for the fractured and porous rock aquifer presented by GHD (2013c), groundwater drawdown predictions presented as part of this assessment are considered to be more reliable for estimating drawdown in the fractured zone immediately above the mine workings.

The predicted location of the 2 m drawdown contour within layer 6 of the hydrogeological model (overburden rock to a height of 50 m above the coal seam) at the completion of mining in 2037 is within approximately 1.8 km of longwalls 22 and 23. The maximum predicted drawdown (within overburden rock to a height of 50 m above the coal seam) above longwalls 22 and 23 is approximately 226 m.

6.2.3 Impacts to groundwater sources

Alluvial groundwater sources

The review of existing data at Mandalong Mine and the hydrogeological model both indicate that alluvial groundwater levels in the vicinity of longwall panels 22 and 23 should not reduce by more than the limit of accuracy of the hydrogeological model (i.e. 0.1 m) as a result of the proposed extensions to these longwall panels. This is minor compared to the typical climatic variation of approximately 1 m. Any reductions in alluvial groundwater levels are expected to be temporary and localised and may occur during undermining as a result of the development of shallow tensile and compressive cracks and resulting localised increases in hydraulic conductivity and porosity. It is expected that these cracks would fill over time and the hydraulic conductivity and porosity should return to pre-mining values.

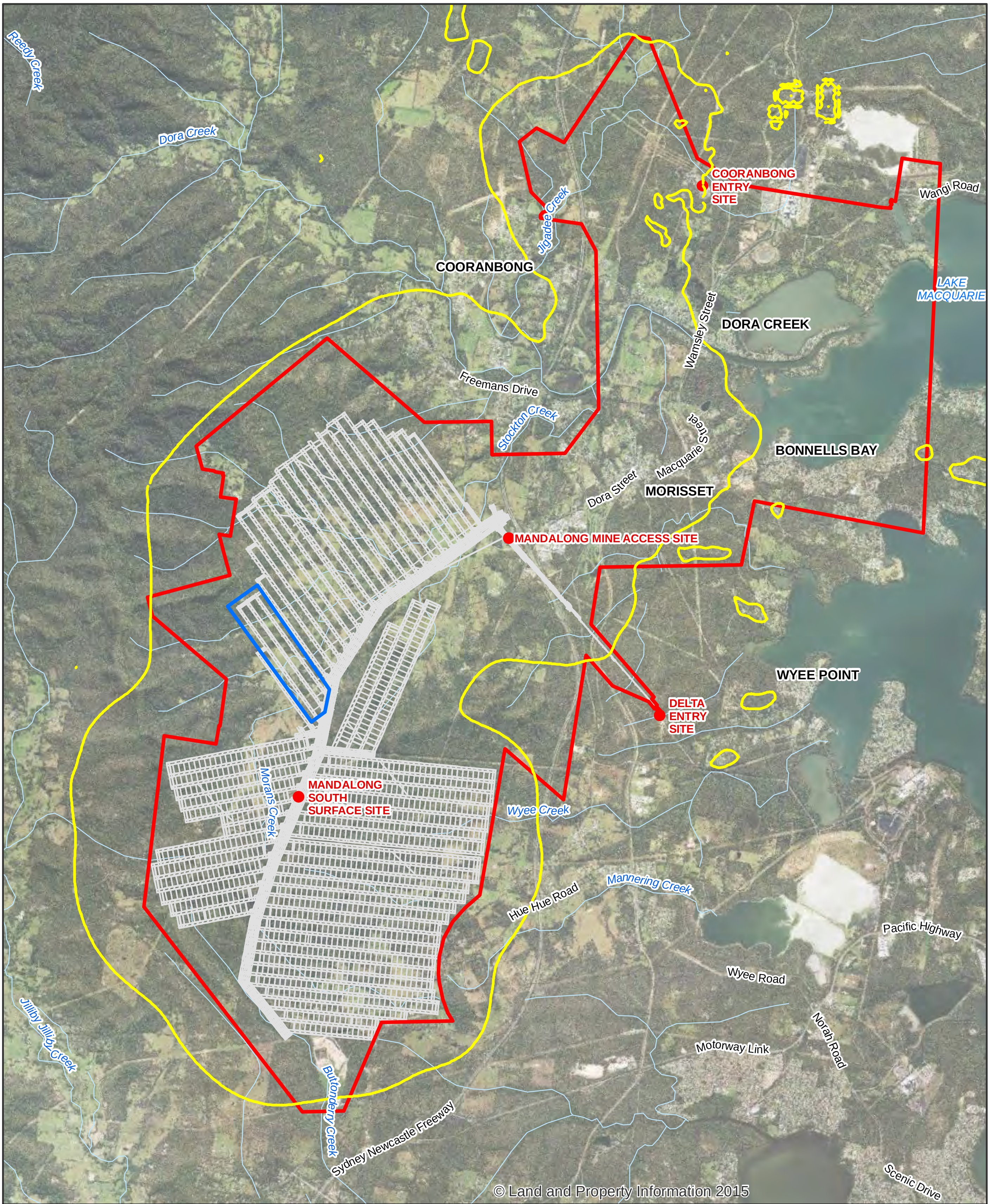
It is not expected that there would be an increase in the vertical migration of alluvial groundwater to underlying groundwater sources as a result of the proposed extension to longwall panels 22 and 23. It is noted that the temporary reductions in alluvial groundwater level at Mandalong Mine were generally at locations where the depth of cover is generally within 170 m. The depth of cover above the extended longwall panels 22 and 23 is greater than 250 m. Of the undermined alluvial bores with depth of cover approximately greater than 200 m (including BH07, BH08, BH09, BH10, BH11, BH12, BH13, BH14, BH22A, BH24A and BH25A) only BH24A and BH25A displayed any drawdown in groundwater level. Therefore, based on the hydrogeological model predictions and review of monitoring data, any reduction in alluvial groundwater level is considered to be unlikely in the vicinity of longwalls 22 and 23.

Based on existing groundwater quality data for Mandalong Mine, it is not expected that the proposed extension to longwalls 22 and 23 would reduce the beneficial use category (i.e. stock watering) of alluvial groundwater in the vicinity of longwalls 22 and 23.

Overall, the predicted impacts on alluvial groundwater within the vicinity of the proposed extension to longwalls 22 and 23 should be less than the Level 1 minimal impact considerations from the NSW Aquifer Interference Policy as outlined in Section 6.2.1 and are therefore considered acceptable.

Fractured and porous rock groundwater sources

The review of existing data at Mandalong Mine indicates that that depressurisation greater than 2 m of fractured and porous rock water sources in the vicinity of longwalls 22 and 23 may occur up to approximately 230 m above the proposed longwalls. The greatest depressurisation is likely to occur up to 120 m above the longwalls. Depressurisation within 120 m of the longwalls may be due to continuous fracturing with groundwater pressures in this zone potentially starting to stabilise or gradually recover at least three to five years after undermining. Depressurisation within heights greater than 120 m is likely to be due to discontinuous fracturing. It is noted that depth of cover above the proposed extension of longwalls 22 and 23 is approximately 250 m and therefore it is unlikely that there would be depressurisation of shallow rock aquifers (and associated potential GDEs) within this area.



1:100,000 for A4

0 500 1,000 2,000 3,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

LEGEND

- Site location
- Study area
- Approved Mine Workings
- Drawdown contour (2m)
- Project application area
- Watercourse

LOCATION	Mandalong
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment
Groundwater Drawdown Contour - Fractured and Porous Rock Groundwater Sources

Centennial Coal
Mandalong

DATE 5/10/2016

Figure 6-2

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\WRIA\LW22_23_MOD\2218510_WRIA017_GW_Drawdown_0.mxd

Data source: Commonwealth of Australia (Geoscience Australia): 250K Topographic Data Series 3, 2008. LPI:DCDB/Imagery, 2012/2015. Centennial: Mine workings, consent boundary, 2016. Created by: smacdonald, kpsroba

Based on the result of transient run 24 of the hydrogeological model, the 2 m drawdown contour extends to approximately 2 km from the Mandalong Mine workings. The 2 m drawdown contour extends to approximately 1.8 km of the proposed extension to longwalls 22 and 23. As discussed further in Section 6.4.1, it is not expected that there will be drawdown greater than 2 m at a private bore installed within the fractured and porous rock water source.

Loss of groundwater from the fractured and porous rock groundwater to the existing, proposed and approved Mandalong and Mandalong South workings is predicted to increase over the period of mining from 0.9 ML/day in 2016 to 2.1 ML/day in 2036.

Under the mining schedule modelled for the Project, mining of longwalls 22 and 23 commences in 2017 is completed in mid-2018. Modelled groundwater inflows are approximately 1.0 ML/day in 2017 and approximately 1.05 ML/day in 2018. Under the mining schedule modelled as part of Mandalong Tonnage Production Project (GHD, 2016a), mining of longwalls 22 and 23 is completed in 2017 and modelled groundwater inflows were estimated to be 0.93 ML/day. Noting that the rate of production differs between the two assessments, there is likely to be an increase in mine inflows in the order of 0.1 ML/day for 2017 and 2018 attributable to the extension of longwalls 22 and 23. Following completion of longwalls 22 and 23 there is modelled to be no ongoing observable increase in groundwater inflows into the mine workings attributable to the secondary extraction of the extended longwalls 22 and 23.

Based on existing groundwater quality data for Mandalong Mine, it is not expected that the proposed extension to longwalls 22 and 23 would reduce the beneficial use category of fractured and porous rock groundwater sources (i.e. primary industry) in the vicinity of Mandalong Mine.

Overall, the predicted impacts on fractured and porous rock groundwater sources attributable to the proposed extension of longwalls 22 and 23 should be less than the Level 1 minimal impact considerations from the NSW Aquifer Interference Policy as outlined in Section 6.2.1 and are therefore considered to be acceptable.

6.3 Surface water environment

6.3.1 Water and salt balance assessment

As discussed in Section 4.3.1, the water and salt cycle for Mandalong Mine was modelled for the projected life of the mine. The inputs to and outputs from the water management system were unchanged from the existing conditions, as discussed in Section 5.4.1. One additional input to the underground workings, from the Sediment Dam at MSSS, was modelled to occur under future conditions from 2017.

The predicted groundwater inflows that were obtained from hydrogeological modelling, presented in Figure 6-1, were incorporated into the water and salt balance model. Results presented for the proposed conditions are for 2018 (end of mining of longwalls 22 and 23) and 2036 (predicted maximum groundwater inflow). It should be noted that the groundwater inflows into the underground workings are predicted to vary over time, as shown in Figure 6-1.

Slight differences in some components of the modelling output between the conditions in 2016 (presented in Section 5.4.1) and 2036 and the conditions in 2018 are attributed to 2016 and 2036 being leap years (i.e. 366 days available) and 2018 not being a leap year (i.e. 365 days available). Therefore, an extra day of simulation is represented in the results for 2016 and 2036 compared to results for 2018.

Water balance results

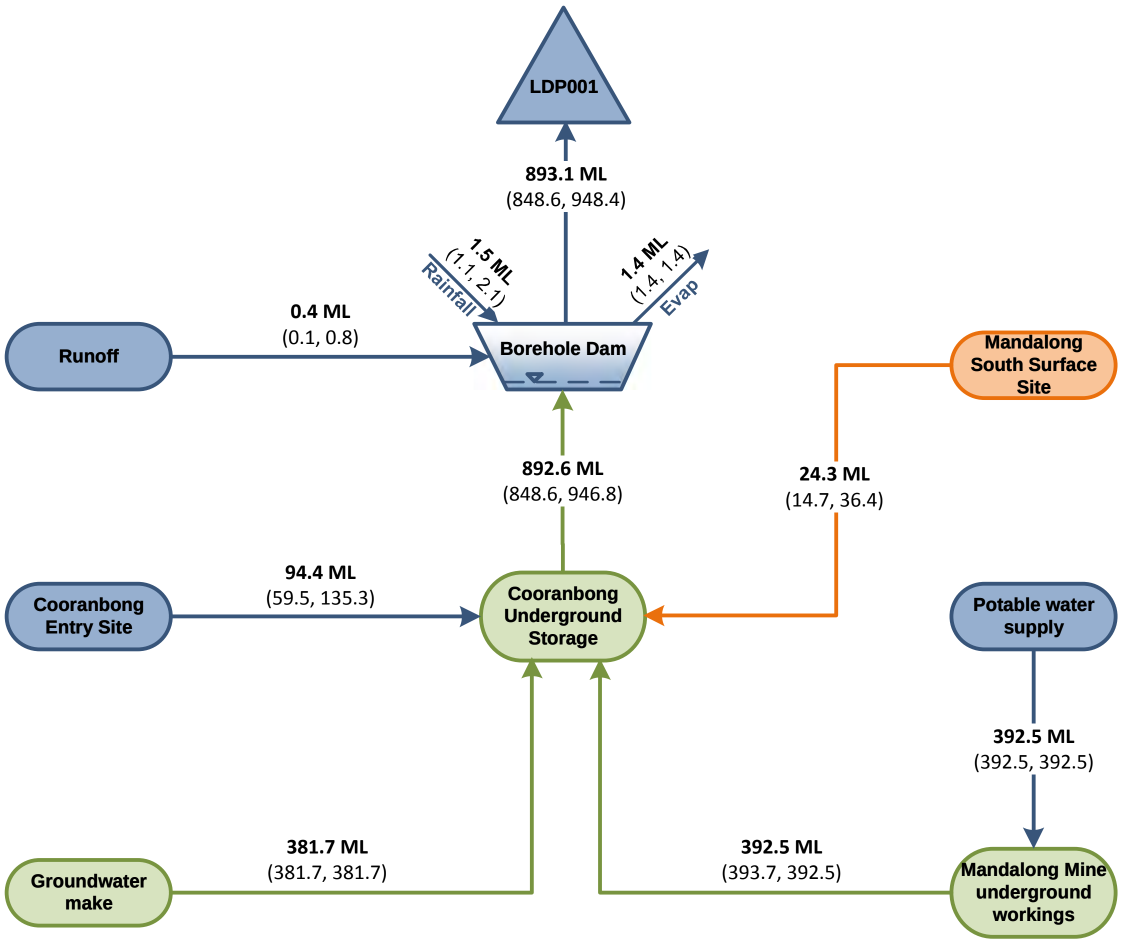
The predicted annual values for each of the water transfers under proposed conditions in 2018 and 2036 are presented in Figure 6-3 and Figure 6-4 respectively. Note that as the Project does not propose any changes to the surface water management at MMAS, MSSS or DES, these elements of the water cycle have not been presented.

From the results provided in Figure 6-3 and Figure 6-4, average annual inputs and outputs for the water balance under proposed conditions were summarised, as shown in . The results of the water balance predicted as part of the approved Mandalong Southern Extension Project (GHD, 2013b) for the year of peak groundwater make (2035) are also presented in for reference.

Table 6-2 Summary of average annual water inputs and outputs under proposed conditions

	Volume (ML/year)		
	2018	2036	2035 [1]
INPUTS			
Rainfall and catchment runoff	1.9	1.9	2.3
Transfer from CES to underground workings	94.4	94.6	57.3
Transfer from MSSS to underground workings	24.3	24.6	24.0
Potable water supply	392.5	393.7	365.0
Groundwater inflow into underground workings	381.7	750.5	2,158.4
TOTAL INPUTS (rounded)	**895**	**1,265**	**2,607**
OUTPUTS			
Evaporation	1.4	1.5	1.5
Discharge to LDP001	893.1	1,263.9	2,599.6
TOTAL OUTPUTS (rounded)	**895**	**1,265**	**2,601**
CHANGE IN STORAGE			
Borehole Dam	0.0	0.0	-0.1
Cooranbong underground storage	0.3	0.0	6.0
TOTAL CHANGE IN STORAGE (rounded)	**0**	**0**	**6**
BALANCE			
Inputs – outputs – change in storage	0	0	0

1. Results predicted as part of the approved Mandalong Southern Extension Project (GHD, 2013b).



GHD

Surface Water Transfer
Underground Water Transfer
Future Water Transfer
Storage

LOCATION	Cooranbong
SEAM	N/A
DRAWN	SM
CHECKED	TD
APPROVED	LH
SCALE	NTS

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

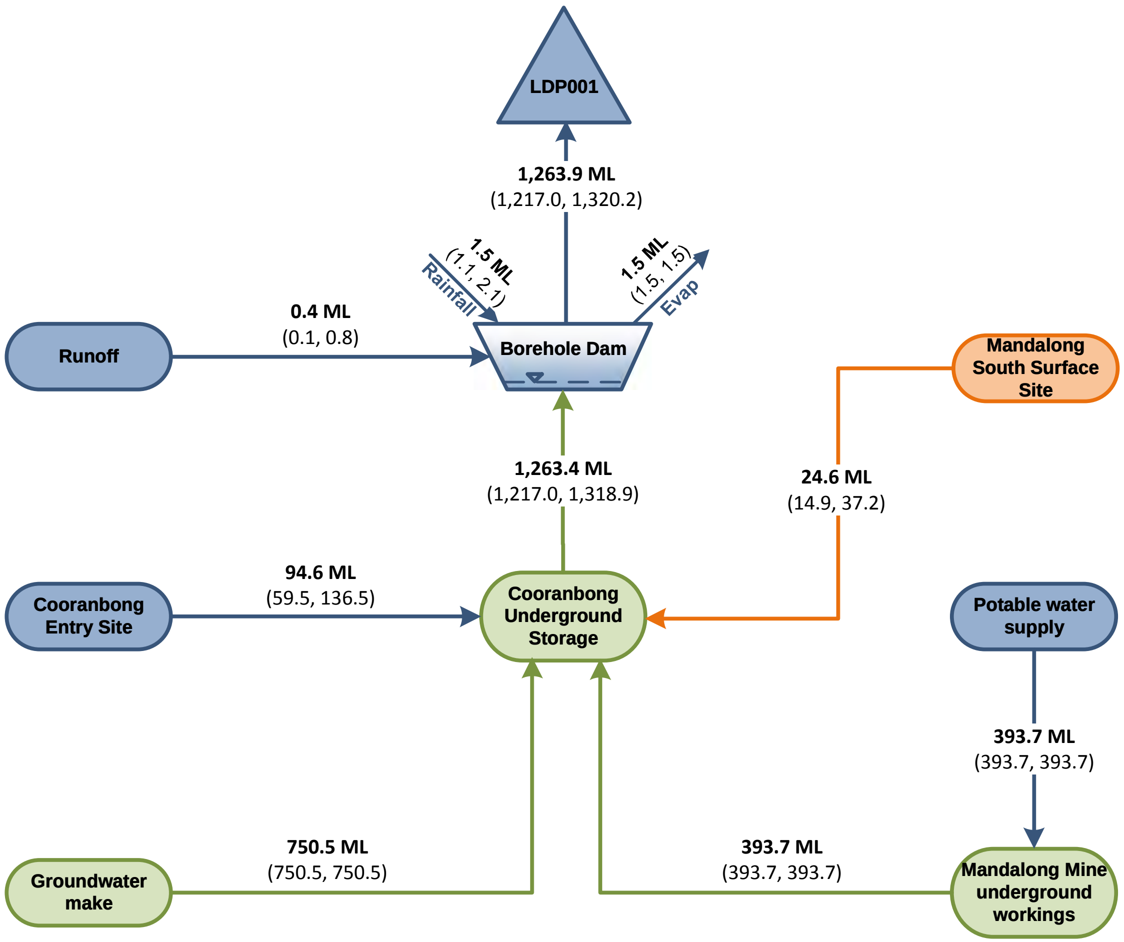
Annual water transfers
Proposed conditions (2018)

Centennial Coal

DATE Sep 2016

Figure 6-3

G:\22\18510\Tech\Visio\2218510_Cooranbong_WaterCycle_proposed_2018.vsdx



GHD

Surface Water Transfer
Underground Water Transfer
Future Water Transfer
Storage

LOCATION	Cooranbong
SEAM	N/A
DRAWN	SM
CHECKED	TD
APPROVED	LH
SCALE	NTS

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

Annual water transfers
Proposed conditions (2036)

Centennial Coal

DATE Sep 2016 | Figure 6-4

G:\22\18510\Tech\Visio\2218510_Cooranbong_WaterCycle_proposed_2036.vsdx

The water balance modelling results indicate that rainfall, runoff, evaporation, transfers from CES and potable water supply to the underground workings were predicted to be similar for existing and proposed conditions. The greatest change to the system is the predicted increase in groundwater make into the underground mining areas, which is estimated to peak in 2036 at approximately 751 ML/year.

The predicted increase in groundwater inflows will be managed through discharge from the Borehole Dam to LDP001 at CES. The average annual contribution of water from the Borehole Dam to LDP001 was predicted to be approximately 1,264 ML/year on average in 2036.

As shown in Figure 6-4, the volume of water transferred from the Cooranbong underground storage to the Borehole Dam at CES via the Cooranbong bore is predicted to peak in 2036 at 1,263 ML/year. This volume is less than the licensed extraction volume under WAL 39767 of 1,825 ML/year.

Figure 6-5 presents the percentiles of daily flow rates predicted to pass through LDP001 at CES under existing conditions in 2016 and proposed conditions in 2018 and 2036. The LDP001 discharge predicted as part of the approved Mandalong Southern Extension Project (GHD, 2013b) is also presented in Figure 6-5, for the year of predicted peak groundwater make in 2035. It should be noted that in addition to discharge from the Borehole Dam, overflows from Sediment Dam 2 at the CES also contributes to LDP001. However, the majority of LDP001 discharge is comprised of groundwater make, with less than 15 ML/year predicted to be discharged from Sediment Dam 2 (GHD, 2016a). The results presented in Figure 6-5 include the contribution of both the Borehole Dam and Sediment Dam 2 to LDP001. The current volumetric limit specified by EPL 365 for LDP001 of 5 ML/day is also shown in Figure 6-5.

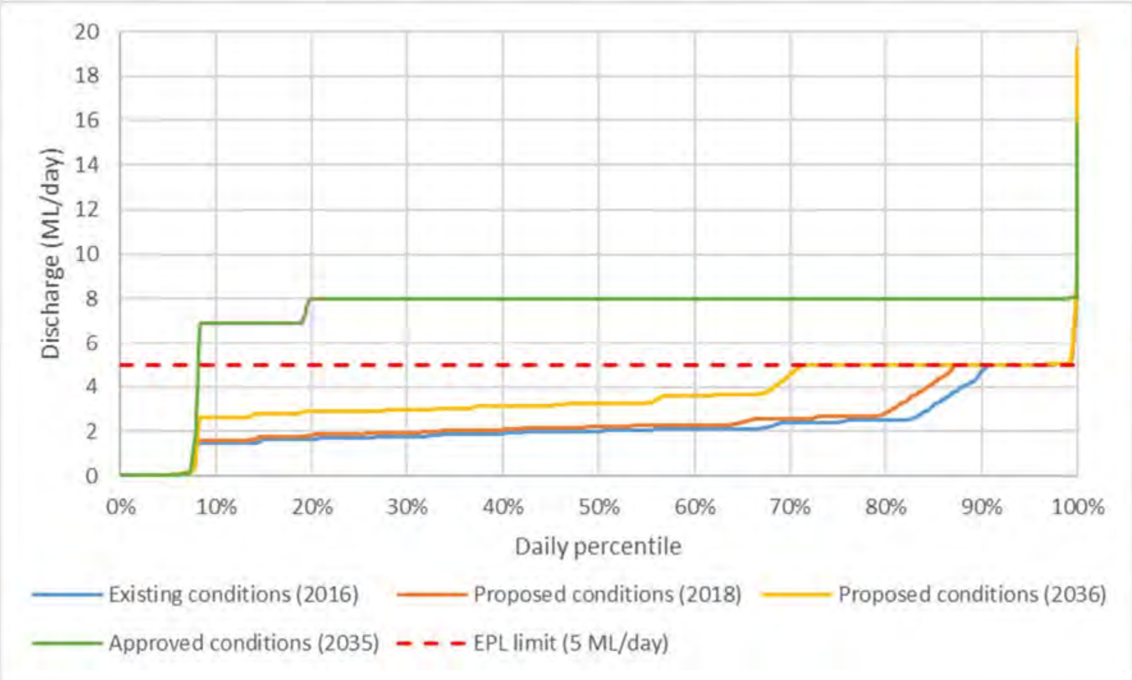


Figure 6-5 Predicted daily discharge from LDP001 at Cooranbong Entry Site

As shown in Figure 6-5, discharges of approximately 2 ML/day, consisting predominantly of groundwater, were modelled to occur for over 80% of days for both existing conditions in 2016 and proposed conditions in 2018. This discharge rate increases to up to 5 ML/day (volumetric limit for LDP001 specified by EPL 365) under proposed conditions in 2036. These rates are lower than the LDP001 discharge predicted as part of the approved Mandalong Southern Extension Project (GHD, 2013b), which was up to 8 ML/day. The predicted LDP001 discharge is lower due to the recalibration of the hydrogeological model, which has resulted in less groundwater required to be discharged via LDP001, as discussed in Section 6.2.2.

Discharge greater than 5 ML/day for the existing and proposed conditions are attributable to the variation in direct rainfall and runoff contributing to the Borehole Dam and Sediment Dam 2 at CES, due to the wide range of possible rainfall conditions modelled.

The maximum daily discharge for conditions in 2016, 2018 and 2036 was predicted to be approximately 19 ML/day. The maximum discharge was modelled to occur on less than 0.1% of days under both existing and proposed conditions.

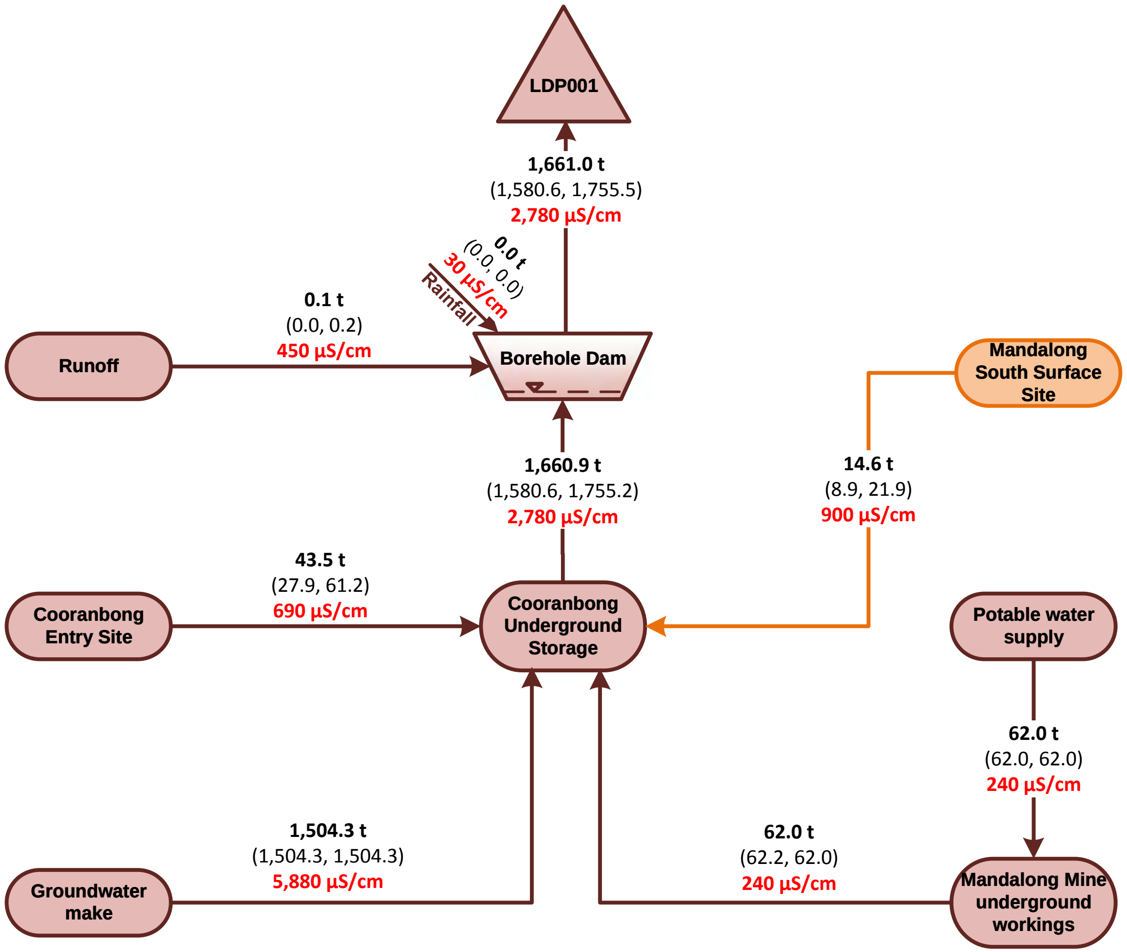
Salt balance results

The predicted annual values for each of the salt transfers under proposed conditions in 2018 and 2036 are presented in Figure 6-6 and Figure 6-7 respectively. From the results provided in Figure 6-6 and Figure 6-7, average annual inputs and outputs for the salt balance under proposed conditions were summarised, as shown in . The results of the salt balance predicted as part of the approved Mandalong Southern Extension Project (GHD, 2013b) for the year of peak groundwater make (2035) are also presented in for reference.

As with the results for the existing conditions presented in Section 5.4.1, the sources and sinks for the salt balance were broadly similar to the water balance. Salt associated with rainfall, runoff, transfers from CES and potable water supply to the underground workings were predicted to be similar for existing and proposed conditions.

The largest source of salt under proposed conditions is expected to be associated with groundwater inflows into underground workings, which accounts for approximately 1,504 tonnes in 2018 and 2,958 tonnes in 2036 on average. The average salinity of groundwater inflows was estimated to be 5,880 µS/cm.

Discharge from the Borehole Dam to LDP001 was predicted to increase to 1,661 t/year on average for 2018, with an average salinity of 2,780 µS/cm. Salt associated with LDP001 discharges from the Borehole Dam was predicted to peak in 2036 at 3,009 t/year on average, with an average salinity of 3,550 µS/cm. The predicted salt load discharged from the Borehole Dam to LDP001 as a result of the Project is significantly lower than the peak salt load of LDP001 discharge predicted as part of the approved Mandalong Southern Extension Project (GHD, 2013b), which was 8,583 t/year in 2035, with an average salinity of 4,970 µS/cm. This is a result of the lower predicted LDP001 discharge due to the recalibration of the hydrogeological model, which has resulted in less groundwater required to be discharged via LDP001, as discussed in Section 6.2.2.



GHD

Surface Water Transfer

Future Water Transfer

Storage

LOCATION	Cooranbong
SEAM	N/A
DRAWN	SM
CHECKED	TD
APPROVED	LH
SCALE	NTS

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

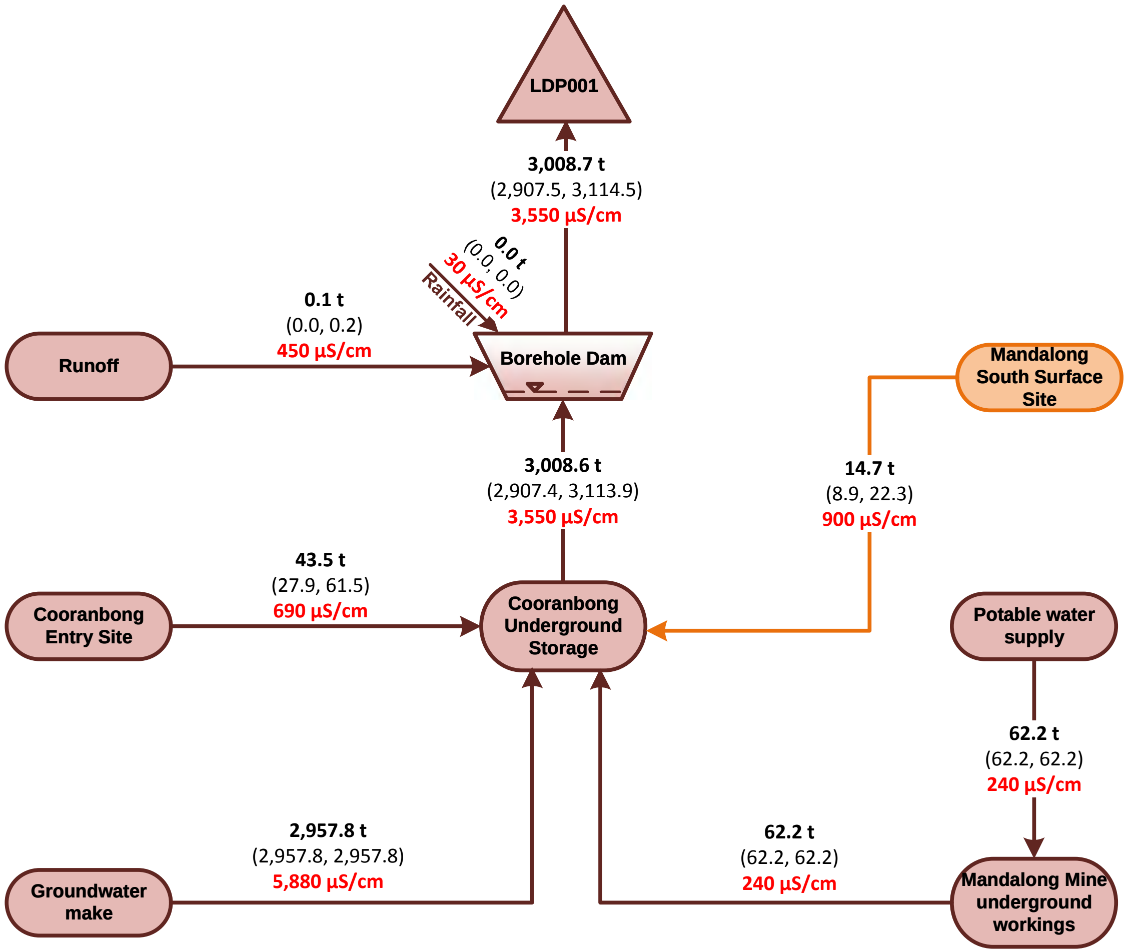
Annual salt transfers
Proposed conditions (2018)

Centennial Coal

DATE Sep 2016

Figure 6-6

G:\22\18510\Tech\Visio\2218510_Cooranbong_Salt_proposed_2018.vsdx



GHD

Surface Water Transfer

Future Water Transfer

Storage

LOCATION	Cooranbong
SEAM	N/A
DRAWN	SM
CHECKED	TD
APPROVED	LH
SCALE	NTS

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment

Annual salt transfers
Proposed conditions (2036)

Centennial Coal

DATE Sep 2016

Figure 6-7

G:\22\18510\Tech\Visio\2218510_Cooranbong_Salt_proposed_2036.vsdx

Table 6-3 Summary of average annual salt inputs and outputs under proposed conditions

	Mass (t/year)		
	2018	2036	2035 [1]
INPUTS			
Rainfall and catchment runoff	0.1	0.1	0.3
Transfer from CES to underground workings	43.5	43.5	34.7
Transfer from MSSS to underground workings	14.6	14.7	14.4
Potable water supply	62.0	62.2	57.7
Groundwater inflow into underground workings	1,504.3	2,957.8	8,506.1
TOTAL INPUTS (rounded)	**1,625**	**3,078**	**8,613**
OUTPUTS			
Discharge to LDP001	1,661.0	3,008.7	8,583.3
TOTAL OUTPUTS (rounded)	**1,661**	**3,009**	**8,583**
CHANGE IN STORAGE			
Borehole Dam	0.0	0.0	0.1
Cooranbong underground storage	-36.5	69.6	29.8
TOTAL CHANGE IN STORAGE (rounded)	**-37**	**70**	**30**
BALANCE			
Inputs – outputs – change in storage	0	0	0

1. Results predicted as part of the approved Mandalong Southern Extension Project (GHD, 2013b).

6.3.2 Flood assessment

Subsidence predictions

Figure 6-8 displays the maximum predicted subsidence contours within the study area for the Project. The maximum vertical subsidence prediction was 950 mm north of Longwall 23; however, predictions generally indicated 900 mm of subsidence within the northern areas after extraction of longwalls 22 and 23. The most significant subsidence impact predicted for proposed conditions compared to the approved conditions will be at the current approved northern limit of both longwalls 22 and 23. This location is approximately 582 m to the south-east of the proposed secondary extraction limit for Longwall 22 and 761 m to the south-east of the proposed secondary extraction limit for Longwall 23.

Overview of flooding impacts

The main impacts of the Project on flooding predicted by Umwelt (2016; refer Appendix A) are:

- A total of 20 structures had reduced freeboard as a result of predicted subsidence. Of these, 19 are private residences, with floors remaining above the 100 year ARI storm event level.
- An increase in flood hazard categories at six private structures during a 100 year ARI storm event.
- An increase in flood hazard categories along two private property access routes during the 100 year ARI storm event and three private property access routes during the 1 year ARI storm event.
- One section of Mandalong Road, near Deaves Road intersection, has been identified as requiring remediation measures to maintain the same degree of access during flooding as the pre-mining landform (identified in previous flood modelling assessments).
- Changes in flooding regimes for subsidence related to mining of longwalls 22 and 23 will be limited to the zone of predicted subsidence.
- Potential remnant ponding areas are predicted to increase both inside and outside of channel areas and will be isolated to zone of predicted subsidence.

Predicted changes to flooding regime

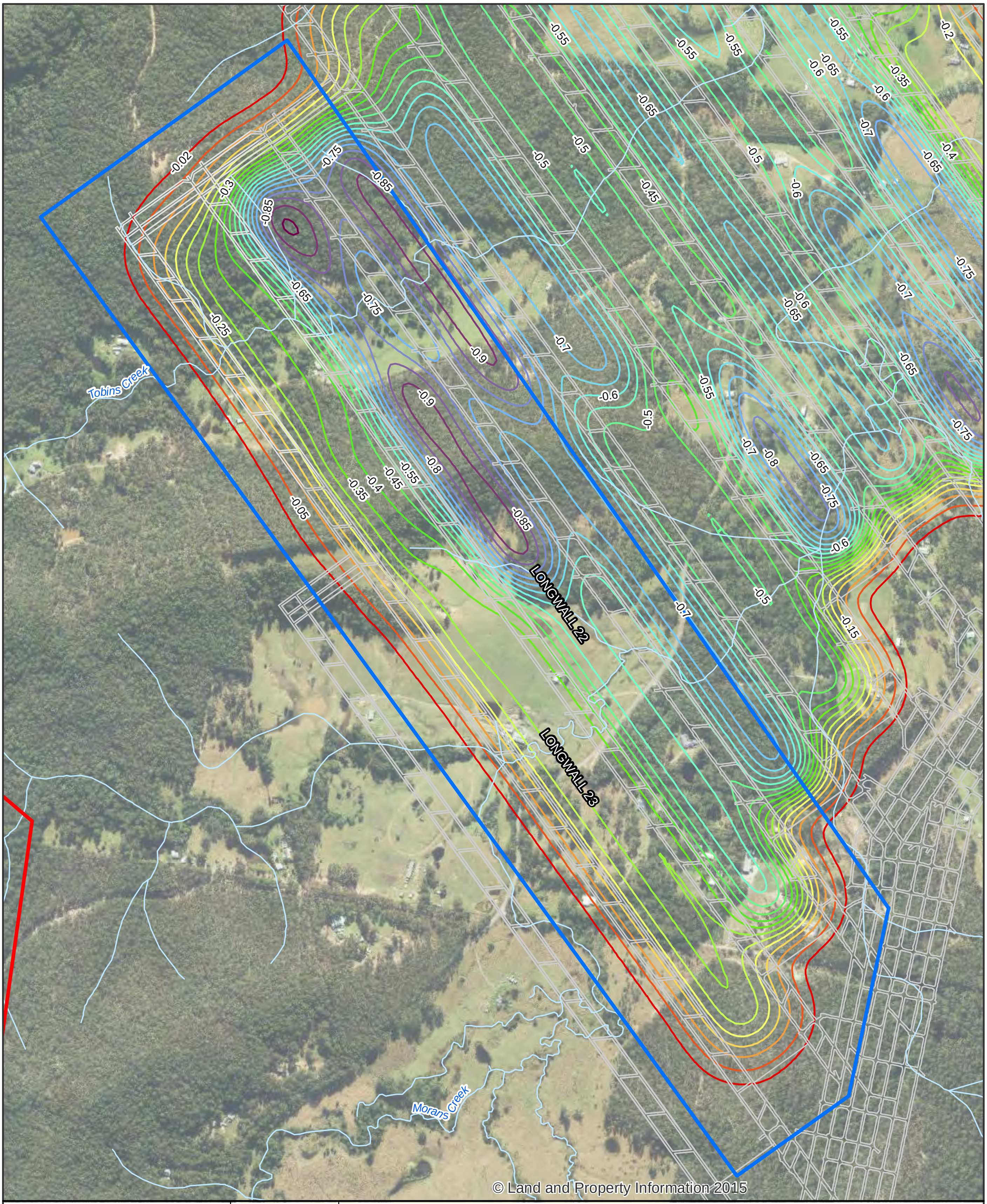
Umwelt (2016) predicted flood depths as a result of subsidence for longwalls 18 to 23. The predicted changes to flood behaviour are likely to be limited to the zone of predicted subsidence. Umwelt (2016) identified potential impacts to two specific channels that are relevant to longwalls 22 and 23. These include:

- Channel 2, Tobins Creek – within the study area this channel flows in an approximately north-east direction, parallel to the northern side of Tobins Road through a number of properties. The creek line crosses Prickly Ridge Road just north of the road's juncture with Tobins Road. Within the study area, the creek has an average grade of 0.33%, with an average modelled flood depth of 1.45 m in the 100 year ARI storm event.
- Channel 3, Morans Creek – within the study area Morans Creek flows in an approximately northerly direction through a number of properties east of Mandalong Road. Within the study area, the creek has an average grade of 0.28%, with an average modelled flood depth of 1.40 m in the 100 year ARI storm event.

Predicted changes to channel stability

Localised changes in grade as a result of subsidence impacts will be limited to channel sections downstream of chain pillars. In these areas, grade can change between 1% to 4%. As this will result in similar gradients to existing channels, the creation of new areas of in-channel ponding may occur. provides the predicted grade change within each impacted channel.

As indicated in , the greatest impact to Tobins Creek is expected to be as a result of mining longwall 21. The proposed extension of longwalls 22 and 23 are likely to result in less channel variation than that predicted in Longwall 21. There were some predicted changes to Morans Creek channel and negligible changes to the predicted grade change in other channels assessed by Umwelt (2016) as a result of the predicted subsidence from the proposed extension of longwalls 22 and 23.



1:12,000 for A4

0 50 100 200 300 400
Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geodetic Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

GHD

LEGEND
- Site location
- Study area
- Approved secondary extraction area
- Approved Mine Workings
- Waterway
- Project application area

LOCATION	Mandalong
DRAWN	K.S.
CHECKED	L.H.
APPROVED	S.G.
SCALE	refer to scalebar

Mandalong Longwall Panel 22 to 23 Modification
Water Resources Impact Assessment
Subsidence Predictions
For Longwalls 22 and 23

Centennial Coal
Mandalong

DATE 5/10/2016

Figure 6-3

GIS Filename: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\WRIA\LW22_23_MOD\2218510_WRIA013_Subsidence_0.mxd

Data source: LPI:DCDB, 2012. Centennial: Mine workings, Extraction area, consent boundary, Subsidence prediction, 2016. GSS, Imagery. Created by: smacdonald, kpsroba

Table 6-4 Predicted grade change for potentially impacted drainage channels (Umwelt, 2016)

Drainage channel	Channel length (m)	Max. predicted subsidence (mm) and location	Average predicted grade change (%) (pre-mining and subsidence)	Max predicted grade change (%) (pre-mining and subsidence) and location
Channel 2, Tobins Creek	2,094	920 Longwall 21	-0.02% (0.38% to 0.36%)	3.14% (0.04% to 3.18%) (Longwall 21)
Channel 3, Morans Creek	1,527	824 Longwall 19	0.05% (0.23% to 0.28%)	1.41% (0.92% to 2.33%) (Longwall 19)

Umwelt (2016) did not consider there to be any significant alterations to flow capacity of the primary channels within the study area or potential for channel realignments as a result of subsidence due to the Project. Predicted channel velocities for pre-mining and subsided modelling scenarios indicated no significant difference in maximum results. Outside channels, flow paths presented a flow risk of erosion, given the limited exposed soil and significant groundcover present within the study area.

Predicted changes to ponding

Umwelt (2016) predicted an increase to remanent ponding areas as a result of underground mining of longwalls 22 to 23 compared to pre-mining conditions. Areas at risk of remanent ponding are those within the zone of predicted subsidence for longwalls 22 and 23 or earlier stages of mining. Success in mitigating remanent ponding has been achieved in road side areas near Deaves Road and Mandalong Road intersection.

Biophysical strategic agricultural land

Biophysical strategic agricultural land (BSAL) is land with high quality soil and water resources capable of sustaining high levels of productivity. BSAL has been mapped by DPE within the valley of Morans Creek upstream of the Study Area. Umwelt (2016) has predicted no change to flood conditions in this BSAL area as a result of the Project.

6.3.3 Waterway geomorphology

Given the nature of channels within the study area, the resilience to subsidence as a result of the Project is high. The geomorphic field investigation identified only one area of risk due to the predicted subsidence as a result of the Project. This area was within the Tobins Creek channel, where a headcut is located within approximately the centre of Longwall 23. Given the location of the headcut, it is likely to be maintained as a result of the Project and is unlikely to be promoted. However, regular monitoring will be undertaken as part of the current visual inspections of flow paths by Mandalong Mine.

6.3.4 Surface water quality

Guideline values

SSGVs have been derived for the Project based on a review of the DGVs presented by ANZECC (2000) and the 80th percentile values for water quality data collected at monitoring locations SWMP06 and SWMP07. Table 6-5 presents the recommended SSGV, as well as the DGVs and 80th percentile results for SWMP06 and SWMP07.

The 80th percentile values for water quality data at SWMP06 and SWMP07 has been calculated from the entire dataset available between June 2011 and June 2016. As samples have been collected for over two years, the dataset covers a range of seasonal, climatic and flow conditions.

Table 6-5 Recommended guideline values for the Project

Parameter	Units	DGV	SWMP06 80th percentile	SWMP07 80th percentile	Recommended SSGV
Physicochemical parameters					
EC	µS/cm	200	940	755	940
pH	pH units	6.5–9.0	6.2[1]–6.7	6.5[1]–7.0	6.2–9.0
TSS	mg/L	6	47	16	47
Turbidity	NTU	6	58	53	58
Nutrients					
Ammonia	mg/L	0.9	0.07	0.15	0.9
Total nitrogen	mg/L	0.35	1.18	1.52	1.52
Total phosphorus	mg/L	0.025	0.08	0.11	0.11
Dissolved metals					
Aluminium	mg/L	0.055	0.70	0.78	0.78
Arsenic	mg/L	0.024	0.001	0.001	0.024
Barium	mg/L	–	0.083	0.066	0.083
Boron	mg/L	0.37	0.05	0.05	0.37
Cadmium	mg/L	0.0002	0.0001	0.0001	0.0002
Chromium	mg/L	0.001	0.001	0.001	0.001
Cobalt	mg/L	0.0025	0.009	0.001	0.009
Copper	mg/L	0.0014	0.001	0.002	0.002
Iron	mg/L	0.3	3.61	3.11	3.61
Lead	mg/L	0.0034	0.001	0.001	0.0034

Parameter	Units	DGV	SWMP06 80th percentile	SWMP07 80th percentile	Recommended SSGV
Manganese	mg/L	1.9	0.828	1.744	1.9
Mercury	mg/L	0.0006	0.0001	0.0001	0.0006
Nickel	mg/L	0.011	0.006	0.004	0.011
Selenium	mg/L	0.011[2]	0.01	0.01	0.011
Silver	mg/L	0.00005	0.001	0.001	0.001
Zinc	mg/L	0.008	0.007	0.006	0.008
Other parameters					
Cyanide (total)	mg/L	0.004	0.004	0.004	0.004

1. 20th percentile value.
2. Guideline value for total selenium.

Impacts to surface water quality

There are not expected to be any changes to surface water quality at MMAS, MSSS or DES or the water quality of LDP001 discharge at CES as a result of the Project compared to the surface water quality assessed as part of the approved Mandalong Southern Extension Project (GHD, 2013d).

Localised changes to water quality, including elevated levels of TSS and turbidity, may occur due to the mobilisation of sediments caused by changes to the surface as a result of subsidence. However, these changes are expected to be negligible (not measurable) and temporary. It is expected that the environmental value of the surface water will be maintained.

6.4 Downstream water users

6.4.1 Groundwater users

Alluvial groundwater sources

As discussed in Section 6.2.3, it is unlikely that there will be any reduction in alluvial groundwater level or reduction in the beneficial use category (i.e. stock and watering) of alluvial groundwater as a result of the Project.

Any impacts on potential GDEs (noting that there are no high priority GDEs in the vicinity of the proposed extension to longwalls 22 and 23 listed in the HUA WSP), basic landholder rights and existing registered bores (noting that no registered alluvial bores are located in the vicinity of the proposed extension to longwalls 22 and 23) are expected to be minor and acceptable under the Level 1 minimal impact considerations from the NSW Aquifer Interference Policy.

Fractured and porous rock groundwater sources

Registered bores (excluding monitoring and test bores) installed within the fractured and porous rock aquifer and located within the predicted radius of depressurisation (based on a drawdown of more than 0.1 m in the 50 m fracture zone above the mine workings) from all historical and future mine workings at Mandalong are listed in Table 6-6.

Table 6-6 Stock and domestic fractured and porous rock bores installed within radius of drawdown

Bore	Easting	Northing	Depth	Licence status	Authorised purpose	Strata	Approx. depth of cover to seam (m bgl)
GW015287	351406	6335997	44.1	Active	Stock, irrigation	–	250
GW033618	358945	6343594	30.4	Active	Stock	Sandstone, shale	50
GW033619	359049	6343596	21.3	Active	Stock	Sandstone, shale	40
GW034950	356963	6335463	76.2	Active	Stock, domestic	Conglomerate	150
GW052111	359475	6339227	49	Active	Stock	Conglomerate, sandstone	50
GW052255	356445	6333638	114	Active	Stock	Shale, Conglomerate	170
GW053438	359235	6339686	53	Lapsed	Stock, irrigation, domestic	Shale	50
GW054183	352923	6335126	18.3	Active	Domestic	–	250
GW056862	356600	6337214	45	Active	Stock, domestic	–	130
GW057310	356467	6342726	61	Active	Stock, domestic, farming	Shale	110
GW060965	354299	6338505	33.6	Active	Stock, domestic	Shale	200
GW062618	358931	6337371	34.5	Active	Domestic	–	90
GW064033	357483	6338921	49.4	Active	Stock, domestic	Sandstone	100
GW064116	356486	6339677	21.3	Active	Stock, domestic	Sandstone	130
GW078043	351532	6332856	33	Active	Stock, domestic	Sandstone	270
GW078084	357181	6334696	62	Active	Stock, domestic	Sandstone	140

Bore	Easting	Northing	Depth	Licence status	Authorised purpose	Strata	Approx. depth of cover to seam (m bgl)
GW078601	354731	6332103	18.85	Active	Stock, domestic	Weathered sandstone	190
GW078608	359054	6338132	60	Active	Stock, domestic	–	80
GW105311	351296	6333045	198	Abandoned	Stock, domestic	–	310
GW200915	357208	6335014	60	Active	Stock, domestic	–	140

Of the bores presented in Table 6-6, only GW078601, GW054183, GW078043 and GW105311 are located within 2 km of longwalls 22 and 23 (the extent of the 2 m drawdown contour for overburden up to 50 m above the mine workings). Bores GW054183 and GW078043 are located over 230 m above of the coal seam and therefore, based on the review of monitoring data at Mandalong Mine, it is not anticipated that aquifer depressurisation will exceed 2 m at these locations. Bore GW105311 is abandoned and therefore potential drawdown at this location has not been assessed.

Bore GW078601 is located approximately 170 m above the mine workings. At the end of mining of longwall 23, at the location of GW078601, drawdown within layer 3 of the hydrogeological model (overburden rock to a height of 180 m above the coal seam) is approximately 0.9 m. Therefore, drawdown attributable to longwalls 22 and 23 at GW078043 is not anticipated to exceed 2 m.

As discussed in Section 6.2.3, it is unlikely that there will be any reduction in the beneficial use category (i.e. primary industry) of fractured and porous rock groundwater as a result of the Project. The predicted impacts on fractured and porous rock groundwater sources are therefore less than the Level 1 minimal impact considerations from the NSW Aquifer Interference Policy.

6.4.2 Surface water users

The Project is not expected to result in any measurable impacts to water quantity or quality downstream of the Project, as discussed in Section 6.3. Adverse impacts to downstream water users are unlikely to occur as a result of the Project due to the low risk of potential impacts and the ephemeral nature of waterways.

7. Mitigation, management and monitoring

7.1 Mitigation and management measures

A regional water management plan (GHD, 2016c) has been developed to provide an overview of the water management requirements across Centennial's northern operations. A site-specific water management plan for Mandalong Mine (GHD, 2016d) has also been developed to address specific water management requirements for the site. An extraction water management plan will also be developed prior to extraction of longwalls 22 and 23.

The water management plans ensure the operation of the mine, with respect to water, meets all relevant regulatory requirements. The regional water management plan and site-specific water management plan will be considered for review every three years or as a result of any regulatory requirements, any significant changes to water management practices or the development of any new mining areas.

Trigger action response plans (TARPs) are provided in the water management plan (GHD, 2016d) and will also be developed for the extraction water management plan for longwalls 22 and 23. These TARPs should be referenced to determine the appropriate actions in response to any impacts of the Project identified as part of the monitoring program. Generally, responses include investigation and monitoring, determination of the risk of impact and remedial measures to be implemented. The TARPs also include reporting, training and personnel responsibilities.

7.2 Monitoring

A comprehensive groundwater and surface water monitoring program has been developed by Mandalong Mine. The water management plan (GHD, 2016d) provides the details of the groundwater and surface water monitoring programs, which will also be provided in the extraction water management plan for longwalls 22 and 23. Monitoring includes groundwater level and quality and surface water quality, flow and watercourse stability. The main objective of monitoring is to ensure that water management measures implemented function as designed.

7.3 Reporting and reviews

Reporting at Centennial involves a number of internal and external reporting procedures that comply with regulatory and operational requirements. For Mandalong Mine, reporting includes an annual review, an annual return for EPL 365, results of environmental monitoring, incident reporting and complaints record.

The dewatering bore that extracts water from the Cooranbong Underground Storage area into the Borehole Dam was previously licensed under the *Water Act 1912* (bore licence 20BL173524). An annual groundwater report was required by the bore licence, which includes a calculation of the annual groundwater take from the fractured and porous rock groundwater sources. The bore licence held under the *Water Act 1912* has recently been converted to WAL 39767 under the NCFPR WSP. No requirements are currently specified by WAL 39767; however, it is expected that the annual compliance report will continue to be required.

The hydrogeological model for Mandalong Mine will be reviewed and revised every three years, including a comparison of monitoring results with modelling predictions. Similarly, the water and salt balance model for Mandalong Mine will be reviewed and revised annually as a minimum or as necessary when there are changes to operations.

8. Summary

The WIRA considers the overall groundwater and surface water management systems associated with Mandalong Mine and the potential impacts of the Project on groundwater and surface water environments under future conditions. The assessment of potential impacts of the proposed mining activities considered the following:

- Groundwater levels and quality.
- Water and salt balance.
- Flooding.
- Waterway geomorphology.
- Surface water quality.
- Downstream water users, including licensed water users and basic landholder rights.

A summary of the existing conditions and potential impact under proposed conditions are outlined in Table 8-1.

Table 8-1 Summary of potential impacts

Component	Existing conditions	Potential impacts
Groundwater levels	• Significant relationship between alluvial groundwater level and CRD. • No clear change in alluvial groundwater levels due to mining. • Some variation in fractured and porous rock groundwater levels due to CRD. • Depressurisation of fractured and porous rock groundwater occurs up to 230 m above longwall panels. A number of monitoring locations have shown stabilisation or increase towards pre-mining levels. • Groundwater inflows in underground mine workings predicted to be 326 ML/year (average 0.9 ML/day).	• Mining unlikely to result in a water table drop greater than 0.1 m within the alluvial groundwater. • Groundwater inflows into the underground mine workings predicted to increase to a peak of 751 ML/year (average 2.1 ML/day) in 2036. • An increase in mine inflows in the order of 0.1 ML/day for 2017 and 2018 is attributable to the extension of longwalls 22 and 23. Following completion of longwalls 22 and 23 there is modelled to be no ongoing observable increase in groundwater inflows into the mine workings attributable to the extension of longwalls 22 and 23. • Maximum predicted drawdown within the overburden up to 50 m above proposed longwalls is 226 m. • Depressurisation greater than 2 m of fractured and porous rock groundwater may occur up to 230 m above proposed longwalls. • Predicted 2 m drawdown area is within 1.8 km of longwalls 22 and 23.
Groundwater quality	• Alluvial groundwater pH ranged from 5 to 8 and EC ranged from less than 1,000 µS/cm to over 10,000 µS/cm. • Fractured and porous rock groundwater pH ranged from 6 to 8 and EC ranged from 6,000 µS/cm to over 10,000 µS/cm. • No change is evident in alluvial or fractured and porous rock groundwater pH or EC due to mining.	• Project is not expected to change the beneficial use category of alluvial or fractured and porous rock groundwater.

Component	Existing conditions	Potential impacts
Water and salt balance	• Largest source of water was predicted to be potable water supply, inputting 394 ML/year on average. • Discharge from Borehole Dam to LDP001 predicted to be 814 ML/year on average. • Largest source of salt predicted to be associated with groundwater inflows, inputting 1,283 t/year on average (average EC of 5,880 µS/cm). • Discharge of salt from Borehole Dam to LDP001 predicted to be 1,564 t/year (average EC of 2,870 µS/cm).	• Largest source of water was predicted to be groundwater inflows, which peak at 751 ML/year in 2036. • Discharge from Borehole Dam to LDP001 predicted to increase to 1,264 ML/year on average in 2036. This is attributable to the life of mine workings and not the extension of longwalls 22 and 23 alone. This is lower than the LDP001 discharge predicted as part of the approved Mandalong Southern Extension Project (GHD, 2013b). • Largest source of salt predicted to be associated with groundwater inflows, inputting 2,958 t/year on average (average EC of 5,880 µS/cm). • Discharge of salt from Borehole Dam to LDP001 predicted to be 3,009 t/year (average EC of 1,010 µS/cm).
Flooding	• Morans Creek flow width between 500 m and 750 m in a 100 year ARI storm event. Flow depths up to 1 m outside of the main channel. • Tobins Creek flow width between 75 m and 200 m in a 100 year ARI storm event. • Flood hazard varied from low to high categories.	• Reduction in freeboard at some properties. • Increase in flood hazard at some properties. • Changes in flooding regimes predicted to be limited to zone of predicted subsidence. • Increase in potential remnant ponding areas predicted to be limited to zone of predicted subsidence.
Waterway geomorphology	• Morans Creek and Tobins Creek were classified as fine-grained meandering systems. • Banks are typically well-vegetated with low bank erosion. • Channel beds have the potential to incise through headcuts. A low headcut in the order of 0.2 m was observed along Tobins Creek.	• Resilience of waterways to subsidence is high. • Headcut observed along Tobins Creek identified as only area of risk; however, it is unlikely to be promoted as a result of the Project.

Component	Existing conditions	Potential impacts
Surface water quality	• Fresh waters with EC in the range of 150 µS/cm to 1,000 µS/cm. • Neutral to slightly acidic pH. • Concentrations of ammonia, some dissolved metals, fluoride, cyanide and oil and grease below LOR and/or DGVs. • Concentrations of total nitrogen, total phosphorus and some dissolved metals (aluminium, cobalt and iron) were elevated and generally above DGVs.	• Low risk of localised changes due to mobilisation of sediments. • Changes expected to be negligible and temporary.
Downstream water users	• Total of 127 bores identified in a 5 km radius of the Mandalong Mine workings, with the majority registered as monitoring/test bores. • Potential vegetation GDEs identified along the reaches of Morans Creek and Tobins Creek. • Total of 14 lots identified as licensed for surface water extraction, with the majority registered for irrigation. • No basic landholder rights were identified.	• Impacts to alluvial and fractured and porous groundwater less than the Level 1 minimal impact considerations. • Adverse impacts to downstream water users are unlikely to occur as a result of the Project.

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