

Airly Mine Extension Project

Aquatic Ecology and Stygofauna Assessment

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Glossary

AIA	Aquifer Interference Activity
ANZECC/ARMCANZ	Australian and New Zealand Environment and Conservation Council / Agriculture and Resource Management Council of Australia and New Zealand
Aquiclude	A solid, impermeable geological unit underlying or overlying an aquifer.
Aquifer	A groundwater resource contained within a geological unit.
Aquitard	A geological unit of low permeability along an aquifer that is restrictive to the flow of groundwater.
AUSRIVAS	Australian River Assessment System
CAA	Controlled Activity Approval
Catadromous	Fish which migrate from freshwater to estuarine and marine habitats to spawn.
Centennial Coal	Centennial Coal Company Limited
CHPP	Coal Handling and Preparation Plant
COI	Commission of Enquiry
CRMP	Closure and Rehabilitation Management Plan
DECCW	The former Department of Environment, Climate Change and Water
DGRs	Director General's Requirements
Diadromous	Fish for which both marine and freshwater habitats are an integral part of the life cycle.
DP&I	Department of Planning and Infrastructure
DPC	Department of Premier and Cabinet
DPI	Department of Primary Industries
DSEWPC	The former Commonwealth Department of Sustainability, Environment, Water, Population and Communities, now the Department of the Environment
DTIRIS	Department of Trade and Investment, Regional Infrastructure and Services, the former Department of Industry and Investment NSW (I&I)
EEC	Endangered Ecological Community
EIS	Environmental Impact Statement
<i>EP&A Act</i>	<i>Environmental Planning and Assessment Act 1979 (NSW)</i>
EP&A Regulation	<i>Environmental Planning and Assessment Regulation 2000 (NSW)</i>
<i>EPBC Act</i>	<i>Environmental Protection and Biodiversity Conservation Act 1999 (Commonwealth)</i>
Ephemeral	Temporary flow, usually following rainfall
Epigeal	Above the soil surface
<i>FM Act</i>	<i>Fisheries Management Act 1994 (NSW)</i>
Gaining streams	Streams that gain water from interflow as opposed to losing it to the surrounding soil and substratum. In other words, streams where the water table is above the stream water level. Also known as effluent streams.
GDE	Groundwater Dependent Ecosystem
Hyporheic	The aqueous zone of interaction between surface water and groundwater.
I&I NSW	The former NSW Department of Industry and Investment
Interburden	Material lying between two zones of economic or scientific interest.
Interflow	Water flowing through the ground below surface flow but above groundwater flow.

KTP	Key Threatening Process
LGA	Local Government Area
MNES	Matter of National Environmental Significance.
NOW	NSW Office of Water
Noxious	Organisms (flora and fauna) designated under state and federal legislation as harmful to agriculture, fisheries, public health and/or native species, populations and communities.
OEH	Department of Environment and Heritage
Overburden	Material overlying the resource of economic or scientific interest.
Phreatic	The area of an aquifer below which all pores and fractures are saturated with water, this lying beneath the vadose zone, where pores are unsaturated. These zones and the boundary between them can be dynamic and fluctuate according to seasonal variation and disruption events.
Phreatophyte	A plant that obtains a vital amount of water from the phreatic zone.
<i>POEO Act</i>	<i>Protection of the Environment Operations Act 1997(NSW)</i>
Project Application Area	The Project Application Area covered by Mining Lease ML1331 and Authorisation Area A232
ROM coal	Run-of-Mine coal
SIGNAL2	Stream Invertebrate Grade Number – Average Level
SSTV	Site Specific Trigger Value
Strahler method	A method of stream ordering whereby the sources of watercourses in the upper catchment are given a stream order of one and the meeting of two first order streams designates a second order stream downstream of their confluence. Using this method, a third order stream is only created at the joining of two second order streams, not the joining of first and second order streams. Classification of higher stream orders also uses this convention.
The Project	The Airly Mine Extension Project
<i>TSC Act</i>	<i>Threatened Species Conservation Act 1995 (NSW)</i>
<i>WM Act</i>	<i>Water Management Act 2000 (NSW)</i>

Executive Summary

Centennial Airly Pty Limited (Centennial Airly) commissioned Cardno to prepare an Aquatic Ecology Impact Assessment to support the Environmental Impact Statement (EIS) for the Airly Mine Extension Project (the Project). Centennial Airly proposes to extend its existing underground mining operations at Airly Mine into the eastern section of its existing Mining Lease ML1331 and within its Authorisation No.232 (A232) situated to the east and north-east of ML1331 (the Project Application Area).

The scope of works for the Aquatic Ecology and Stygofauna Assessment was determined by the requirements of Centennial Airly and the requirements of the Commonwealth Department of the Environment (the former Federal Department of Sustainability, Environment Water, Population and Communities (DSEWPAC)), NSW Department of Planning and Infrastructure (DP&I), NSW Office of Water (NOW) and NSW Office of Environment and Heritage (OEH) in the preparation of an EIS. This report contains sections on legislative requirements, policies and guidelines and conservation issues that are relevant to the Project, information on the existing environment, potential impacts that may occur during the Project and appropriate mitigation measures.

Proposed Project

The Project would involve continuation and extension of the existing underground coal mine using bord and pillar mining and panel and pillar extraction techniques and utilisation of existing surface infrastructure. A coal preparation plant (washery), a rejects emplacement area and other mine and water management infrastructure would be constructed. Underground access headings and roadways would also be developed from the current mining area to the proposed mining areas. Run-of-mine coal would be transferred from underground workings via the existing conveyor system. Beneficiated (processed) coal would be transported to market by rail. Decommissioning and rehabilitation of the site would commence following resource extraction.

Legislative Requirements

The major legislative requirements that are relevant to the Project are the NSW *Environmental Planning and Assessment Act 1979 (EP&A Act)* under which the proposed mine extension will be assessed are, the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)*, NSW *Threatened Species Conservation Act 1995 (TSC Act)* and NSW *Fisheries Management Act 1994 (FM Act)* (including *Fisheries Management Amendment Act 1997*), which all contain provisions that relate to the conservation of threatened species, populations and communities. The Project has been identified as a controlled action under the *EPBC Act* by the Minister of the Environment (referral decision number 2013/7076).

Policies and Guidelines

The Policy and Guidelines for Fish Habitat Conservation and Management issued by the NSW Department of Primary Industries (DPI) and NOW Guidelines for Controlled Activities are applicable to instream ecology and the riparian zone. The NSW State Groundwater Ecosystem Policy, NSW Aquifer Interference Policy and NOW's Risk Assessment Guidelines for Groundwater Dependent Ecosystems are applicable to the stygofauna occurring within the Project Application Area.

Conservation Issues

Three threatened fish species listed under the *EPBC Act*, or their habitat, may occur within the Lithgow Local Government Area (LGA). Two of these species, Murray cod (*Maccullochella peelii*) and Australian grayling (*Prototroctes maraena*), are considered to be vulnerable to extinction, whilst the third, Macquarie perch (*Macquaria australasica*), is endangered. Two other threatened fish species (silver perch and trout cod) listed under the *FM Act* have been recorded in the Hawkesbury-Nepean Catchment.

One endangered semi-aquatic invertebrate species, the giant dragonfly (*Petalura gigantea*) listed under the *TSC Act* has been recorded in the Lithgow LGA. The expected distribution range of Adam's emerald

dragonfly (*Archaeophya adamsi*) and Sydney hawk dragonfly (*Austrocordulia leonardi*) listed as endangered under the *FM Act* includes the Hawkesbury-Nepean Catchment.

An endangered ecological community (White Box Yellow Box Blakely's Red Gum Woodland) associated with riparian vegetation within the Project Application Area is being considered by terrestrial ecologists.

Two Key Threatening Processes (KTPs) relevant to the aquatic ecosystem are listed under the *EPBC Act*:

- > Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants;
- > Novel biota and their impact on biodiversity.

Three additional KTPs relevant to the aquatic ecosystem and the Project are listed under the *TSC Act*:

- > Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands;
- > Predation by *Gambusia holbrooki* Girard, 1859 (plague minnow, mosquito fish or eastern gambusia).

A further three relevant KTPs are listed under the *FM Act*:

- > Degradation of native riparian vegetation along New South Wales watercourses;
- > Installation and operation of in-stream structures and other mechanisms that alter natural flow regimes of rivers and streams;
- > Introduction of fish to waters within a river catchment outside their natural range.

Existing Surface Aquatic Environment and Biota

The overall quality of the water in the Gap, Genowlan and Dog Trap creeks was better than that in Airly and Torbane creeks. Electrical conductivity levels were much greater at lower altitude sites than at the sites on Mount Airly and Genowlan Mountain. Dissolved oxygen and pH were lower in Grotto Creek than at the other sites, probably due to natural factors such as greater organic matter content and low light penetration. A number of water quality parameters at Airly Creek exceeded the Australian and New Zealand Environment and Conservation Council (ANZECC) guidelines during all sampling seasons.

The aquatic habitat in Genowlan Creek was in the best condition, followed by that in the Gap and Grotto creeks. The poorer condition of the habitat in Airly, Torbane and Dog Trap creeks was associated with disturbance of the stream channel and riparian zone. Fish habitat was classified as highly sensitive at all sites, except for those in Gap Creek and Grotto Creek where it was classified as sensitive due to their ephemeral nature.

Aquatic macroinvertebrate communities in Dog Trap Creek were more diverse and in a better condition, as indicated by the Australian River Assessment System, than those in the other creeks. Stream Invertebrate Grade Number – Average Level (SIGNAL2) scores were greatest at Gap, Grotto and Genowlan Creek, meaning more pollution sensitive taxa were present and suggesting the water quality was better in these creeks.

Five native fish species were recorded. Dog Trap Creek had the most diverse fish fauna, with four native species being found. Mountain galaxias were the most abundant fish recorded, but were found in Torbane Creek only. No fish were captured at Gap, Grotto or Genowlan Creek, but tadpoles were observed. Eastern gambusia was caught in Airly Creek in all sampling events. This fish species is native to the Americas and listed as a noxious species under the *FM Act*. No threatened species were captured or observed.

Sampling of the aquatic ecosystem indicated that the sites on Airly Creek followed by those on Torbane Creek were the most biologically impaired. This impairment is probably due to extensive deforestation and use of the land in the catchment for agriculture and mining activities. Biological impairment observed at all sites may be due to the ephemeral or low flow characteristics of these catchments.

Stygofauna

Stygofauna were not recorded within the Project Application Area in the current investigation. As sampling effort and the number of available sampling sites were limited, the precautionary principle was adopted, with all aquifers assumed to contain some stygofauna species. The physical characteristics and the groundwater quality within the alluvial aquifer and the Narrabeen Group aquifer indicate they are the most likely to harbour stygofauna. A more extensive sampling program is required to determine if stygofauna are present.

Potential Impacts and Mitigation Measures

Construction Phase

Mobilisation of sediment and aquatic contaminants from construction areas represents the primary potential impact on creek habitat and aquatic organisms during the construction phase. This would primarily affect Airly Creek, as the Airly Creek catchment is where the majority of the proposed surface works (establishment of the reject emplacement area and the construction of the coal preparation plant) would be located. The upland catchments of Gap Creek and Genowlan Creek could potentially be impacted by vehicular movements within the respective catchments.

The following measures would be implemented to mitigate potential sediment and water quality impacts:

- > An Erosion and Sediment Control Plan with details of specific work areas and erosion control structures and measures required would be used to minimise construction related sediment mobilisation and dispersion;
- > Sediment and water quality control dams of appropriate sizes would be used to treat runoff from disturbed areas;
- > Fuel, oils and other chemicals would be stored and handled within designated, controlled, bunded areas;
- > Spill response plans (oil, fuel) will be implemented if required; and
- > A Vegetation Management Plan would be used to ensure riparian vegetation removal is minimised and controlled.

Hydrological changes may also occur during construction, although these are expected to be minor, short term and largely restricted to Airly Creek, where the majority of the proposed works would occur and aquatic habitats downstream. The measures implemented to reduce the impacts of hydrological changes would include: preparation of a Water Management Plan and an Erosion and Sediment Control Plan, adherence to the NSW DPI Policy and Guidelines for Fish Habitat Conservation and Management and restriction of works to areas away from watercourses.

Degradation or loss of aquatic habitat could occur as a result of construction activities due a combination of the impacts listed above. Habitat degradation and construction-related vehicular movements and water transfers could also result in the spread and/or establishment of invasive species. The measures implemented to reduce the impacts of habitat degradation and invasive species would include:

- > Establishment and maintenance of riparian buffer zones of appropriate width for the type of habitat and class of waterway that would ensure lateral connectivity between aquatic and riparian habitat;
- > Retention of existing riparian vegetation in an undamaged state, where possible;
- > Revegetation of disturbed areas with local native species and monitoring to ensure revegetation is successful;
- > If rehabilitation is required, this should include native instream vegetation and snags, where appropriate; and
- > Appropriate wash down and decontamination procedures, education of construction staff and limiting non-essential inter-catchment water movements.

Potential impacts to groundwater ecosystems associated with construction works include:

- > Construction of boreholes that penetrate groundwater resources during piezometer installation; and

- > Sediment and contaminant infiltration to groundwater.

Mitigation measures for these impacts include:

- > Implementation of the Water Management Plan and the Erosion and Sediment Management Plan;
- > Use of appropriate drilling methods, if required, that limit sub-surface impacts; and
- > Further assessment and monitoring of groundwater and stygofauna to inform for adaptive management.

Operation Phase

Centennial Airly plans to use several mining methods to extract coal, with the aim to limit subsidence within five distinct mining zones to defined levels. The Project has adopted subsidence criteria that would result in 'minimal subsidence impact', being limited to 100 mm and not exceeding 125 mm. Modifications to mining zones have also been made to accommodate watercourse features and other sensitive surface features.

Overall, the proposed mining system has the following advantages:

- > The restriction of caving heights to the immediate Permian overburden and minimal deformation of the Triassic sandstone is expected to reduce disturbance to overlying aquifers, particularly the perched aquifers within the Narrabeen Group that feed springs and surface groundwater expressions; and
- > No appreciable adverse surface impacts as surface cracking would be avoided and mining-related rock falls would be minimised.

Surface damage has already occurred in the New Hartley Shale Mine Potential Interaction Zone and additional surface impacts may be experienced due to mine operations. This zone is overlain by approximately 634 m of first order streams which constitute a very small proportion of the total number of watercourses within the Project Application Area. These first order streams are likely to be little more than valley drainage depressions and would provide negligible aquatic habitat due to their size and position in the catchment.

Genowlan Creek overlies the Shallow Zone, Partial Pillar Extraction Zone and Cliff Line Zone, for 47, 523 and 517 m, respectively. These reaches of the creek have been classified as highly sensitive, major fish habitat and show minimal degradation of aquatic habitat. Although subsidence predictions indicate minimal surface impacts within these zones, this reach of Genowlan Creek represents a highly sensitive receptor for any potential subsidence related impacts, should they occur.

The main channel of Gap Creek has been excluded from the defined subsidence zones to reduce the potential for impacts due to the low depth of cover in this area. Gap Creek has been classified as highly sensitive, moderate fish habitat with limited degradation of aquatic habitat. Within the Project Application Area, Gap Creek has less aquatic habitat than Genowlan Creek and contains natural barriers to fish passage, but still represents a sensitive receptor for any potential subsidence related impacts, should they occur.

There is a potential for subsidence-related ground movements to impact the aquifer that feeds springs and other surface expressions of groundwater, in particular the Village Spring and Grotto Creek. These two areas are considered sensitive receptors to the potential impacts of subsidence. Disruption of aquifers that leads to redirection of groundwater flow or depressurisation could reduce or eliminate the flow of water to these surface expressions from groundwater sources.

Potential impacts to groundwater ecosystems during the operation phase include impacts associated with ground movements, groundwater drawdown and water extraction. Impacts associated with ground movements are expected to be greatest in the New Hartley Shale Mining Interaction Zone. Overall, subsidence impacts on the Alluvial and Narrabeen Group aquifers elsewhere in the Project Application Area are expected to be minimal. The main mitigation measures are adaptations of the mine design and an adaptive management approach to mining operations. Development of Trigger Action Response Plans and ongoing monitoring of ecosystem health for adaptive management are also key mitigation measures.

Rehabilitation and Decommissioning Phases

During the rehabilitation and decommissioning phases, there is potential for erosion of denuded areas and for runoff containing sediments and contaminants, such as fertilisers and herbicides, to enter watercourses during rainfall events. The ingress of sediments into watercourses and potential for impacts on instream ecology would be minimised by implementing appropriate measures specified in the Erosion and Sediment Control Plan.

Impacts on Threatened Species

The literature review concluded that the most likely threatened aquatic species that could be impacted by the Project were Macquarie perch, giant dragonfly and Adam's emerald dragonfly. Assessments of Significance prepared for each of these species indicate the Project is unlikely to have a significant impact on their populations.

Regional coal mining activities, such as Charbon Colliery and the Inglenook Exploration Project, along with Airly mine, could potentially have a cumulative impact on Macquarie perch and Adam's emerald dragonfly with respect to water quality and hydrological pressure in this unregulated and relatively undisturbed catchment of the Hawkesbury-Nepean system.

Cumulative Impacts

Cumulative impacts associated with regional disruption to groundwater may occur in response to other mining and quarrying activities within the regional groundwater resource. Other mines and quarries in the region have been outlined in **Section 6.6**. Airly Mine is located in relative isolation to other significant mining and quarrying activities, and is dominantly surrounded by conservation areas, rugged bushland and cleared agricultural land. There are no other mining or groundwater activities in the area that impact the Alluvial and Quaternary groundwater sources. Therefore, the cumulative impact of the Project in relation to aquatic ecology and stygofauna is expected to be minimal.

Conclusion

The Project Application Area is located in a precipitous surface environment with limited surface water. Although the extent of the surface watercourses is limited, they are important resources for local aquatic and terrestrial fauna, providing habitat for aquatic species, water supply for terrestrial fauna and aesthetics for recreational activities. Groundwater habitats are similarly important, having the potential to support locally and regionally important stygofauna populations and biodiversity; however none have been found to date.

The mine plan has been designed to minimise impacts on the surface waters of Gap and Genowlan creeks and consequently impacts on their aquatic ecology are unlikely. Similarly, predicted impacts on Alluvial and Narrabeen Group aquifers are predicted to be localised and minimal with implementation of recommended mitigation measures. No stygofauna have been recorded in three limited sampling events, however impacts on any stygofauna that may be present are unlikely because the mining plan design will avoid disturbance to the upper aquifers, the most likely location of stygofauna.

The assessment of both the surface aquatic environment and groundwater aquifers within the Project Application Area is limited by the relatively small amount of available data. This is particularly the case for stygofauna, where sampling is limited in both extent and time, although low volume of water in bores sampled to date may indicate low probability of stygofauna. Continued baseline data collection is being conducted to build a more comprehensive dataset and understanding of the aquatic environment and groundwater aquifers.

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1 Introduction

1.1 Background

Centennial Airly Pty Limited (Centennial Airly) is seeking approval to extend its existing mining operations at Airly Mine into the eastern section of its existing Mining Lease ML1331 and within its Authorisation No.232 (A232) situated to the east and north-east of ML1331. These two areas, referred to hereafter as the Project Application Area, are depicted in **Figure 1-1**. The Project Application Area is within the Lithgow Local Government Area (LGA) and is located approximately, forty-three km north-north-west of Lithgow and seventy km south-east of Mudgee, on the eastern side of the Castlereagh Highway in NSW. The closest township, Capertee, is approximately four and a half km south-west of the Airly Mine surface workings. The land surrounding the Project Application Area is used for rural residential purposes, agricultural activities and conservation (Capertee National Park and Gardens of Stone National Park).

The Airly Mine Extension Project will:

- > Continue to extract up to 1.8 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal from the Lithgow seam underlying the Project Application Area;
- > Extend the life of mine by 25 years;
- > Increase extraction up to 3.0 Mtpa of ROM using bord and pillar mining and panel and pillar extraction methods within the mining lease (ML1331) and extend the mining area to the east of the existing workings into Authorisation 232 (A232) area;
- > Develop underground access headings and roadways from the current mining area to the east to allow access to the proposed mining areas;
- > Use various bord and pillar mining and panel and pillar extraction mining methods, that will manage subsidence to a maximum of 100 mm and not exceed 25 mm in previously unmined areas and minimise further potential subsidence impacts in areas where the historical New Hartley Shale Mine has already impacted the environment;
- > Continue to operate and maintain the existing ancillary surface infrastructure for mine access, underground ventilation, electricity, water, materials supply, and communications at the pit top, and upgrade the infrastructure as required for mining operations;
- > Continue to manage the handling of ROM coal through a crusher and screening plant at the pit top for transfer to the existing and proposed stockpile areas as required to meet market demands;
- > Construct a coal handling and preparation plant (CHPP) to process ROM coal;
- > Transfer processed coal from the CHPP, using the existing and new overland conveyor systems, to the product stockpile area for temporary storage prior to despatch to offsite locations;
- > Construct a life-of-mine reject emplacement area (REA) for the emplacement of reject materials from the CHPP and the underground mine;
- > Continue to use the existing water storage dams at the pit top for the separation of clean and dirty water;
- > Construct appropriately sized new management storage dams for the proposed life-of-mine REA;
- > Continue to manage non-production waste in accordance with the site's Mining Operations Plan;
- > Despatch ROM coal and product coal off site using the existing rail load out facilities for the export and domestic markets;
- > Continue to undertake existing and initiate new environmental monitoring and geological exploration programs as appropriate;
- > Review and update existing environmental management plans as required;
- > Operate 24 hours per day and seven days per week for 52 weeks per year;

- > Provide employment to a full time workforce of up to 135 persons and 20 contractors;
- > Progressively rehabilitate disturbed areas at the pit top no longer required for mining operations and exploration boreholes; and
- > Undertake life-of-mine rehabilitation at the pit top infrastructure disturbance areas to create final landforms commensurate with the surrounding areas and the relevant zoning in accordance with the Draft Lithgow City Local Environmental Plan 2013.

Centennial Airly commissioned Cardno (NSW/ACT) Pty Ltd, trading as Cardno Ecology Lab, to prepare an Aquatic Ecology and Stygofauna Impact Assessment to support their Environmental Impact Statement (EIS) and development application for the Airly Mine Extension Project (the Project).

1.2 Scope of Works

The scope of works for the Aquatic Ecology and Stygofauna Assessment was determined by the requirements of Centennial Airly, the Commonwealth Department of the Environment (the former Federal Department of Sustainability, Environment, Water, Population and Communities (DSEWPAC)), NSW Department of Planning and Infrastructure (NSW DP&I), NSW Office of Water (NOW) and NSW Office of Environment and Heritage (OEH). The scope of works from Centennial Airly included:

- > Addressing issues pertaining to aquatic ecology and stygofauna identified in the Director General's Requirements (DGRs) and Supplementary DGRs issued by the DP&I on 6 November 2012 and 4 February 2014, respectively;
- > Compilation and synthesis of existing information on the condition of aquatic habitats, quality of water and diversity and abundance of aquatic biota (macrophytes, macroinvertebrates and fish) and stygofauna, within and downstream the Project Application Area;
- > Identification of legislative requirements, guidelines and policies that are relevant to potential impacts of the proposed works on aquatic ecology;
- > Identification of threatened aquatic species, populations, ecological communities, Groundwater Dependant Ecosystems (GDEs) and key threatening processes that could be affected by the proposed mining and associated works;
- > Assessment of the potential impacts of: modifications to existing and construction of new infrastructure; the proposed bord and pillar mining and panel and pillar extraction mining methodology; rehabilitation works; and decommissioning of the mine; on aquatic habitats and biota (particularly threatened species, populations and communities and GDEs) occurring within and downstream of the Project Application Area; and
- > Recommending measures that could be used to avoid, manage, mitigate or offset the potential impacts on aquatic ecology identified.

The spatial scope of works extends beyond the Project Application Area (**Figure 1-1**) due to inland surface waterways representing a continuum of water upon which a variety of organisms (aquatic, semi-aquatic and terrestrial) rely on for survival. The spatial scope of works for the assessment includes waterways that derive water from within the Project Application Area, but excludes the estuarine and marine environments of the lower Hawkesbury-Nepean River, which are hydrologically distinct and a sufficient distance downstream such that impacts would be undetectable.

Data collected during the desktop assessment were compiled from available historical sources. Specific project related field investigations, consisting of one preliminary aquatic habitat investigation (April 2013) and four sampling events comprising three climatic sampling seasons (May and June 2013 (autumn), November 2013 (spring), and June 2014 (autumn)), were undertaken by Cardno. In-stream macroinvertebrates, aquatic macrophytes, fish and subterranean fauna were sampled and aquatic habitat condition and water quality were assessed.

The specific issues identified by the government agencies and the sections in the report where these are addressed are summarised in **Table 1-1** to **Table 1-3**.

Table 1-1 Director General's requirements pertinent to the Aquatic Ecology and Stygofauna Impact Assessment

Assessment Requirements	Relevant Section of the Report
Description of the existing environment, using sufficient baseline data.	4 and 5
Assessment of the potential impacts of all stages of the development, including any cumulative impacts, taking into consideration relevant guidelines, policies, plans and statutes.	6 and 7
Assessment of impacts on riparian, ecological, geo-morphological and hydrological values of watercourses, including GDEs and environmental flows.	6 and 7
Detailed assessment of potential impacts of the development on aquatic threatened species or populations and their habitats, endangered ecological communities (EECs) and GDEs	6.4
Description of measures that would be implemented to avoid, minimise and, if necessary, offset the potential impacts of the development.	6 and 7
Measures that would be taken to avoid, reduce or mitigate impacts on biodiversity	6 and 7
Detailed assessment of the impacts to any aquatic threatened species or populations and their habitats, EECs and GDEs	6.4
A detailed assessment of the impact the project would have on the Mugii Murumban State Conservation Area (SCA) with reference to the issues identified in the Draft Plan of Management for the SCA.	6.5

Table 1-2 NSW Office of Environment and Heritage's requirements pertinent to the Aquatic Ecology and Stygofauna Impact Assessment

Assessment Requirements	Relevant Section of the Report
Identification and assessment of Matters of National Environmental Significance	3.1 and 6.4
Identification of national and state-listed threatened species that could potentially occur on the site and their conservation status	3.2 and 6.4
Description of survey methodology	4.3, 5.3.2 and Appendix A
Likely impacts on biodiversity, native vegetation and habitat	6 and 7
Impact of quality, temperature and quantity of discharged water on aquatic biodiversity	6 and 7
Impact of changes to groundwater levels	6 and 7
Likely impacts on threatened biodiversity	6.4
Measures to avoid, mitigate and manage impacts	6 and 7

Table 1-3 NSW Office of Water's requirements pertinent to the Aquatic Ecology and Stygofauna Assessment

Assessment Requirements	Relevant Section of the Report
Identification of potential GDEs	5.2, 0 and 5.4
Baseline monitoring of all groundwater and surface water dependent ecosystems within and adjacent to mining operation	4 and 5
Assessment of GDEs for condition and water quality and quantity requirements for aquatic ecosystems (macroinvertebrates, macrophytes, stygofauna)	4 and 5
Assessment of impacts on groundwater and surface water dependent ecosystems within and adjacent to mining operation	6 and 7
Mitigation measures to address impacts on groundwater and surface water dependent ecosystems during and after mining operations	6 and 7
Monitoring to enable comparison with ongoing monitoring	4, 5 and Appendix A

1.3 Structure of the Report

This report contains the following sections:

- > Legislative requirements, policies and guidelines that are relevant to the assessment of the potential effects of the Project on aquatic ecology and stygofauna;
- > Conservation issues – identification of threatened species, populations and communities of national and state significance, key threatening processes and other important conservation issues, such as GDEs, fish habitat and noxious species that may occur within the Project Application Area;
- > Surface aquatic ecosystems – description of aquatic habitats, hydrology, water quality, aquatic plants and algae, aquatic macroinvertebrates and fish found at study sites;
- > Groundwater ecosystems – description of groundwater systems in the vicinity of the Project Application Area, and results of groundwater quality and stygofauna sampling undertaken in these systems;
- > Potential impacts and mitigation measures – surface water ecosystems – description of the nature and magnitude of possible direct, indirect and cumulative impacts arising during the construction, operational, decommissioning and rehabilitation phases of the Project and measures that could be taken to avoid, minimise or manage these impacts;
- > Potential impacts and mitigation measures – groundwater ecosystems – description of the nature and magnitude of possible direct, indirect and cumulative impacts arising during the construction, operational, decommissioning and rehabilitation phases of the Project and measures that could be taken to avoid, minimise or manage these impacts;
- > Conclusions about the effect of the Project on surface and subterranean aquatic ecology;
- > Literature cited – a list of the reports, scientific publications and other documents used to support statements made.

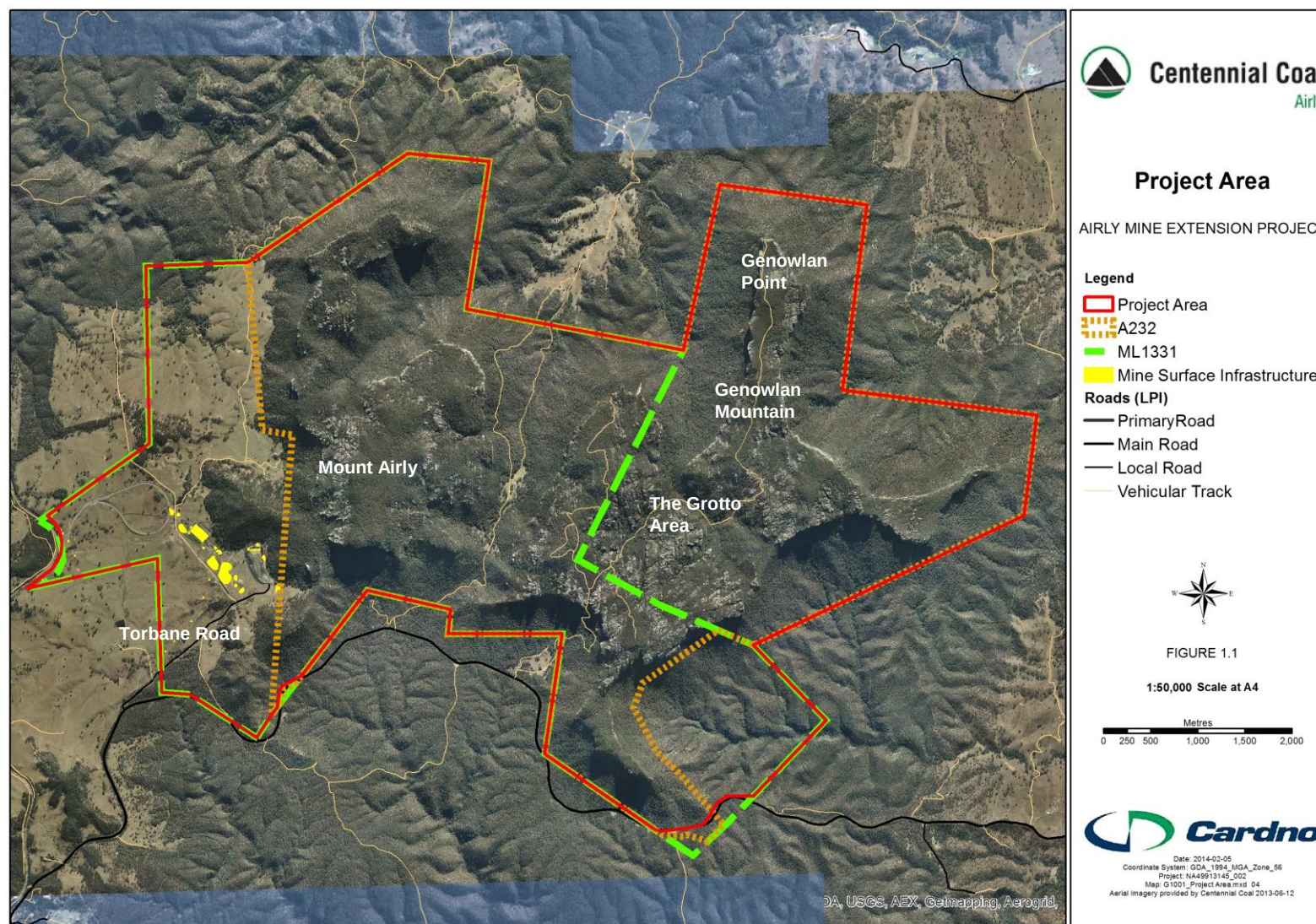


Figure 1-1 Aerial photograph showing the Project Application Area, existing mining lease and roads

2 Legislative Requirements, Guidelines and Policy

2.1 Legislative Requirements

2.1.1 Development Applications

The Project has been declared a State Significant Development and will therefore be assessed under Division 4.1, Part 4 of the NSW *Environmental Planning and Assessment Act 1979 (EP&A Act)*. The development application must be accompanied by an Environmental Impact Statement (EIS) that addresses the issues specified in the Director-General Requirements (DGRs) issued on 6 November 2012 and the Supplementary DGRs issued on 4 February 2014. This followed the declaration by the Commonwealth Department of the Environment on 24 December 2013 that the proposed action in relation to EPBC 2013/7076 referral is a controlled action under the *Environmental Protection and Biodiversity Conservation Act 2000 (EPBC Act)*.

One of the requirements relevant to the ecological studies supporting the EIS is that specific factors and assessment guidelines must be taken into account when deciding whether the Project is likely to have a significant effect on threatened species, populations or ecological communities, as defined under the NSW *Threatened Species Conservation Act 1995 (TSC Act)* administered by OEH, and NSW *Fisheries Management Act (FM Act) 1994* (including *Fisheries Management Amendment Act 1997*), administered by NSW Department of Primary Industries (DPI). The factors to be considered are specified in Section 5A of the *EP&A Act* and constitute an Assessment of Significance (7-part test). The factors relevant to consideration of effects on threatened species, for example, are:

1. Whether the proposed action is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction;
2. The extent to which the species habitat is likely to be removed or modified as a result of the action proposed, whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and whether the habitat to be removed, modified, fragmented or isolated is important to the long-term survival of the species in the locality;
3. Whether the proposed action is likely to have an adverse effect on critical habitat (either directly or indirectly);
4. Whether the proposed action is consistent with the objectives or actions of a recovery plan or threat abatement plan, and
5. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

Similar factors need to be considered when assessing effects on threatened populations and ecological communities.

Division 4.1, Part 4 of the *EP&A Act* indicates some of the authorisations required under other Acts do not apply to State Significant Developments. These include provisions under the *FM Act* with respect to permits for dredging and reclamation work, harm to marine vegetation and blockage of fish passage. The controlled activity approval under section 91 of the *Water Management Act 2000 (WM Act)* that confers a right on its holder to carry out a specified controlled activity at a specified location in, on or under waterfront land, is also not required. An aquifer interference approval that confers a right on its holder to carry out one or more specified aquifer interference activities at a specified location, or in a specified area, in the course of carrying out specified activities, however, is required.

2.1.2 Threatened Species, Populations and Communities

Threatened freshwater species, populations and communities are listed under the *EPBC Act* administered by the Commonwealth Department of the Environment, and the State *TSC Act* and *FM Act*.

The *EPBC Act* provides a legal framework for the protection and management of nationally and internationally important flora, fauna, ecological communities and heritage places. It also includes provisions for nationally threatened species of plants, fish, birds, frogs, reptiles, mammals and other animals. These

conservation assets are referred to collectively as Matters of National Environmental Significance (MNES). The Department of the Environment is also responsible for the development and implementation of recovery plans for threatened fauna, threatened flora (other than conservation dependent species) and threatened ecological communities listed under the *EPBC Act*. The Department of Environment also develops Significant Impact Guidelines for assessment of MNES.

The *TSC Act* provides for the conservation of species, populations and ecological communities of animals and plants in NSW that are threatened with extinction. The *TSC Act* contains provisions for the preparation of recovery plans for listed threatened species, populations and ecological communities, the declaration and mapping of habitats that are critical to their survival and threat abatement plans to manage key threatening processes. The *TSC Act* also provides for the facilitation of the appropriate assessment, management and regulation of actions that may damage critical or other habitat or significantly affects threatened species, populations and ecological communities and contains provisions related to Biodiversity Banking and offsets. The provisions of this act apply to algae, aquatic plants, invertebrates and all major vertebrate groups except fish.

The *FM Act* contains provisions for the conservation of fish stocks, key fish habitat, biodiversity, threatened species, populations and ecological communities of fish and marine vegetation and the development and sharing of the fishery resources of NSW for present and future generations.

2.1.3 Key Threatening Processes

Key Threatening Processes (KTPs) that threaten or may threaten the survival or evolutionary development of threatened species, population or ecological community are listed under the *EPBC Act*, *TSC Act* and *FM Act*.

2.1.4 Noxious Species

Noxious species threaten the conservation of native species and have the potential to impact on fisheries, agriculture and other important industries. Noxious species of fish and marine vegetation are listed under the *FM Act*. Noxious species of terrestrial and freshwater vegetation are listed under the *Noxious Weeds Act (NW Act)*, administered by NSW DPI.

2.1.5 Protected Areas and Species

National Parks and World Heritage Areas are afforded legislative protection under the *EPBC Act*. State Conservation Areas are afforded legislative protection under the *NSW National Parks and Wildlife Act 1974 (NP&W Act)* administered by OEH. Native fauna and flora are also protected under the *NP&W Act*.

2.1.6 Critical Habitat

Critical habitats are areas of land or water that are crucial to the survival of particular threatened species, populations and ecological communities. Registers of critical habitats are maintained by OEH and DPI.

2.1.7 Key Fish Habitat

One of the objectives of the *FM Act* is to conserve key fish habitats. These are defined as aquatic habitats that are important to the sustainability of recreational and commercial fishing industries, the maintenance of fish populations generally and the survival and recovery of threatened aquatic species. In freshwater systems, most permanent and semi-permanent rivers, creeks, lakes, lagoons, billabongs, weir impoundments and impoundments up to the top of the bank are considered key fish habitats. Small headwater creeks and gullies that flow for a short period after rain and farm dams on such systems are excluded, as are artificial water bodies except for those that support populations of threatened fish or invertebrates.

2.2 Guidelines and Policies

2.2.1 NSW Office of Water Guidelines for Controlled Activities

Approval is required under the *WM Act* for certain types of developments and controlled activities that are carried out in or near a river, lake or estuary. Four types of controlled activities are recognised:

- > Erection of a building or the carrying out of a work (within the meaning of the *EP&A Act*);

- > Removal of material or vegetation from land, by way of excavation or other means;
- > Deposition of material on land as a result of landfill operations or other means; and
- > Carrying out any other activity that affects the quantity or flow of water in a water source.

The agency responsible for administering the *WM Act*, NOW, has developed guidelines to assist applicants who are considering carrying out controlled activities on waterfront land (i.e. the land within forty m of the highest bank of the river, lake or estuary). These guidelines provide information on the design and construction of a controlled activity, and other mechanisms for the protection of waterfront land. The following guidelines are relevant to the potential effects of the Project and are applicable to all developments on waterfront land:

- > Laying pipes and cables in watercourses (NOW 2010a);
- > Riparian corridors (NOW 2011a);
- > In-stream works (NOW 2010b); and
- > Outlet structures (NOW 2010c).

2.2.2 NSW DPI Policy and Guidelines for Fish Habitat Conservation and Management

The NSW DPI Policy and Guidelines for Fish Habitat Conservation and Management (2013) is an update of the Policy and Guidelines for Aquatic Habitat Management and Fish Conservation (NSW Fisheries 1999). The new document also incorporates the requirements of the former Fisheries NSW Policy and Guidelines for Fish Friendly Waterway Crossings (2003) and two Fish Habitat Protection Plans No. 1 (General) and 2 (Seagrasses), which are in the process of being revoked.

The aims of the updated policies and guidelines are to maintain and enhance fish habitat for the benefit of native fish species, including threatened species, in marine, estuarine and freshwater environments. The updated document assists developers, their consultants and government and non-government organisations ensure their actions comply with the legislation, policies and guidelines that relate to fish habitat conservation and management. It is also intended to inform land use and natural resource management planning, development planning and assessment processes and to improve awareness and understanding of the importance of fish habitats and how impacts can be mitigated, managed or offset. The policies and guidelines outlined in this document are taken into account when NSW DPI assesses proposals for developments and other activities that affect fish habitats.

The document contains:

- > Background information on aquatic habitats and fisheries resources of NSW;
- > An outline of the legislative requirements relevant to planning and development which may affect fisheries or aquatic habitats in NSW;
- > General policies and classification schemes for the protection and management of fish habitats and outlines the information that NSW DPI requires to be included in development proposals that are affecting fish habitats;
- > Specific policies and guidelines aimed at maintaining and enhancing the free passage of fish around in-stream structures and barriers;
- > Specific policies and guidelines for foreshore works and waterfront developments; and
- > Specific policies and guidelines for the management of other activities affecting waterways.

The document indicates NSW DPI will consider the 'sensitivity' of any key fish habitats that will be affected by the Project. The term 'sensitivity' refers to the importance of the habitat to survival of the fish and its ability to withstand disturbance. In freshwater ecosystems, instream gravel beds, rocks greater than five hundred mm in two dimensions, snags greater than three hundred mm in diameter or three m in length, and native aquatic plants, and areas known or expected to contain threatened and protected species are considered to be highly sensitive key fish habitats. Other freshwater habitats plus weir pools and dams across natural waterways are considered to be moderately sensitive key fish habitats. Ephemeral aquatic habitat that does not support native aquatic or wetland vegetation is considered to be of minimal sensitivity.

It is important to note that aquatic habitats within first and second order gaining streams, sections of stream that have been concrete-lined or piped (but excluding waterway crossings) and artificial ponds are not regarded as key fish habitat unless they support a listed threatened species, population or ecological community or 'critical habitat'. NSW DPI may in addition assess development proposals in relation to waterway class (i.e. their ability to provide habitat that is suitable for fish). Details of this classification are provided in **Appendix B**.

The general policies and/or guidelines that are likely to be relevant to the current project include those for:

- > Riparian and freshwater aquatic vegetation;
- > Snag management;
- > Habitat rehabilitation and environmental compensation; and
- > Maintaining and enhancing the free passage of fish in NSW waters.

The specific policies and guidelines that may be relevant include those for:

- > Temporary instream structures (e.g. coffer dams, construction pads, sediment erosion booms);
- > Instream rehabilitation works;
- > Instream structure removal; and
- > Minimizing water pollution.

2.2.3 NSW State Groundwater Dependent Ecosystems Policy

The species composition and natural ecological processes within some ecosystems (e.g. wetlands, red gum forests, limestone caves, springs, hanging valleys and swamps) are dependent on water that has filtered down below the surface of the earth and is held in rocks, gravel and sand. In NSW, groundwater often provides the base flows in rivers and streams after rainfall events that appears as springs or as diffuse flows from saturated sediments or rock underlying the watercourse or its banks.

The NSW GDEs Policy (DLWC 2002) is designed to protect valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of their dependent ecosystems are maintained or restored, for the benefit of present and future generations. The document provides guidance on the protection and management of GDEs and includes information on:

- > The location of groundwater systems in NSW;
- > Different types of GDEs;
- > Value of and threats to GDEs;
- > The principles that underpin the management of GDEs; and
- > Policies and legislation relating to management of GDEs, including how policy will be implemented and reviewed.

2.2.4 NSW Aquifer Interference Policy

The Aquifer Interference Policy explains the role and requirements of the Minister administering the *WM Act* in the water licensing and assessment processes for aquifer interference activities under the *WM Act* and other relevant legislative frameworks (NSW DPI 2012a). The term aquifer interference as defined under the *WM Act* refers to the following:

- > Penetration of an aquifer;
- > Interference with water in an aquifer;
- > Obstruction of the flow of water in an aquifer;
- > Taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations; and
- > Disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

The Aquifer Interference Policy is applicable to all aquifer interference activities but has been specifically developed to address high risk activities. Mining operations such as open cut voids, underground mine workings and the disposal of water taken from an aquifer including water taken as part of coal seam gas extraction are considered high risk activities. A water licence is required for any activity that interferes with an aquifer and for activities that result in the movement of water from one part of the aquifer to another or to and from a surface water body. The Aquifer Interference Policy outlines the requirements under NSW Legislation for obtaining water licences for aquifer interference activities, explains how development applications under Part 4, Division 4.1 and Part 5.1 of the *EP&A Act* will be assessed and specifies the factors that must be taken into consideration when assessing the potential effects of groundwater interference activities on an aquifer and its dependent assets, including ecosystems.

The framework for assessing the impacts of aquifer interference activities on water resources indicates the proponent will need to:

- > Demonstrate their ability to obtain the necessary licences in order to account for the take of water from any relevant water source or that appropriate mitigation or avoidance strategies would be used to reduce the take of water to a point where it can be accounted for;
- > Indicate adequate arrangements will be implemented to ensure that the minimal impact considerations specified in the policy can be met; and
- > Propose remedial actions for impacts greater than those that were predicted as part of the relevant approval.

Minimal impact considerations have been developed for impacts on each of the highly productive and less productive groundwater sources, connected water sources, and their dependent ecosystems, culturally significant sites and water users. Two levels of minimal impact considerations have been specified. Predicted impacts that are less than the Level 1 minimal impact considerations will be considered to be acceptable. Predicted impacts that exceed the Level 1 thresholds by no more than the accuracy of an otherwise robust model, will be considered within the range of acceptability, provided that extra monitoring and mitigation or remediation is undertaken if required. In this case, appropriate conditions may be imposed to ensure the impacts of the activity are acceptable. If the predicted impacts exceed the Level 1 minimal impact considerations by more than the accuracy of an otherwise robust model, additional studies will be required to fully assess the predicted impacts. If the subsequent assessment shows that the predicted impacts would not prevent the long-term viability of the relevant water-dependent asset, the impacts will be considered to be acceptable.

The Aquifer Interference Policy also describes the information the proponent would need to supply to enable the aquifer interference activity to be assessed against the minimal impact considerations. This includes:

- > Establishment of baseline groundwater conditions including depth, quality and flow based on sampling of all existing and future bores in the area potentially affected by the activity;
- > Potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems;
- > Potential for increased saline or contaminated water inflows to aquifers and highly connected river systems; and
- > Potential for river bank instability, or high wall instability or failure to occur.

The Aquifer Interference Policy also indicates the likely conditions of approval for projects and that a security deposit may be required to cover the costs of remediation works for unforeseen impacts or ongoing post-closure activities.

2.2.5 NSW Office of Water's Risk Assessment Guidelines for GDEs

NOW and OEH have developed comprehensive risk assessment guidelines to manage the effects of land and water use activities on GDEs. These guidelines are available in four volumes:

- > Volume 1 - Risk assessment guidelines for groundwater dependent ecosystems – the conceptual framework;
- > Volume 2 – Risk assessment guidelines for groundwater dependent ecosystems. Worked examples for seven pilot coastal aquifers;

- > Volume 3 – Identification of high probability groundwater dependent ecosystems on the Coastal Plains of NSW and their ecological value; and
- > Volume 4 – The ecological value of groundwater sources on the Coastal Plains of NSW and the risk from groundwater extraction.

The conceptual framework (Serov *et al.* 2012) provides the following:

- > Definitions of groundwater, GDEs and high priority GDEs;
- > A classification of different types of GDEs;
- > A description of the relevant policy and legislative framework;
- > Information on ecological valuation and risk assessment process and activities that threaten aquifers and/or their associated GDEs;
- > A method for determining the ecological value of an aquifer and associated GDEs to assist in reporting against the state-wide Target for Groundwater;
- > A method for assessing the risk of an activity to the ecological value of an aquifer and associated GDEs; and
- > A method for developing management strategies for aquifers and identified GDEs based on a Risk Matrix Approach;

The accompanying appendices contain background information, including:

- > A method to identify the type and location of GDEs within an aquifer or defined area;
- > A method for inferring the groundwater dependency of identified ecosystems; and
- > A description of surface and subsurface activities that threaten aquifers and associated GDEs.

This volume of the guidelines is the most relevant to the Project. The others show how the framework has been applied to groundwater resources and GDEs on the Coastal Plain.

3 Conservation Issues

In this section, threatened aquatic species, populations and communities of national and state significance that may occur in the Project Application Area are identified. Information on the occurrence of threatened amphibians, terrestrial fauna and flora and migratory species and assessments of potential impacts on these are presented in the report prepared by the specialist terrestrial ecology consultant (RPS 2014).

The potential impacts of the construction, operation, decommissioning and rehabilitation phases of the Project and measures for avoiding, minimising and managing and offsetting such impacts on threatened aquatic species, populations and communities are discussed in **Section 6.4**.

3.1 Matters of National Environmental Significance

3.1.1 Methods

The Protected Matters Search Tool, a database maintained by the Department of the Environment, was used to identify threatened aquatic species, populations and communities of national environmental significance that occur or may occur in the Lithgow LGA. A search was undertaken over the entire LGA to ensure that mobile, threatened species that may periodically move into the Project Application Area were considered.

3.1.2 Protected Areas

The Wollemi National Park and Gardens of Stone National Park are part of the Greater Blue Mountains Area, which is classified as both a world heritage and national heritage area under the *EPBC Act*.

3.1.3 Threatened Species and their Likelihood of Occurrence

Three threatened fish species listed under the *EPBC Act* may occur or suitable habitat for them may occur within the Lithgow LGA. Two of these species, Murray cod (*Maccullochella peelii*) and Australian grayling (*Prototroctes maraena*), are considered to be vulnerable to extinction, whilst the third, Macquarie perch (*Macquaria australasica*), is endangered.

3.1.3.1 Australian grayling

The Australian grayling occurred historically in coastal streams from the Grose River, west of Sydney, southwards through NSW and Victoria (DSEWPAC 2013). The Australian grayling is diadromous and requires access to freshwater and coastal habitats to complete its life cycle. The construction of dams, weirs and other barriers to fish passage has had a major impact on their populations in some river systems. It is currently found on the eastern and southern flanks of the Great Dividing Range from Sydney southwards to the Otway Ranges in Victoria (NSW DPI 2006). This species inhabits streams and rivers, particularly clear gravelly streams with a moderate flow, as well as estuarine areas.

Threats to Australian grayling include:

- > Construction of weirs and dams, which prevent downstream and upstream migration;
- > Land clearing that degrades water quality and causes salinisation;
- > Smothering of gravel beds by fine sediment; and
- > Competition from introduced brown trout.

The NSW DPI Record Viewer indicates that this species only occurs south of Sydney. Its identification by the Protected Matters Search Tool therefore probably reflects its historical distribution. The current distribution of Australian grayling indicates they are highly unlikely to occur in the Project Application Area and as such, preparation of an assessment of significance was not considered necessary.

3.1.3.2 Murray cod

Murray cod are large predatory fish and the largest freshwater fish found in Australia. This species has been found in flowing and standing waters, including small, clear, rocky streams on the inland slopes and uplands of the Great Dividing Range, to large, turbid, meandering slow-flowing rivers, creeks, anabranches, and lakes and larger billabongs, of the inland plains of the Murray Darling Basin (National Murray Cod Recovery Team 2010). Murray cod are endemic to the Murray-Darling River system, but both hatchery-bred and wild-caught individuals have been translocated and stocked outside this natural distribution range. This species has been recorded in the Hawkesbury-Nepean Catchment, but the records are all from coastal rivers and represent stocked fish (NSW DPI 2006b). Murray cod are usually found in association with large rocks, large snags and smaller structural woody habitat, undercut banks and over-hanging vegetation, but also frequent the main river channel and larger tributaries and anabranches.

Threats to Murray cod include:

- > Flow regulation associated with agricultural processes e.g. water impoundments, irrigation channels and direct pumping from rivers;
- > Habitat degradation;
- > Lowered water quality;
- > Migration barriers (e.g. weirs) for native fish species (may interfere with spawning movements and isolate populations);
- > Alien species;
- > Commercial fishing;
- > Recreational fishing;
- > Illegal fishing;
- > Genetic issues from stocking and translocation programs leading to loss of genetic diversity;
- > Disease;
- > Stocking and translocation; and
- > Climate change.

The NSW DPI Record Viewer indicates that Murray cod are highly unlikely to occur in the Project Application Area and as such, with the nearest recorded populated approximately 100 km to the south-east (near Appin), preparation of an assessment of significance was not considered necessary.

3.1.3.3 Macquarie perch

There are two distinct populations of Macquarie perch in NSW, a western form found in the Murray-Darling Basin, and an eastern form found in south-eastern coastal NSW, including the Hawkesbury-Nepean catchment and the adjacent Shoalhaven catchment (NSW DPI 2005). Macquarie perch have also been translocated into a number of river systems. Macquarie perch are found in rivers and lakes, but particularly the upper reaches of rivers and their tributaries. This species prefers clear water and deep, rocky holes with lots of cover in the form of aquatic vegetation, large boulders, debris and overhanging banks (DSEWPAC 2010). They spawn in spring or summer and lay their eggs in shallow, fast-flowing water over stones and gravel in shallow upland streams or flowing parts of rivers.

Threats to Macquarie perch include:

- > Changes in water quality associated with agriculture and forestry;
- > Modification of natural river flows and temperatures as a result of the construction of dams and weirs;
- > Spawning failures resulting from cold water releases from dams;
- > Competition from introduced fish species;
- > Diseases, such as epizootic haematopoietic necrosis, which is carried by redfin perch; and
- > Over-fishing in the past.

The NSW DPI Fish Record Viewer indicates Macquarie perch has been recorded in the Capertee River in 2006 and Colo River in 2007 (approximately 30 and 50 km downstream of the Project Application Area, respectively) as well as in other parts of the Hawkesbury-Nepean River system. NSW DPI has also caught this species in the Wolgan River which flows into the Capertee River (Cumberland Ecology 2006), but this was not reported by the Fish Record Viewer. Although Macquarie perch have been recorded in larger rivers downstream of the Project Application Area, barriers to fish passage are likely to restrict movement of this species upstream of Glen Davis. As the types of habitat preferred by this species are also scarce within the Project Application Area, it is considered unlikely that this species would inhabit waterways close to or within the Project Application Area. However, as this species has been recorded downstream, an assessment of the significance has been completed as a precautionary measure (**Section 6.4**).

3.1.4 Threatened Populations

None of the threatened populations listed under the *EPBC Act* are relevant to aquatic ecosystems of the Project Application Area. Threatened populations listed under the *EPBC Act* within the search area are restricted to terrestrial habitats.

3.1.5 Endangered Ecological Communities

Two *EPBC Act* listed EECs found in association with aquatic ecosystems occur within the search area, these being:

- > Temperate Highland Peat Swamps on Sandstone (Endangered); and
- > White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland (Critically Endangered).

Three components of the Temperate Highland Peat Swamps on Sandstone EEC occur within the Blue Mountains and Newnes Plateau region: hanging swamps, low slope headwater valley swamps; and valley bottom swamps. Temperate Highland Peat Swamps on Sandstone are not known to occur within the study area and as such the preparation of assessments of the significance of impacts for these species is unnecessary. The closest occurrence of this EEC to the Project Application Area is along the Newnes Plateau approximately 25 km away.

A subset of the White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland EEC, classified as Capertee rough-barked apple – redgum – yellow box grassy woodland, was identified in riparian zones on low lands within the Project Application Area (Centennial Coal 2012). This community has been observed in low lying riparian zones along Airly Creek, Torbane Creek, Gap Creek, Genowlan Creek, Emu Swamp Creek, Dog Trap Creek, Malcolms Gully Creek close to the Project Application Area boundary.

Assessments of significance for these and other terrestrial vegetation communities have been included in the terrestrial ecology impact assessment RPS (2014).

3.1.6 Key Threatening Processes

Two aquatic Key Threatening Processes (KTPs) listed under the *EPBC Act* may be relevant to the Project:

- > Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants; and
- > Novel biota and their impact on biodiversity.

Both KTPs are concerned with the potential for invasive organisms to spread at the detriment of native ecosystems. As the Project would involve limited surface disturbance and no specific in-stream works, the risk to aquatic ecosystems associated with these KTPs is considered to be low. However, these are addressed in the impact assessment as a precautionary measure.

3.2 Matters of State Conservation Significance

3.2.1 Methods

A search for information regarding records and distribution of threatened and protected species of fish in the Lithgow LGA and Hawkesbury-Nepean Catchment Management Authority (now the Central Tablelands Local

Land Service (LLS)) was undertaken using the online Fish Record Viewer developed by the Threatened Species Unit of the former NSW I&I (now DTIRIS).

A second online search facility, NSW BioNet managed by OEH's Wildlife Unit, was used to search for records of flora and fauna sightings within the Lithgow LGA held in the Atlas of NSW Wildlife. This Atlas contains records of plants, mammals, birds, reptiles, amphibians, some fungi, some invertebrates (such as insects and snails listed under the *TSC Act*) and some fish. The Atlas was also searched for information on known and predicted distributions of vegetation communities, endangered populations and key threatening processes listed under the *TSC Act* that occur within the Lithgow LGA.

3.2.2 Protected Areas

The Mugii Murum-ban SCA covers the majority of the Project Application Area, including the Mount Airly and Genowlan Mountain mesas. The Mugii Murum-ban SCA is afforded legislative protection under the *NP&W Act* to preserve natural and cultural heritage values and provide recreational opportunities, and allows for mineral exploration and mining.

3.2.3 Threatened Species and their Likelihood of Occurrence

According to the NSW DPI Threatened Species Record Viewer, Macquarie perch is the only threatened fish species listed under the *FM Act* (listed as endangered) to have been recorded in the Lithgow LGA (see **Section 3.1.2.3** for information on its distribution). As such, an Assessment of Significance was undertaken for this species. Two other threatened fish species (silver perch and trout cod) listed under the *FM Act* have been recorded in the Hawkesbury-Nepean Catchment; however, these records are all from coastal rivers and represent stocked fish (NSW DPI 2006b). Assessments of significance for these species were therefore not considered necessary because these species have not been recorded within the reaches of watercourse within the Project Application Area, and are considered unlikely to occur due to the mainly ephemeral headwater habitats within the Project Application Area.

The search undertaken using NSW BioNet showed that one endangered semi-aquatic invertebrate species, the giant dragonfly (*Petalura gigantea*), listed under the *TSC Act*, has been recorded in the Lithgow LGA. The expected range of two dragonfly species, Adam's emerald dragonfly (*Archaeophya adamsi*) and Sydney hawk dragonfly (*Austrocordulia leonardi*) both listed as endangered under the *FM Act*, includes the Hawkesbury-Nepean Catchment.

3.2.3.1 Giant dragonfly

This species is typically found in permanent swamps and bogs containing some free water and open vegetation (NSW Scientific Committee 2011). The giant dragonfly is considered to be an obligate groundwater dependent mire (peat-forming wetland) dwelling species, because its breeding success is dependent on sites with a groundwater regime that provides enough surface moisture to minimise desiccation of eggs and early larval instars, peat land soils suitable for burrowing by larvae, and a water table height that allows larvae to access or extend their burrows (Benson and Baird 2012). The larval stage is unusually long, from at least 10 to 30 years. Adults emerge in October to November and survive until late January. They are poor flyers and do not readily disperse (NSW Scientific Committee 2011).

Threats to the giant dragonfly include:

- > Changes to natural fire regimes;
- > Clearing and development of land resulting in habitat loss and/or degradation;
- > Weed invasion;
- > Decreased water quality through pollution;
- > Eutrophication and sedimentation; and
- > Impacts on swamp hydrology from factors such as construction of works.

There are two records of the giant dragonfly from the Wolgan and Ben Bullen State Forest areas in 2008, approximately 15 to 20 km to the south of the Project Application Area. This species has also been recorded within Newnes State Forest to the south-east. It is considered possible, although unlikely, that the giant

dragonfly occurs within the Project Application Area, as marginal aquatic habitat exists. An Assessment of Significance has been prepared as a precautionary measure (**Section 6.4**).

3.2.3.2 Adam's emerald dragonfly

The Adam's emerald dragonfly (*Archaeophya adamsi*) is extremely rare having been collected from only a few localities, suggesting that populations are highly localised. The Adam's emerald dragonfly has been collected from four localities near Sydney: Somersby Falls and Floods Creek in Brisbane Waters National Park near Gosford; Tunks Creek near Berowra and Hornsby; Bedford Creek in the Lower Blue Mountains; and Hungry Way Creek in Wollemi National Park. This species has not been found elsewhere in the Hawkesbury watershed or in the Sydney region, despite active collecting over the last 35 years (NSW DPI 2012). The larvae of this species have been found in narrow, shaded riffle zones with moss and abundant riparian vegetation in small creeks with gravel or sandy bottoms (NSW DPI 2012). It is possible that Adam's emerald dragonfly may occur in the Project Application Area, as suitable, albeit limited, habitat exists in Genowlan Creek. As the occurrence of Adam's emerald dragonfly cannot be discounted, an Assessment of Significance has been prepared as a precautionary measure (**Section 6.4**).

3.2.3.3 Sydney hawk dragonfly

The Sydney hawk dragonfly (*Austrocordulia leonardi*) is extremely rare having been collected at three locations between Audley and Picton to the south of Sydney and in the Hawkesbury-Nepean, Georges River and Port Hacking drainages (NSW DPI 2007). The predicted distribution of this species, however, does not extend much beyond Penrith (NSW DPI 2007), thus, it is highly unlikely to occur in the Project Application Area. The Sydney hawk dragonfly has only ever been collected from deep and shady river pools with cooler water. Larvae are found under rocks where they coexist with the eastern hawk dragonfly (NSW DPI 2007). It is considered highly unlikely that the Sydney hawk dragonfly would occur in the study area given its known distribution and habitat and it was therefore not deemed necessary to complete an Assessment of Significance for this species.

3.2.4 Threatened Populations

None of the threatened populations listed under the *TSC Act* or *FM Act* are relevant to aquatic ecosystems of the Project Application Area. Any relevant threatened terrestrial populations are assessed in the terrestrial ecology impact assessment (RPS 2014).

3.2.5 Threatened Communities

Four swamp communities are listed as EECs under the *TSC Act*:

- > Blue Mountains Swamps in the Sydney Basin Bioregion;
- > Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South-East Corner, South-Eastern Highlands and Australian Alps bioregions;
- > Newnes Plateau Shrub Swamp in the Sydney Basin Bioregion; and
- > White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland.

These EECs are considered in the terrestrial ecology impact assessment (RPS 2014).

3.2.6 Key Threatening Processes

The following KTPs listed under the *TSC Act* are potentially relevant to the aquatic ecosystems within the Project Application Area:

- > Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands;
- > Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants; and
- > Predation by *Gambusia holbrooki* Girard, 1859 (plague minnow, mosquito fish or eastern gambusia).

Two additional KTPs listed under the *FM Act* may also be relevant:

- > Degradation of native riparian vegetation along New South Wales watercourses; and

- > Introduction of fish to waters within a river catchment outside their natural range.

As stated previously, the Project involves limited surface disturbance and no specific in-stream works, and therefore the likelihood of most of these KTPs being accelerated is low. Project-related subsidence could potentially have secondary effects on creek flows and riparian habitat. The potential for changes of this nature are covered in **Section 6** and **Section 7**.

3.3 Noxious Species

Eastern gambusia (*Gambusia holbrooki*) a noxious fish species listed under the *FM Act* was found during the survey. This species is listed as a Class 1 noxious fish in the Lithgow LGA.

Two weeds, Blackberry (*Rubus fruticosus* sp. agg.) and Willow (*Salix* sp.), listed as noxious within the Lithgow LGA under the *NW Act*, were observed in riparian zones during the survey. No in-stream submerged or emergent noxious aquatic macrophytes were observed.

3.4 Protected Species

Australian grayling, one of the threatened fish species listed under the *EPBC Act* potentially occurring in the Lithgow LGA, is listed as a protected species under the *FM Act*. The information on its current distribution, presented in **Section 3.1.3.1** indicates this species is highly unlikely to occur in the Project Application Area.

The BioNet search indicated that two semi-aquatic mammals, platypus (*Ornithorhynchus anatinus*) and water rat (*Hydromys chrysogaster*), protected under the *NP&W Act*, occur within the Lithgow LGA. Platypus has been recorded in the Capertee River downstream of Glen Davis and the water rat has been recorded in Coco Creek within the Gardens of Stone National Park, however there are no records of either species occurring within the Project Application Area.

3.5 Wild Rivers

Wild Rivers are rivers that are in near-pristine condition in terms of animal and plant life and water flow, and are free of the unnatural rates of siltation or bank erosion that affect many of Australia's waterways. In NSW, Wild Rivers may be declared within national parks and other reserves that are protected under the *NP&W Act*. The declaration of 'Wild Rivers' ensures that their high conservation values are maintained and that Aboriginal objects and places associated with them are identified, conserved and protected. The Colo River and its four sub-catchments (Capertee, Colo, Wolgan and Wollemi) is one of the river systems declared a Wild River in 2008 (DECCW 2008). The Colo Wild River Assessment recommended that the section of the Capertee River from the junction of (and including) Dingo Creek (10 km downstream of Glen Davis), to the Colo River and their tributaries be declared a Wild River. The assessment concluded that this should provide adequate distance for the river to recover from mining disturbances upstream (DECCW 2008).

3.6 Critical Habitat

Critical habitats are areas of habitat (land and/or water) that are crucial to the survival of particular threatened species, populations and communities. None of the critical aquatic habitats listed under the *TSC Act* or *FM Act* are relevant to the Project.

3.7 Key Fish Habitat

The NSW DPI map showing the distribution of key fish habitats within the Lithgow LGA indicates that reaches of Airly Creek, Torbane Creek, Dog Trap Creek, Gap Creek and Genowlan Creek within the Project Application Area are considered key fish habitats (BioNet, 2013).

3.8 Groundwater Dependent Ecosystems

The definition and classification of GDEs adopted in this report are those from the Risk Assessment Guidelines for GDEs produced by the NSW Office of Water (Serov *et al.* 2012). According to these guidelines, GDEs are ecosystems in which the species composition and natural ecological processes are wholly or partially determined by groundwater.

The classification scheme recognises three broad types of GDEs associated with underground ecosystems:

- > Karst and caves;
- > Subsurface phreatic aquifer ecosystems; and
- > Baseflow stream (hyporheic or subsurface water ecosystems).

The classification scheme also recognises four broad types of GDEs are associated with above ground ecosystems;

- > Groundwater dependent wetlands;
- > Baseflow streams (surface water ecosystems);
- > Estuarine and near shore marine ecosystems, and
- > Phreatophytes – Groundwater dependent terrestrial vegetation.

Each of these GDE types comprises a number of distinct subtypes. Many of the groundwater flows within the Project Application Area are too deep for these GDEs to occur, however some areas of alluvium contain shallow aquifers within the Project Application Area that may support GDEs (GHD 2014a).

Due to the depths of these aquifers, the Project could potentially impact on subsurface phreatic aquifer ecosystems and baseflow streams. By overlaying vegetation mapping on the GHD (2014a) drawdown scenarios, RPS have identified four vegetation communities within the Project Application Area that are likely to be impacted by drawdown (however, without appropriate sampling, these may not be GDEs) (RPS 2014):

- > MU 3 Hillslope Talus Mountain Gum - Brown Stringybark - Grey Gum – Broad-leaved Hickory Moist Forest;
- > MU 13 Tableland Gully Ribbon Gum - Blackwood - Apple Box Forest;
- > MU 21 Capertee - Wolgan Slopes Red Box - Grey Gum - Stringybark Grassy Open Forest; and
- > MU 40 Capertee Slopes Red Ironbark - Red Stringybark - Narrow-leaved Stringybark Shrubby Woodland.

3.9 Summary of Conservation Issues and Likelihood of Occurrence

A summary of relevant aquatic threatened species and communities is provided in **Table 3-1** along with an assessment of their likelihood of occurrence within the Project Application Area. Likelihood of occurrence was determined by examining historical species records, published distributions and habitat preferences. Professional judgement was then used to determine the likelihood that a species, population or community would occur.

Table 3-1 Relevant aquatic species and communities listed as threatened under state and federal legislation

Species or community name	TSC Act status	FM Act status	EPBC Act status	Likelihood of occurrence
Australian grayling			Vulnerable	Unlikely
Murray cod			Vulnerable	Unlikely
Trout cod		Endangered		Unlikely
Silver perch		Vulnerable		Unlikely
Macquarie perch		Endangered	Endangered	Unlikely*
Adams emerald dragonfly		Endangered		Unlikely*
Sydney hawk dragonfly		Endangered		Unlikely
Giant dragonfly	Endangered			Unlikely*
Temperate Highland Peat Swamps on Sandstone			Endangered	Unlikely
Blue Mountains Swamps in the	Vulnerable			Unlikely

Species or community name	TSC Act status	FM Act status	EPBC Act status	Likelihood of occurrence
Sydney Basin Bioregion				
Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South-East Corner, South-Eastern Highlands and Australian Alps bioregions	Endangered			Unlikely
Newnes Plateau Shrub Swamp in the Sydney Basin Bioregion	Endangered			Unlikely
White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland	Endangered		Critically Endangered	Highly Likely

*Assessment of Significance completed in this report due to potential, albeit unlikely occurrence within the Project Application Area

4 Existing Environment – Surface Water Ecosystems

The following description of the aquatic ecosystems is based primarily on field-based investigations of the aquatic habitats, quality of water, aquatic flora and fauna in Dog Trap Creek, Genowlan Creek, Grotto Creek, Gap Creek, Torbane Creek and Airly Creek. Information on rainfall, topography, stream water quality and hydrology derived from Centennial Airly monitoring is also presented. All sites were surveyed during the autumn 2013 sampling event, however Genowlan Creek, Grotto Creek and Gap Creek sites were not included in subsequent sampling events, as per the monitoring program design. Further monitoring of these creeks will be undertaken within a timeframe that reflects the planned west-to-east progression of mining activities.

4.1 Topography and Landuse

The Project Application Area is located in the Western Coalfield of NSW, within the Sydney Basin. The area is characterised by steep and rugged topography, with Mount Airly to the west and Genowlan Mountain to the east. Site elevation varies from <400 m in the south-east to >1000 m.

Most of the Project Application Area consists of rugged bushland, of which the majority is the Mugii Murum-ban State Conservation Area. The area has been subject to historical mining activities, including an area of shale oil mining on the northern side of Mount Airly. The Project Application Area is dominantly surrounded by conservation areas (Mugii Murum-ban SCA), rugged bushland and cleared agricultural land. The Gardens of Stone National Park is located to the south while the Capertee Valley continues east of the Project Application Area towards the Wollemi National Park. Glen Davis Road and the Airly Mine Access Road and Torbane Road pass through the south-western corner of the Project Application Area.

4.2 Watercourses

The Project Application Area lies within the Capertee River catchment, which is part of the Greater Hawkesbury/Nepean catchment. There are four major sub-catchment areas within the Project Application Area (**Figure 4-2**):

- > Torbane-Oaky Creek;
- > Emu Swamp Creek;
- > Airly-Coco Creek; and
- > Genowlan/Gap Creek.

All four sub-catchments drain into the Capertee River approximately eight km downstream, which flows in a south-easterly direction and joins the Colo River which is a tributary of the Hawkesbury-Nepean Catchment.

The headwaters of most creeks around the Project Application Area are ephemeral and have low or zero flow for much of the year (**Plate 1**). Creek discharge is dependent on rainfall and surface conditions (e.g. soil saturation/permeability and underlying geology).

The Torbane-Oaky Creek system is located in the north-west section of the Project Application Area. Torbane Creek converges with Oaky Creek approximately two km downstream of the Project Application Area. Approximately 590 ha of the Torbane-Oaky Creek sub-catchment lie within the Project Application Area (GHD 2014b).

Emu Swamp Creek is located in the north-eastern section of the Projection Application Area, fed by a series of drainage lines and flows eastwards, converging with the Capertee River approximately ten km downstream of the Project Application Area. Approximately 355 ha of the Emu Swamp Creek sub-catchment lie within the Project Application Area (GHD 2014b).

The Airly-Coco Creek system is located in the southern section of the Project Application Area and flows into the Capertee River approximately 12 km upstream of Glen Davis. Approximately 1,400 ha of the Project Application Area drain into the Airly-Coco Creek sub-catchment.

Genowlan Creek and Gap Creek are the main watercourses crossing the Project Application Area and principally drain from Mount Airly and Genowlan Mountain, respectively. These creeks converge near the base of the mountains outside the Project Application Area (**Plate 2a**). Both are fed by springs located around the Mount Airly and Genowlan Mountain escarpment, such as the Village Spring (**Plate 2b**), which feeds lower Gap Creek and Genowlan Creek adjacent to the Grotto (**Plate 2c and d**).

4.3 Rainfall and Stream Hydrology

Centennial Airly provided site-specific rainfall data for Airly Mine for the period from April 2010 onwards. This data series was not considered long enough to sufficiently represent local trends in rainfall. Therefore, long term monthly rainfall statistics were sourced from Bureau of Meteorology (BOM) weather station at Running Stream (Brooklyn), located approximately 20 km to the east of the Airly site office. The Running Stream (Brooklyn) weather station was selected for its proximity to the Project Application Area and the availability of recent data that coincided with biota sampling dates. Rainfall statistics for Running Stream (Brooklyn) are calculated from 1899 to 2014, with near continuous data. , the greatest monthly rainfall at the Running Stream (Brooklyn) weather station occurred in January and February (greater than 80 mm/month) and lowest between April and May (around 60 mm/month) (**Table 4-1**).

Table 4-1 Monthly rainfall statistics for the Running Stream (Brooklyn) BOM weather station (1899-2014)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	81.9	80.7	70.6	61.4	61.4	69.6	68.8	70.2	62.2	71.7	75.8	78.6	849.1

The Surface Water Impact Assessment (GHD 2014a) used SILO Patched Point Data from the BOM Ilford (Warragunyah) weather station. This station stopped recording rainfall data in January 2011, and therefore is not suitable for the purpose of this report.

Recent near continuous daily rainfall data sourced from the Airly site office weather station from January 2013 are presented alongside stream flow data from the Gap Creek and Genowlan Creek gauging stations in **Figure 4-1**. Note that the secondary y-axis has been transformed logarithmically to better represent the data and that all zero values were converted to 0.001 m³/day for display purposes. The Gap Creek and Genowlan Creek gauging stations were commissioned in early 2013 so the data depicted represents all available data up to end June 2014. Due to mechanical failure, rainfall data were not collected for several months during the middle of 2013. No aquatic ecology sampling events occurred during that period, although data were collected for several months prior to the spring 2013 sampling event.

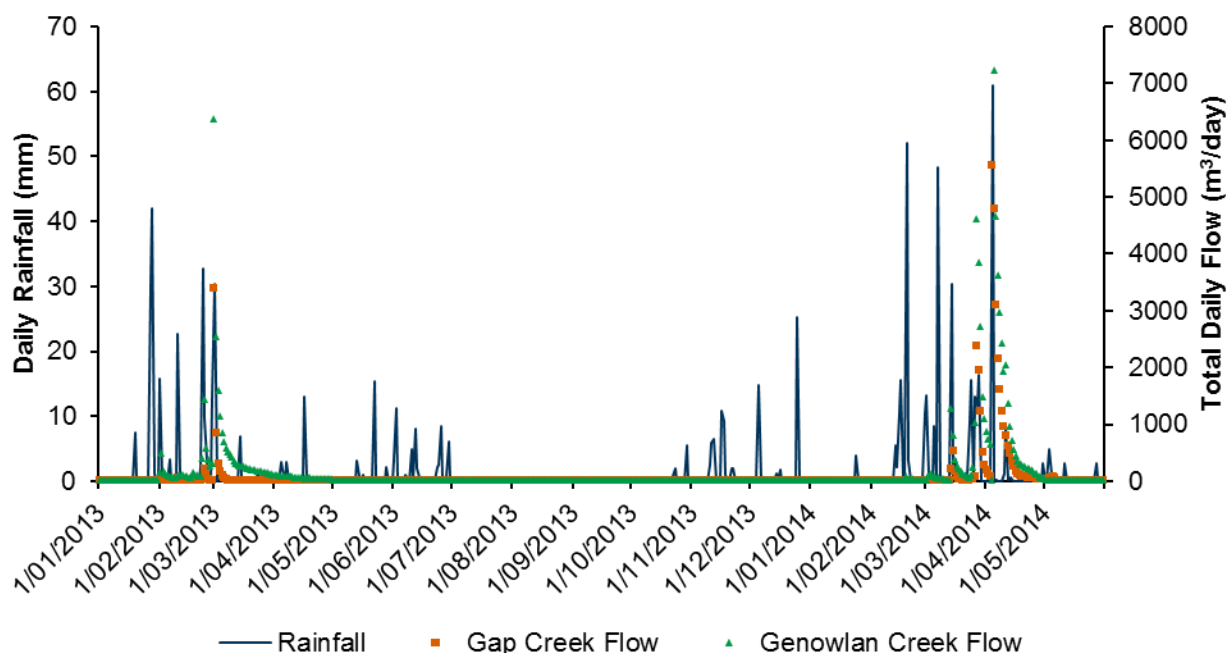


Figure 4-1 Daily rainfall (Airly site office weather station) and flow at the Genowlan and Gap creeks v-notch weir. Rainfall data from Airly site office weather station not available from 1 July to 8 October 2013.

Stream flow at both gauging stations was highly ephemeral, as illustrated by frequent periods of zero flow (**Figure 4-1**). Flow persisted for numerous weeks following moderate rainfall events that occurred between January and April 2013. Similarly moderate to heavy rainfall events between February and April 2014 also stimulated stream flow during March/April 2014. However, rainfall during the middle and end of 2013 was generally insufficient to induce flow at the gauging stations.

4.4 Monitoring Methods

The aims of the aquatic ecology sampling undertaken for the Project were:

1. To obtain an adequate representation of aquatic habitats and biodiversity within and around the Project Application Area to describe the existing environment and support the assessment of potential impacts; and
2. To collect specific baseline data for ongoing aquatic ecosystem monitoring.

An initial site visit to assess the availability of permanent aquatic habitat and select sampling sites that were appropriate for a Before-After-Control-Impact monitoring program was completed on 15 April 2013.

Twelve monitoring sites were selected based on available surface water and to achieve an adequate representation of aquatic habitats present. The monitoring sites were located on creeks within and outside of the Project Application Area that appeared to have permanent water. Two sites were selected on each creek to ensure data were representative. Three pairs of sites were situated on creeks at higher altitudes within the Project Application Area (Gap Creek, Grotto Creek and Genowlan Creek) and two pairs of sites were situated along creeks at lower altitude (Airly Creek and Torbane Creek), with these sites expected to receive runoff during the initial stages of the Project. One additional pair of sites was selected on a reference creek (Dog Trap Creek) for the lower altitude creeks and was not expected to be affected by the Project. The geographic coordinates of the ecological sampling sites associated with baseline monitoring events undertaken in autumn and spring 2013, and autumn 2014 are outlined in **Table 4-2**. In autumn 2013, the Project Application Area was visited over two events (May and June), which have been combined to form the autumn season. The location of the sites is shown in **Figure 4-2** and photographs of the study sites and other key locations within the Project Application Area are presented in **Plate 1** to **Plate 6**.

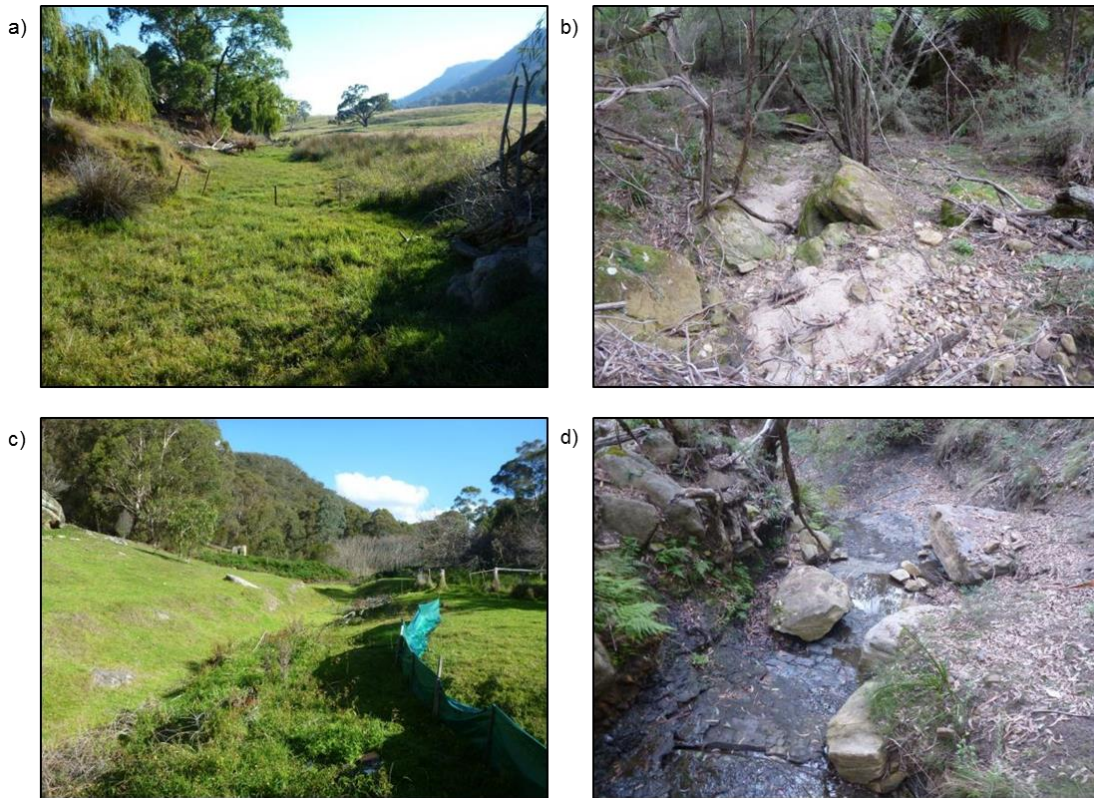


Plate 1 Dry or ephemeral creeks within the Project Application Area including: a) swampy grass channel of Torbane Creek in cleared pastoral land around one kilometre downstream of 'Carinya'; b) Genowlan Creek, dry along the upper south-eastern arm, also known as 'the Oasis'; c) dry grass channel upstream of the Gap Creek sampling sites; and d) small and apparently ephemeral tributary of Gap Creek on the eastern side of Mount Airly.



Plate 2 Key natural water features: a) Genowlan Creek at the confluence of the two upper arms; b) the Village Spring on the north-eastern side of Mount Airly; c) spring water feeding the 'Grotto' near the upper constriction of this sandstone canyon formation; and d) the 'Grotto' canyon formation.

Table 4-2 Geographic position of sampling sites and ecological components sampled.

Location	Site	Northing ¹	Easting ¹	Fish	AUSRIVAS	Quantitative ²
Genowlan Creek	GEN 1	6333278	225729	✓	✓	N/A
	GEN 2	6333340	225725	✓	✓	N/A
Grotto Creek	GRO 1	6332795	225384	✓	✓	N/A
	GRO 2	6332826	225433	✓	✓	N/A
Gap Creek	GAP 1	6334015	224195	✓	✓	N/A
	GAP2	6334091	224233	✓	✓	N/A
Airly Creek	AIR 1	6331091	220336	✓	✓	✓
	AIR 2	6331035	220340	✓	✓	✓
Torbane Creek	TOR 1	6335012	220637	✓	✓	✓
	TOR 2	6335080	220553	✓	✓	✓
Dog Trap Creek	DOG 1	6330078	230390	✓	✓	✓
	DOG 2	6330086	230524	✓	✓	✓

¹Coordinate datum are WGS 84 UTM (Zone 56 H)

²Quantitative macroinvertebrate sampling using the Brooks (1993) suction sampler was completed on lowland creeks. Only sites with imminent potential impact from the proposed works (impact) and a reference creek (control) with similar habitat and geographical attributes were sampled using this method. Data from this sampling will be analysed using a robust BACI experimental design.

A brief description of the monitoring methods is provided below and further details are presented in **Appendix A:**

- > Description of surface water habitats and vegetation using the AUSRIVAS (Australian River Assessment System) habitat assessment (Turak *et al.* 2004), a modified version of the Riparian, Channel and Environmental (RCE) inventory (Chessman *et al.* 1997) and the NSW DPI fish habitat assessment criteria (DPI 2013);
- > Measurement of temperature, electrical conductivity, salinity, pH, dissolved oxygen and turbidity just below the surface of the water column and comparison with ANZECC/ARMCANZ (Australian and New Zealand Environment and Conservation Council / Agriculture and Resource Management Council of Australia and New Zealand) (2000) guidelines for south-east Australian upland streams and Site Specific Trigger Values (SSTVs);
- > Water sampling and laboratory analysis of a range of metals, nutrients and other water quality indicators, completed by Australian Laboratory Services Pty Ltd (ALS) as part of ongoing water quality monitoring for Centennial Airly and assessed against the ANZECC/ARMCANZ (2000) guidelines for south-east Australian upland streams and the 95% species protection guidelines (autumn 2013 only);
- > Sampling of macroinvertebrates from stream edge habitats using the NSW AUSRIVAS sampling method (Turak *et al.* 2004);
- > Sampling of macroinvertebrates using the quantitative suction sampler method described by Brooks (1993) (imminent potential impact sites and a reference creek only); and
- > Sampling of fish using a backpack electrofisher.

The SIGNAL2 score (Stream Invertebrate Grade Number – Average Level), a biotic index that uses information on the occurrence of macroinvertebrate families and their sensitivity to pollution, was used as an indicator of water quality (Chessman 2003). The current report also includes an assessment of ‘creek health’ based on the AUSRIVAS predictive modelling software (Coysh *et al.* 2000) for autumn and spring surveys independently. A combined model has not been used due to the dry conditions during the spring 2013 sampling event. This software compares the macroinvertebrates collected at a site (i.e. Observed) to those predicted to occur (i.e. Expected) at undisturbed reference sites with similar environmental characteristics.

Two of the indices generated by the AUSRIVAS model were examined:

- > OE50 Taxa Score - This is the ratio of the number of macroinvertebrate families with a greater than 50% predicted probability of occurrence that were actually observed (i.e. collected) at a site to the number of macroinvertebrate families expected with a greater than 50% probability of occurrence. OE50 taxa values range from 0 to greater than 1 and provide a measure of the impairment of macroinvertebrate assemblages at each site, with values close to 0 indicating an impoverished assemblage and values close to 1 indicating that the condition of the assemblage is similar to that of the reference streams; and
- > Overall Bands derived from OE50 Taxa scores which indicate the level of impairment of the assemblage. These bands are graded as follows:
 - Band X = Richer invertebrate assemblage than reference condition.
 - Band A = Equivalent to reference condition.
 - Band B = Sites below reference condition (i.e. significantly impaired).
 - Band C = Sites well below reference condition (i.e. severely impaired).
 - Band D = Impoverished (i.e. extremely impaired).

Data collected using the quantitative suction sampler method were examined by calculating the Bray-Curtis similarity coefficients for each pair of samples and then using an ordination technique known as non-metric Multi-Dimensional Scaling (MDS) to produce a graphical representation of the assemblages based on their similarity between sites and replicates (Clarke 1993). In MDS plots, samples which have similar sets of organisms are grouped closer together than ones containing different sets of organisms. This grouping is visualised in the MDS plot by overlaying outputs of a group average cluster analysis of the Bray-Curtis similarity.

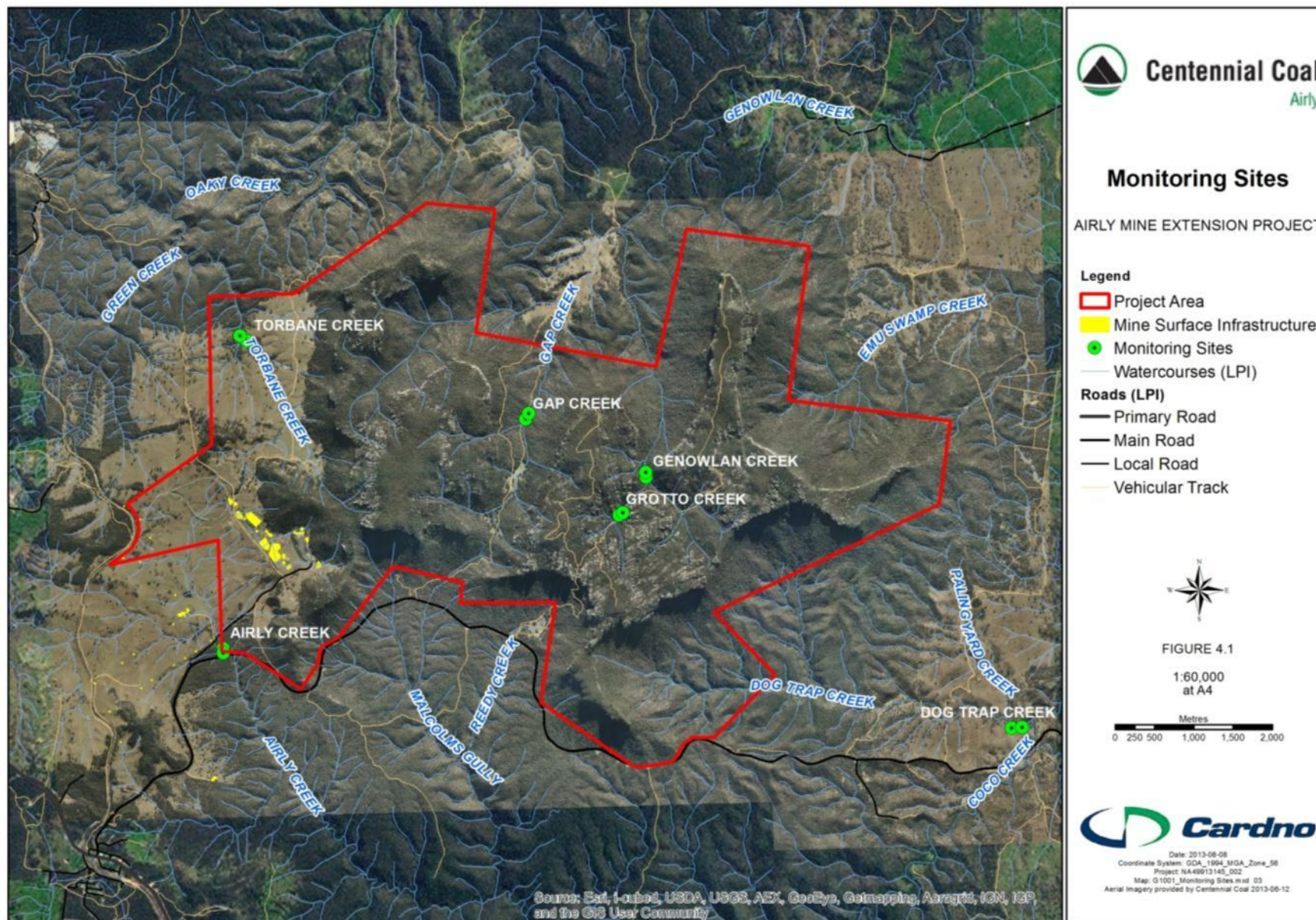


Figure 4-2 Paired aquatic ecology sampling sites on Airly, Torbane, Gap, Genowlan, Grotto and Dog Trap creeks.

4.5 Water Quality

4.5.1 Site Specific Trigger Values

Site Specific Trigger Values (SSTVs) for the Airlly Creek catchment based on a review of default values, hardness correction factors and the water quality of a reference site (Airlly Creek) have been developed in the Surface Water Impact Assessment (GHD 2014a), and relevant parameters are summarised in **Table 4-3**.

Table 4-3 Relevant Site Specific Trigger Values

Parameter	Units	ANZECC (2000) DTV	Airlly Creek (80 th percentile)	Selected SSTV
pH	pH Units	6.5-8.0	7.2-7.6	6.5-9.0*
Electrical Conductivity	µS/cm	30-350	2,998	2,998
Turbidity	NTU	2-25	83	83
Nitrogen	mg/L	0.25	1.88	1.88
Phosphorous	mg/L	0.02	0.24	0.24
Iron	mg/L	0.3	0.108	0.3
Manganese	mg/L	1.9	0.434	1.9
Zinc	mg/L	0.072	0.0198	0.072

*Upper pH limit based on the EPL discharge limit

4.5.2 Existing Information

Water quality data have been collected since January 2010 for Airlly Creek and since July 2012 for the Grotto and Gap creeks and are outlined in the Surface Water Impact Assessment (GHB 2014a) and summarised in **Table 4-4**. The 50th percentile is representative of the ambient water conditions. These results are consistent with the *in-situ* water quality measurements outlined in **Section 4.5.3** and **Section 4.5.4**.

Table 4-4 Surface Water Impact Assessment Monitoring Points Statistical Summary

Analyte	Unit	Airlly Creek		The Grotto		Gap Creek	
		50 th %	95 th %	50 th %	95 th %	50 th %	95 th %
Physico-chemical parameters							
pH	pH Unit	7.5	7.8	5.6	6.1	7.2	7.6
Electrical Conductivity	µS/cm	2,365	3,330	60	70	150	174
Turbidity	NTU	7	211	-	-	-	-
Nutrients							
Total Nitrogen	mg/L	0.8	6.24	-	-	-	-
Total Phosphorus	mg/L	0.075	0.96	-	-	-	-
Dissolved metals							
Iron	mg/L	0.05	0.18	0.53	1.18	0.21	1.0
Manganese	mg/L	0.17	3.26	0.008	0.014	0.036	0.17
Zinc	mg/L	0.0095	0.043	0.005	0.015	0.006	0.021

4.5.3 *In-situ* Measurements

The mean and standard error (S.E.) of electrical conductivity, pH, dissolved oxygen and turbidity for each waterway over the three sampling seasons are presented in **Figure 4-3**, **Figure 4-4** and **Figure 4-5**. The *in-situ* water quality measurements are presented in **Appendix C**.

4.5.3.1 *Water Temperature*

The mean water temperature was lowest in Airly Creek in autumn 2013 (8.2°C) and greatest in Dog Trap Creek in spring (19.1°C). Gap, the Grotto and Genowlan creeks had similar mean water temperatures of 11.1, 11.5 and 11.6°C, as did Airly, Torbane and Dog Trap creeks during the spring 2013 and autumn 2014 sampling events (**Figure 4-3a**). Dog Trap Creek had a slightly higher mean temperature during the autumn 2013 sampling event. The mean waterway temperatures correlate with site elevation (colder at higher elevation) and aspect (shading and prevailing weather factors). Seasonal changes can be seen in the generally higher temperatures during the spring sampling event.

4.5.3.2 *Electrical Conductivity*

Electrical conductivity is a measure of the total concentration of inorganic ions (salts) dissolved in water. The ANZECC/ARMCANZ (2000) guidelines specify lower and upper guidelines of 30 $\mu\text{S}/\text{cm}$ and 350 $\mu\text{S}/\text{cm}$, respectively for upland streams, while the selected SSTV is 2,998 $\mu\text{S}/\text{cm}$. The mean electrical conductivity levels at Airly, Torbane and Dog Trap creeks were above the upper ANZECC/ARMCANZ guideline during all sampling seasons. Airly Creek had mean levels above the SSTV in autumn and spring 2013, while Torbane was near or above the SSTV during all sampling seasons. Gap, Grotto and Genowlan creeks were all within the ANZECC/ARMCANZ guidelines and SSTV. Electrical conductivity levels at Airly and Torbane creeks were an order of magnitude greater than those for Gap, Grotto and Genowlan creeks (**Figure 4-3b**).

The pattern of land use and soil/geological properties associated with Airly Creek, Torbane Creek, and to a lesser extent, Dog Trap Creek contribute to the higher electrical conductivity values. Gap, Grotto and Genowlan creeks have forested catchments on Narrabeen Group sandstones and as such have water of low salinity in their upper reaches.

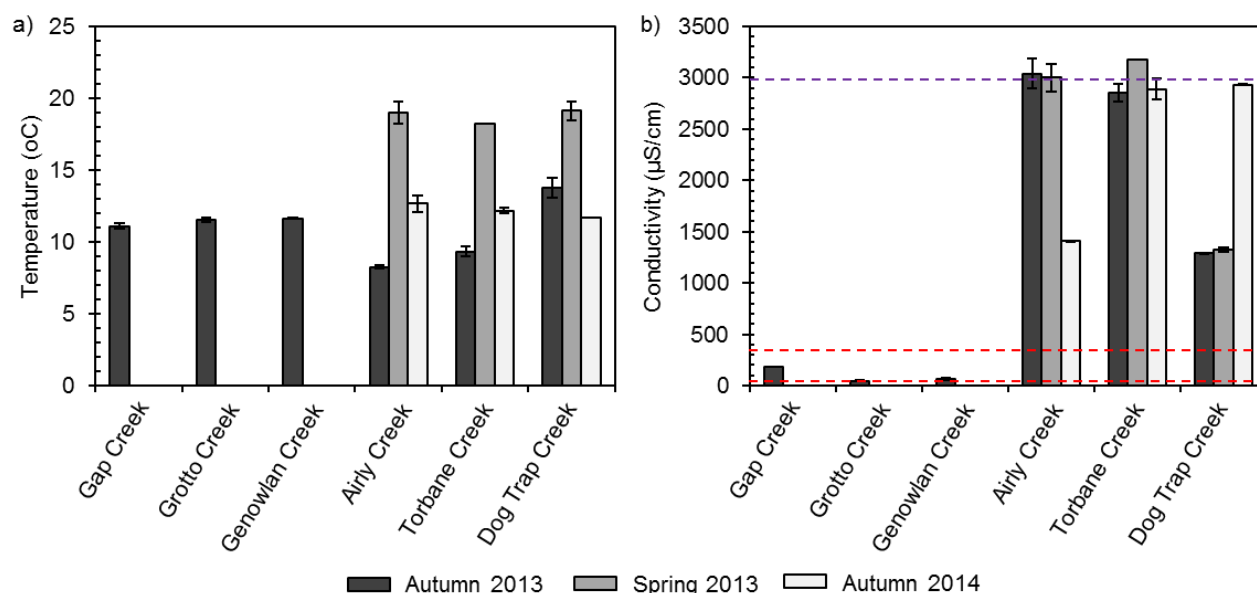


Figure 4-3 Mean ($\pm$ S.E.): (a) water temperature; and (b) electrical conductivity measurements for each creek. Red lines depict upper and lower ANZECC (2000) guidelines and the purple line depicts SSTV for conductivity. Water quality parameters were not monitored at Gap, Grotto and Genowlan creeks during spring 2013 and autumn 2014.

4.5.3.3 pH

Acidity of water is measured using pH, which is derived from the concentration of hydrogen ions and ranges from zero (very acidic) to seven (neutral) through to fourteen (highly alkaline). The pH ANZECC/ARMCANZ (2000) guidelines for slightly disturbed upland rivers in south-east Australia is 6.5-8.0 units and the SSTVs (GHD 2014a) is 6.5-9.0 units. The mean pH level was below both the guidelines and the SSTV at Grotto Creek in autumn 2013 (6.2 units). The water in this creek was consistently mildly acidic. This may be due to organic decomposition and very low pH buffering capacity (low alkalinity, see **Section 4.5.4.2, Figure 4-8**). All other sites remained within ANZECC/ARMCANZ 2000 guidelines and SSTVs throughout all sampling seasons, varying slightly from mildly acidic to mildly alkaline, most likely naturally (**Figure 4-4a**).

4.5.3.4 Oxidation-Reduction Potential

Oxidation-reduction or 'redox' reactions involve species losing (oxidation) or gaining (reduction) electrons, thereby causing chemical changes to the oxidation state of the species involved. Apart from Dog Trap Creek during the spring 2013 sampling season, all sites were oxidising, being greatest at Grotto Creek and Airly Creek (autumn 2014) (115 and 111 mV, respectively) (**Figure 4-4b**). During spring 2013 and autumn 2014, all sites (excluding Dog Trap Creek in spring) had similar ORP levels.

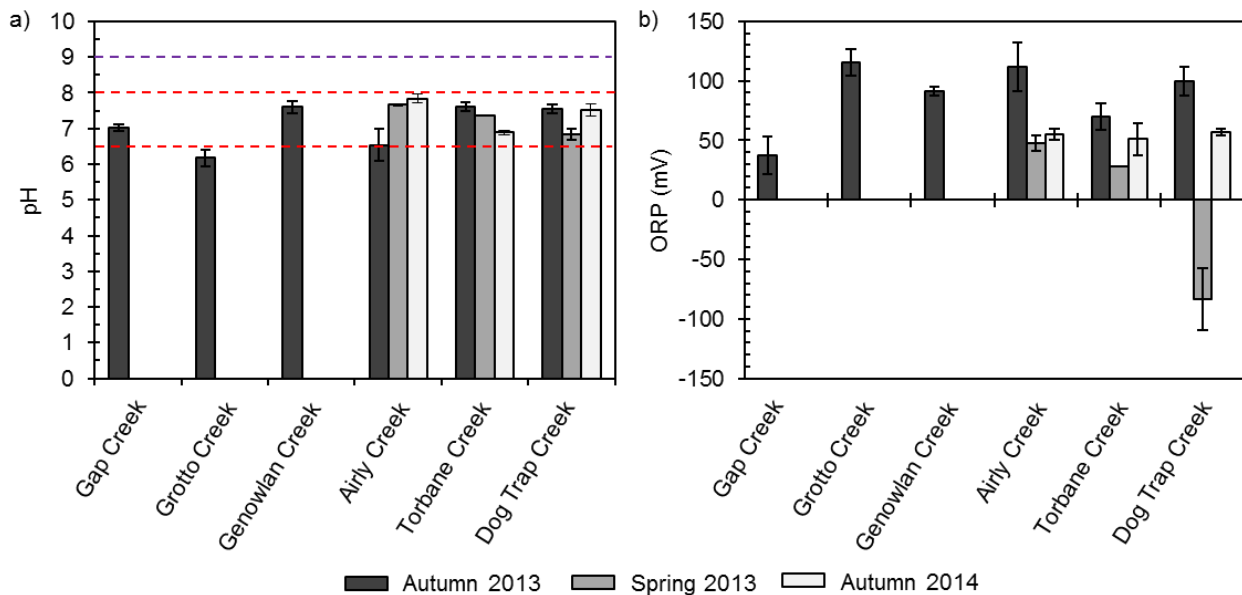


Figure 4-4 Mean ($\pm$ S.E.): (a) pH; and (b) oxidation reduction potential (ORP) measurements for each creek. Red lines depict upper and lower ANZECC (2000) guidelines and purple line depicts the upper level SSTV for pH. Water quality parameters were not monitored at Gap, Grotto and Genowlan creeks during spring 2013 and autumn 2014.

4.5.3.5 Dissolved Oxygen

The dissolved oxygen (DO) concentration of a waterbody reflects the equilibrium between oxygen-consuming processes (e.g. respiration) and oxygen-releasing processes (e.g. photosynthesis and the physical transfer of oxygen from the atmosphere to the waterbody) (ANZECC/ARMCANZ 2000). Levels of DO were below ANZECC/ARMCANZ (2000) guidelines in all sampling seasons for all creeks, apart from Dog Trap Creek during the autumn 2013 sampling event (94.4% saturation). (**Figure 4-5a**).

The relatively high DO levels at Dog Trap Creek during the two autumn seasons (**Figure 4-5a**) were probably due to abundant aquatic macrophytes, while the low measurements at Grotto Creek in autumn 2013 and Dog Trap Creek in spring 2013 (**Figure 4-5a**) may have been due to high organic content and lack of submerged macrophytes.

4.5.3.6 Turbidity

Turbidity is a measure of the degree that light is scattered and absorbed by particulates in the water and is related, although not directly proportional to the concentration of suspended solids (different solids cause different scattering and absorption of light). The mean turbidity level was below the lower ANZECC/ARMCANZ (2000) guideline (2 NTU) at Grotto and Genowlan Creek (0.6 and 0.8 NTU, respectively) but within the guidelines and SSTV (83 ntu) at Airly, Torbane, Dog Trap and Gap creeks during all sampling seasons (**Figure 4-5b**). Low turbidity is generally considered a positive water quality indicator, hence the lower values at the Grotto and Genowlan Creek are not indicative of water quality impairment.

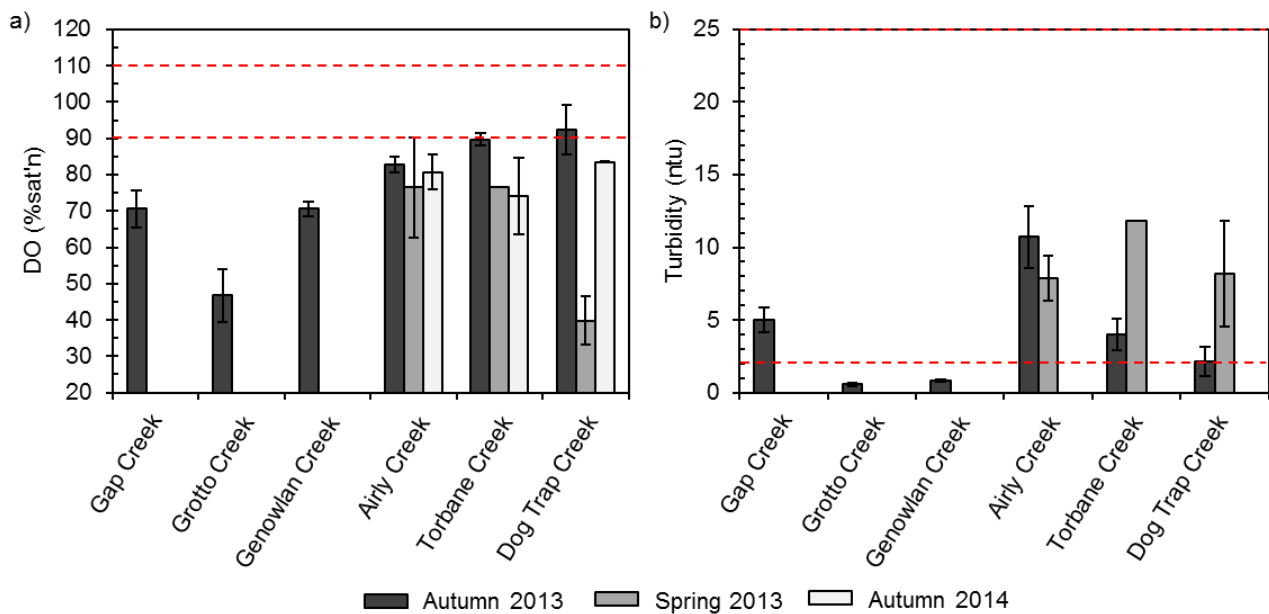


Figure 4-5 Mean ($\pm$ S.E.): (a) dissolved oxygen; and (b) turbidity measurements for each creek. Red lines depict upper and lower ANZECC (2000) guidelines. Water quality parameters were not monitored at Gap, Grotto and Genowlan creeks during spring 2013 and autumn 2014.

4.5.4 *Ex-situ* Laboratory Analysis

The results of laboratory analysis of water quality samples undertaken by ALS for Centennial Airly are presented as 'box and whisker plots' in **Figure 4-6**, **Figure 4-7** and **Figure 4-8**. The top and bottom of each 'box' represents the 1st and 3rd quartile, respectively, while the middle horizontal line represents the median value. The top and bottom 'whiskers' represent the maximum and minimum values, respectively. Data below the limit of reporting were changed to ½ the limit for calculation of statistics. The number of samples (n) varies from 12 to 1, with more samples generally collected from Airly Creek than Gap Creek and Grotto Creek. The raw data are presented in the annual water quality monitoring reports prepared by RPS Aquaterra (2011 and 2012). Water samples for *ex-site* analysis were only taken during the autumn 2014 sampling event.

4.5.4.1 *Nutrients*

The total nitrogen concentrations at Airly Creek (n=12) were generally greater than those at both Gap Creek (n=1) and Grotto Creek (n=1), with most values above the ANZECC/ARMCANZ (2000) guideline but within SSTV (1.88 mg/L). The single measurements taken at Gap Creek and Grotto Creek were collected on 15 August 2012 and were just above and just below the guideline, respectively (**Figure 4-6a**).

Total phosphorus concentrations were also generally higher at Airly Creek (n=12) than at Gap Creek (n=1). The measurement from Grotto Creek (n=1), however, was above the Airly Creek median (**Figure 4-6b**) and concentrations at both these sites were above the ANZECC/ARMCANZ (2000) guidelines. Grotto Creek was also above the SSTV (0.24 mg/L). The total nitrogen and phosphorus measurement collected at Airly Creek on 17 August 2012 was comparable to the August 2012 measurement at Gap and Grotto creeks. Comparison of nutrient levels among creeks may be misleading as data confidence is low for Gap and Grotto creeks, with only a single measurement available. The maximum total nitrogen and total phosphorus values at Airly Creek were both recorded on April 8 2013 and were many times the ANZECC/ARMCANZ (2000) guideline value.

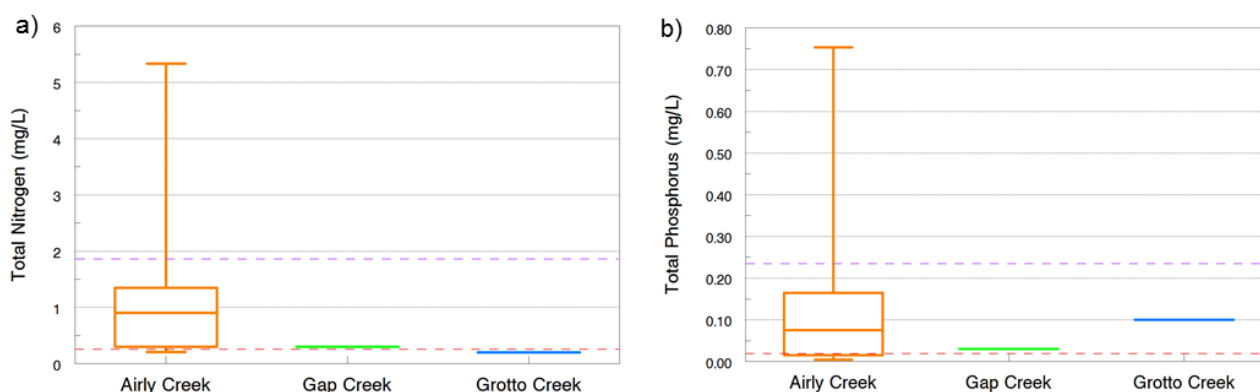


Figure 4-6 Box and whisker plot for dissolved concentrations of: (a) total nitrogen; and (b) total phosphorus in Airly, Gap and Grotto creeks. The red line depicts the ANZECC (2000) 95% protection trigger value and the purple line depicts the SSTV.

4.5.4.2 *Metals and Alkalinity*

Iron and manganese are utilised by bacteria in the production of energy when this comes to the surface (see **Section 4.5.3.4**). The visible signs of this process can be magnified through mining related changes to surface water/groundwater dynamics. Dissolved iron concentrations were greatest at Grotto Creek but also greater at Gap Creek than at Airly Creek (**Figure 4-7a**). There are no ANZECC/ARMCANZ guidelines for iron concentrations; however Grotto Creek had levels above the selected SSTV (0.3 mg/L).

Dissolved manganese concentrations displayed the opposite trend to iron, with the greatest values at Airly Creek and the lowest at Gap and Grotto creeks (**Figure 4-7b**). The ANZECC/ARMCANZ (2000) 95% protection default trigger value and selected SSTV for Manganese is 1.9 mg/L and therefore, all values were well below this threshold.

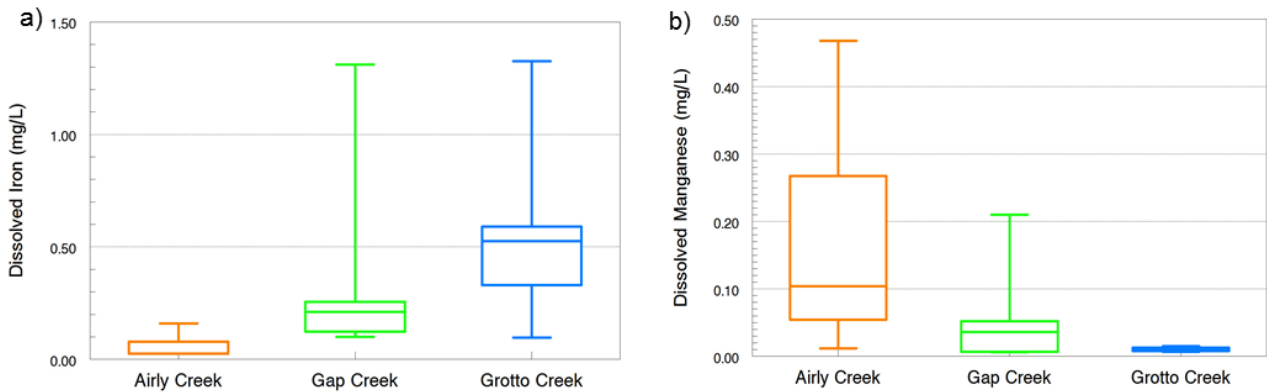


Figure 4-7 Box and whisker plot for dissolved concentrations of: (a) iron; and (b) manganese in Airly, Gap and Grotto creeks.
The red line depicts the ANZECC (2000) 95% protection trigger value and SSTV.

Dissolved zinc concentrations were greatest at Airly Creek and lowest at Gap and Grotto creeks (**Figure 4-8a**). The ANZECC/ARMCANZ (2000) 95% protection default trigger value for zinc is 0.008 mg/L and several values recorded in each creek were above the guideline, with the greatest exceedances being in Airly Creek.

Most of the other metals sampled at the Gap Creek and Grotto Creek sites were below the limit of reporting. In Airly Creek, the dissolved cadmium and copper concentrations occasionally exceeded the ANZECC (2000) guideline (RPS Aquaterra 2012).

Alkalinity is a measure of the capacity of water to buffer against pH change and is measured as the concentration of carbonate ions, usually bicarbonate in freshwater. In freshwater carbonate is typically derived by contact with rock and soils containing calcium carbonate, these commonly being of marine or estuarine origin. Bicarbonate alkalinity was always greater at Airly Creek than at Gap and Grotto creeks (**Figure 4-8b**). This is consistent with *in-situ* measurements of total alkalinity taken during the May and June 2013 ecological sampling (**Appendix C**). These showed that Airly, Torbane and Dog Trap creeks had a greater total alkalinity than Gap, Grotto and Genowlan creeks.

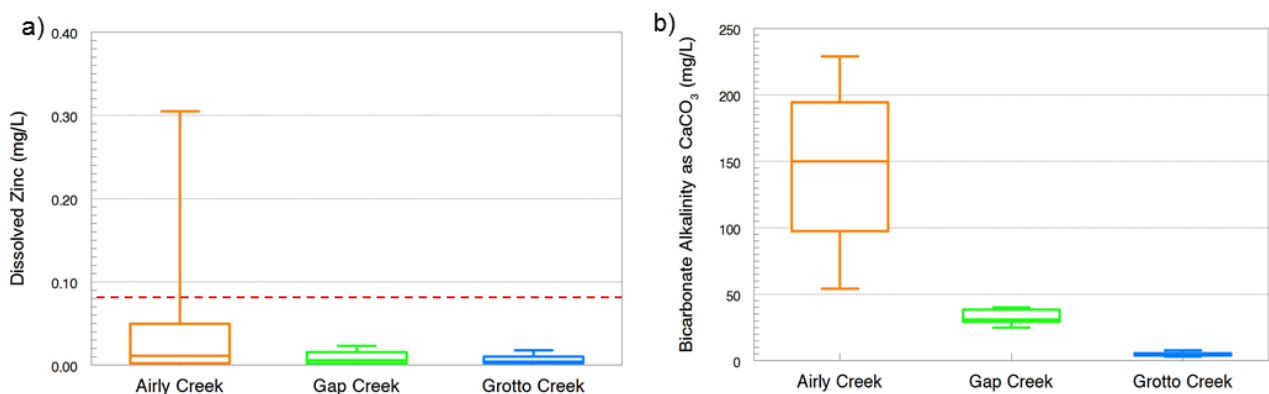


Figure 4-8 Box and whisker plot for dissolved concentrations of: (a) zinc; and (b) alkalinity in Airly, Gap and Grotto creeks.
The red line depicts the ANZECC (2000) 95% protection trigger value and SSTV for zinc.

4.6 Aquatic Habitat

The aquatic habitat within the Project Application Area was limited to small ephemeral creeks draining numerous vegetated sub-catchments originating from Mount Airly and Genowlan Mountain. Outside the Project Application Area, the catchment was less vegetated and creeks were larger and more permanent. Artificial dams were present throughout the area. The stream order, as defined using the Strahler method, is depicted in **Figure 4-9**. This provides an indication of the size and importance of aquatic habitat within the Project Application Area.

Aquatic habitat descriptions for each site are provided below. Habitat assessment descriptions for the RCE inventory scores (Chessman *et al.* 1997) and fish habitat classes based on the NSW DPI (2013) Policy and Guidelines for Fish Habitat Conservation and Management, are outlined in **Appendix B**. RCE Scores were classified according to the following scale:

- > 43 - 52 = Excellent;
- > 33 - 42 = Good;
- > 23 - 32 = Fair; and
- > 13 - 22 = Poor.

Aquatic habitat did not significantly change throughout sampling events. For Airly, Torbane and Dog Trap creeks, the April and May 2013 sampling events have collectively been categorised as autumn 2013.

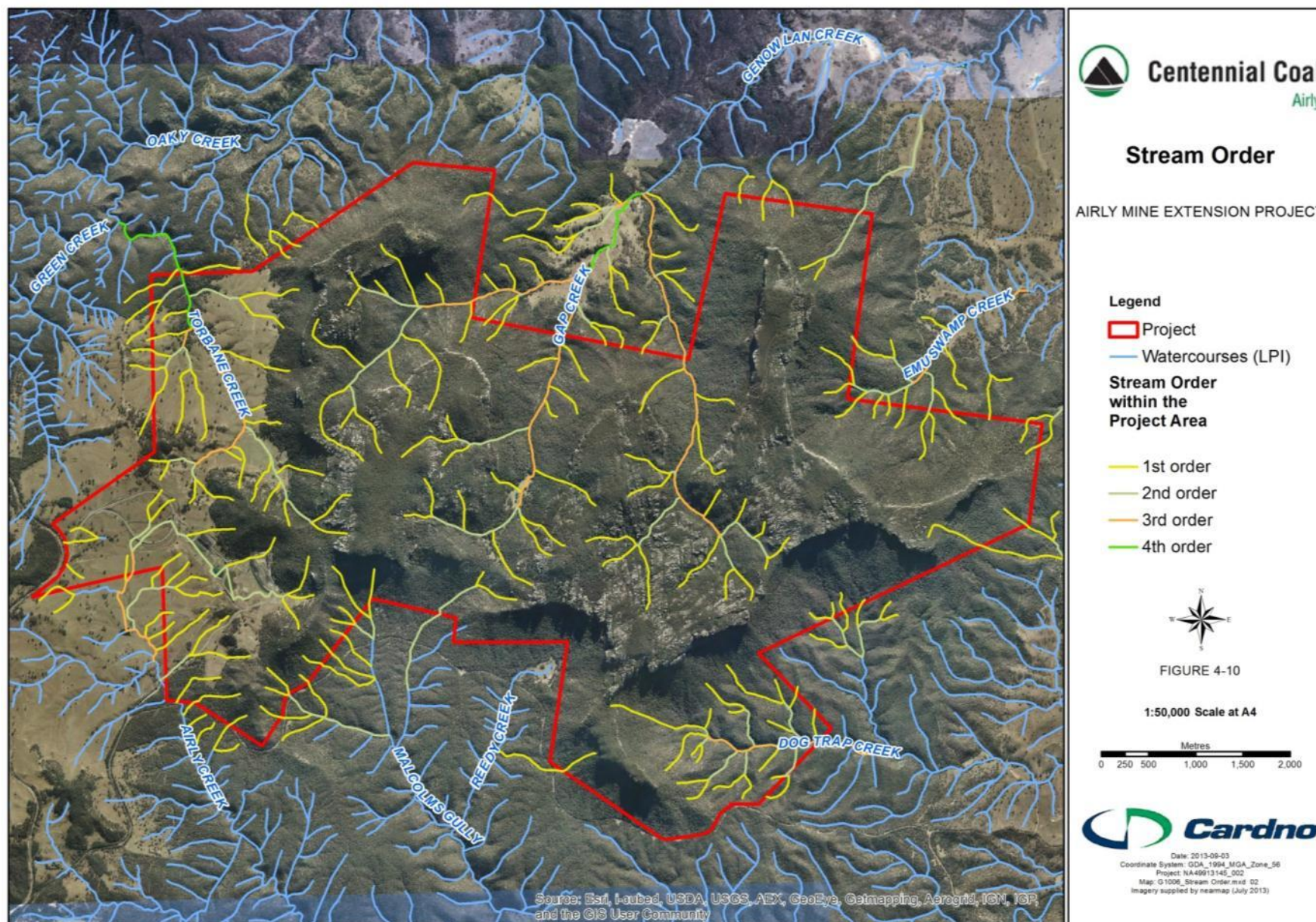


Figure 4-9 Stream order for creeks within the Project Application Area following the Strahler method

4.6.2 Airly Creek

The sites on Airly Creek (AIR 1 and AIR 2) were located directly adjacent to one another between the Glen Davis Road and the Airly Mine access road in a broad valley surrounded by native open forest (Figure 4-2, Plate

Plate 3 and Plate 4). Both sites had relatively wide (four to five m), deep (greater than one metre) pools (Plate 3a and Plate 3c) interspersed by narrow (less than one metre wide), shallower (less than ten cm deep) sections of gently to moderately flowing water (Plate 3c and Plate 4b). During spring, both sites on Airly Creek had several isolated narrow, shallow pools with no flowing water. Some of the larger pools had steep bedrock banks on the erosional side of the channel (Plate 3b and Plate 4c), with shallower soil banks more common on the depositional side. Banks were undercut by moderate to severe erosion in several sections.

The creek substratum consisted predominantly of angular bedrock, boulder and cobble, with areas of silt and clay. The water level was similar during the autumn sampling events (Plate 3 and Plate 4), but much lower during spring 2013. Flow was approximately ten litres per second during the two autumn sampling events. An underground pipeline easement crossed the creek between the upstream and downstream sites. An ephemeral creek line entered from the west at the downstream site (AIR 2) through a low tussock grass bank (right section of Plate 4b), which was dry during spring 2013. The water at both sites appeared turbid during autumn 2013, but relatively clear during autumn 2014 (Plate 4c). An oily sheen was observed on the surface of the water during both autumn sampling events, most likely due to natural sources.

Riparian vegetation consisted of a small stand of tall (greater than twenty m) oaks (*Casuarina* sp.) and a variety of grasses, mat-rush *Lomandra* spp. and weeds, including patches of blackberry (*Rubus fruticosus* sp. agg.). Beyond the riparian zone, there was open eucalypt forest containing a variety of native and exotic shrubs and grasses. Dense stands of in-stream macrophytes, dominated by cumbungi (*Typha* sp.) and common reed (*Phragmites* sp.), were present upstream of AIR 1 and downstream of AIR 2. Small patches of the river buttercup (*Ranunculus inundatus*) were also observed instream at the upstream site (AIR 1). Vegetation did not significantly change between sampling events. There was also moderate cover of filamentous green algae and substantial diatom cover during both autumn sampling events.

Both sites were classified as highly sensitive (Type 1) major fish habitat (Class 1) using the NSW DPI (2013) criteria. Both sites received an RCE score of 37 in autumn and spring 2013, indicating there was some degradation of aquatic habitat and 42 in autumn 2014 due to higher flow and reduced macrophyte growth. The RCE score for in-stream aquatic vegetation was low at these sites due to the presence of substantial emergent macrophytes and algal growth. A minor barrier to fish migration was present at the Glen Davis Road Bridge (Plate 5a), with a drop of approximately 0.3 m from the concrete bridge base to the channel downstream.

4.6.3 Torbane Creek

The sites on Torbane Creek (TOR 1 and TOR 2) were located approximately two km to the north of the abandoned mining settlement of Carinya in a steep valley surrounded by open forest (Plate 5 and Plate 6). The sites were approximately one hundred m apart and were on either side of a small ephemeral tributary that entered the main channel from the south-west. In autumn 2013, both sites contained small (two to three m wide), shallow (twenty to forty cm deep) pools (Plate 5a and Plate 6a-d) interspersed by narrow, shallow sections of flowing water. In spring 2013, TOR 1 was dry, and TOR 2 had one small (one metre wide) stagnant pool with water less than 20 cm deep. Autumn 2014 showed more flow due to prior rainfall, creating intermittent narrow, shallow pools with flowing water between. The banks at the upstream site (TOR 1) were shallow and covered in grass close to the creek, but became steep and rocky further away (Plate 4). At the downstream site (TOR 2) the banks were relatively steep and predominantly rock (Plate 5). Both sites had evidence of moderate erosion.

The creek substratum consisted of a large proportion of silt, sand and some gravel in pools. Angular bedrock, boulder and cobble substrata were also present, more commonly at bends and constrictions. The water appeared relatively clear during autumn 2013, and the single pool sampled in spring. In autumn 2014, the water at TOR 1 appeared clear, however water with high levels of iron flocculent was observed several m upstream of the converging creek. The bright orange flocculent seeped from the ground approximately 20 m further upstream of the detection point, and was evident until towards the downstream section of TOR 2,

where it dissipated. This was most likely due to natural causes, and not acid mine discharge, which can cause iron flocculation. In autumn 2013, an oily sheen and some foam were observed on the surface, most likely from natural sources. This oily sheen was also evident close to the iron flocculent seepage point. A dense cover of what appeared to be diatoms was present on the substratum and some green filamentous algae were observed in pools in both autumn sampling events. Cattle access to the creek was also evident. Small to medium-sized farm dams were present in the channel around one kilometre upstream of the sampling points within pastoral land. The waterway in these areas was generally restricted to a swampy grass channel.

Riparian vegetation was sparse close to the channel and consisted of grasses and forbs. Patches of blackberry (*Rubus fruticosus* sp. agg.) occurred higher up the banks, particularly at the upstream site (TOR 1), spreading through TOR 2 in autumn 2014. Eucalyptus-dominated open forest with an understorey of blackthorn (*Bursaria spinosa*) and *Acacia* sp. was present on the banks further from the creek and graded into cleared pastoral land on higher ground fifty to one hundred m from the creek. A small stand of unidentified deciduous saplings were present between the two sites where the ephemeral tributary entered the creek. A short length of the creek within the upstream site (TOR 1) contained a patch of emergent macrophytes dominated by knotgrass (*Paspalum distichum*), rushes (*Juncus* sp.) and a small amount of *Typha* sp. Further downstream (TOR 2) emergent aquatic macrophytes were very sparse, consisting of strands of *Juncus* sp. Discrete patches of in-stream macroalgae (*Chara* sp.) were present at both sites. Vegetation did not change significantly between sampling events.

The TOR 1 and TOR 2 sites were classified as highly sensitive (Type 1) major fish habitat (Class 1) using the NSW DPI (2013) criteria. Both sites received an RCE score of 38 in autumn and spring 2013, and 39 in autumn 2014, which is indicative of some degradation of aquatic habitat. The RCE scores for substratum composition were reduced due to the presence of fine detritus and silty substratum.



Plate 3 Airly Creek - AIR 1: Left to right – autumn 2013, spring 2013, autumn 2014: a) Upstream of reach of site looking upstream; and b) Upstream of reach of site looking downstream; c) Downstream of reach of site looking upstream.

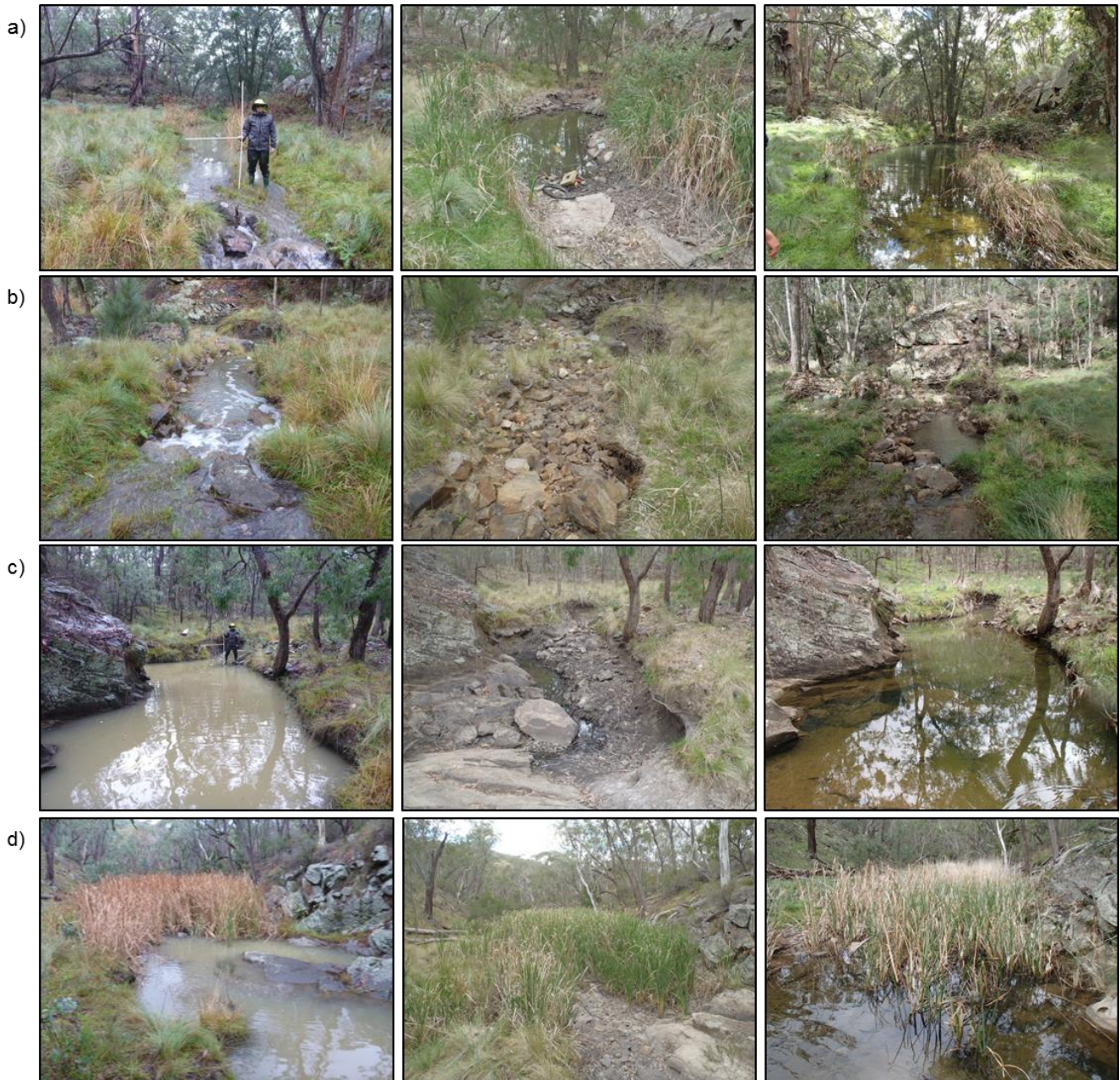


Plate 4 Airly Creek - AIR 2: Left to right – autumn 2013, spring 2013, autumn 2014: a) Upstream of reach of site looking upstream; b) Upstream of reach of site looking downstream; c) Downstream of reach of site looking upstream; and d) Downstream of reach of site looking downstream.



Plate 5 Torbane Creek - TOR 1: Left to right – autumn 2013, spring 2013, autumn 2014: a) Upstream of reach of site looking upstream; b) Middle of site looking upstream; c) Middle of site looking downstream; and d) Converging point of stream between TOR 1 and TOR 2.

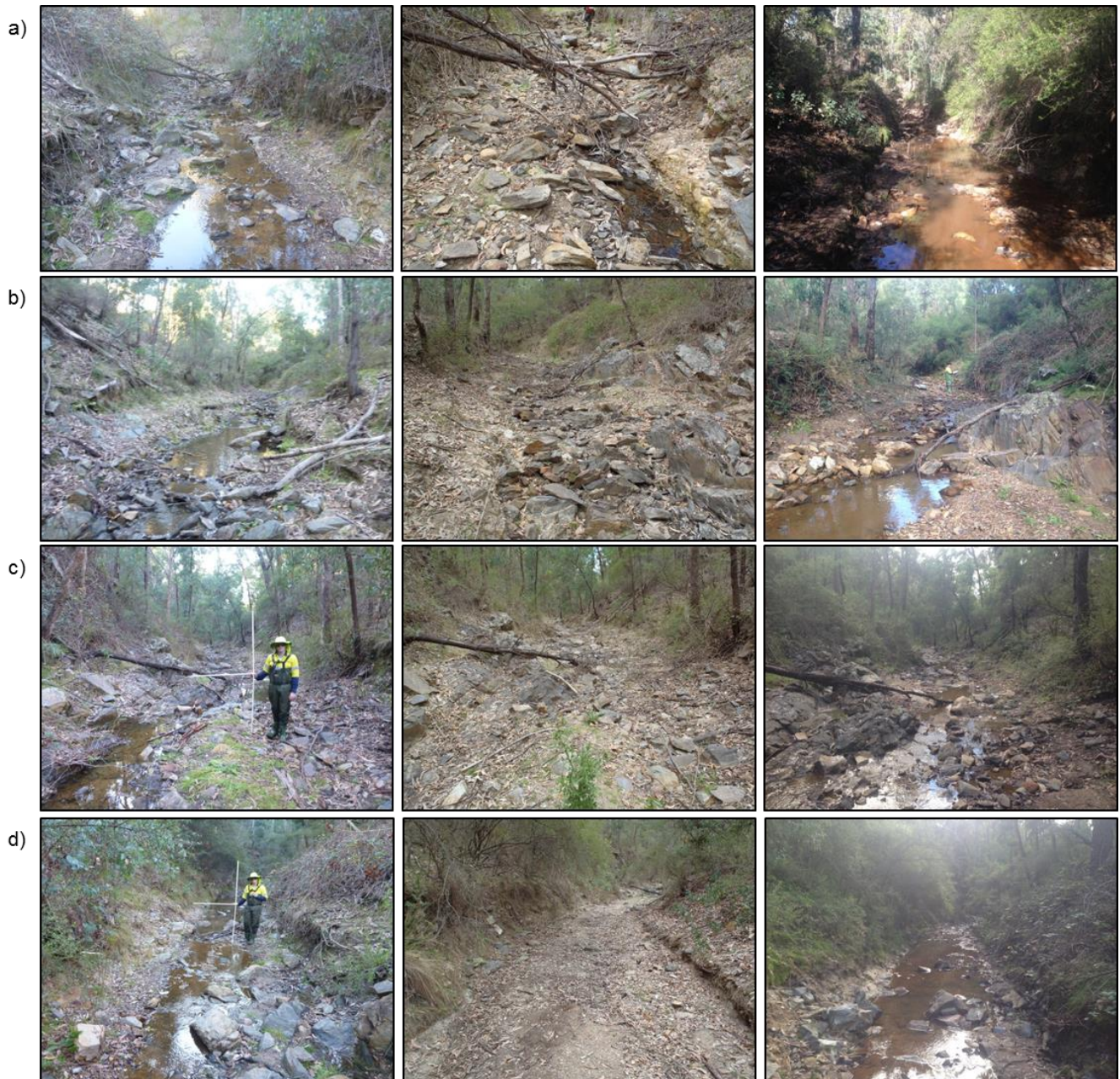


Plate 6 Torbane Creek - TOR 2: Left to right – autumn 2013, spring 2013, autumn 2014: a) Upstream of reach of site looking upstream; b) Middle of site looking upstream; c) Middle of site looking downstream; and d) Downstream of reach of site looking downstream.

4.6.4 Dog Trap Creek

The sites on Dog Trap Creek (DOG 1 and DOG 2) were located upstream and downstream of a small artificial earthen impoundment and approximately two hundred m upstream of the confluence with Coco Creek (**Plate 7** and **Plate 8**). The pool created by the earthen impoundment at DOG 1 had a maximum width of approximately five m and was fifty m long and about one metre deep (**Plate 7**). The site upstream of the impounded water section (DOG 1) consisted of a chain of small (approximately five to ten m long and less than fifty cm deep), clear pools (**Plate 7**) with rocky substrata separated by some flowing water and several swampy areas. In autumn 2013, the downstream site (DOG 2) consisted of a small running water section over rocky substratum (**Plate 8a-c**), running into a large, shallow (approximately forty cm deep) pool terminating in a swampy grass ford (**Plate 8a**). The downstream half of DOG 2 was generally dry during spring 2013 and autumn 2014 (**Plate 8a-c**). Apart from a gradual reduction in water flow in the downstream half of DOG 2, the sites on Dog Trap Creek did not change significantly between sampling events.

The creek substratum consisted of large amounts of silt and detritus, with that in the impounded area being deep and anoxic. The substratum in pools above and below the impoundment was dominated by angular bedrock, boulder and cobble, with approximately one to five litres per second observed on all visits. Surface flow appeared to cease directly upstream and downstream of the sampling sites. Paling Yard Creek entered the channel upstream of the DOG 1 site but no flow was observed. Here and further upstream along Dog Trap Creek, aquatic habitat was limited to shallow grassy pools and swampy zones. Downstream of the sampling sites along Coco Creek larger, permanent pools were present.

Riparian vegetation consisted of eucalyptus-dominated woodland on previously cleared pastoral land. Several tall (approximately twenty five m) river oaks (*Casuarina cunninghamiana*) were located upstream and downstream of the central impoundment, close to the creek. Sparse blackthorn shrubs (*Bursaria spinosa*) and a variety of native and exotic grasses were evident further away from the creek. *Lomandra* sp. was present close to the creek and was more common at the downstream site. Sparse emergent macrophytes, including *Juncus* spp. and *Isolepis inundata*, were present along the banks. In-stream vegetation was dominated by dense Charophyta in the deeper open water with small patches of *Nitella* sp. also present. The watercress *Rorippa nasturtium-aquaticum* was abundant in the shallower swampy areas. Vegetation did not change significantly between sampling events.

The DOG 1 and DOG 2 monitoring sites were classified as highly sensitive (Type 1) major fish habitat (Class 1) using the NSW DPI (2013) criteria. Both sites received an RCE score (37) indicative of some degradation of aquatic habitat, with a slightly higher score (38) in autumn 2014 due to increased flow. The RCE scores for surrounding land use and in-stream disturbance were low.

4.6.5 Gap Creek

The sites on Gap Creek (GAP 1 and GAP 2) were located directly adjacent to one another (**Plate 9** and **Plate 10**) with the upstream end of GAP 1 bordering the flow gauging station. On both visits, no flow was observed in the creek at the gauging station and limited water was observed in its vicinity. Approximately fifty m downstream of the gauging station within the upstream site (GAP 1), large rounded sandstone boulders surrounded small (one to five m long), shallow (approximately 0.5 m at deepest) semi-permanent pools (**Plate 9c**) that were isolated by dry sections of creek or small trickles of water over wedged boulders (**Plate 9a**). At the downstream site (GAP 2), the water in pools and small rocky runs was generally interconnected (**Plate 10a**). There was a large pool at the downstream end of this site around two hundred m from the gauging station (**Plate 10c**). Downstream of here, the channel dropped approximately four m over a large rock fall. Banks were steep, predominantly rocky with some sections of heavily eroding soil (**Plate 10a**).

The creek substratum consisted of sand, gravel and silt in pools surrounded by large rounded bedrock and boulder. Surface flow between pools was limited to less than one litre per second. No surface water was observed in the creek channel approximately 500 m downstream of the sampling points when this location was visited in June 2013. In April 2013, the small tributary that entered Gap Creek from the west was flowing at a trickle. A moderate sized dam surrounded by emergent macrophytes (*Eleocharis* sp.) was present within the channel approximately one kilometre upstream of the site. The creek channel further upstream was dry. Gross pollutants, particularly car tyres and other vehicle parts, were observed in the

creek channel and on surrounding land. Several other small artificial dams were observed around Mount Airly and Genowlan Mountain.

The riparian vegetation consisted of Eucalypt-dominated open forest containing a variety of native trees and shrubs including Coachwood (*Ceratopetalum apetalum*) *Cassinia* sp., Teatree (*Leptospermum* sp.), and *Acacia* sp. Some native Maidenhair fern (*Adiantum* sp.) was present close to the channel with *Lomandra* sp. commonly fringing pools. Emergent macrophytes, including *Juncus prismatocarpus*, *Juncus* sp., *Isolepis inundata* and *Gahnia melanocarpa*, were present in damp areas along the creek. Some sparse in-stream macroalgae (*Chara* sp.) was present at both sites.

GAP 1 and GAP 2 monitoring sites were classified as highly sensitive (Type 1) moderate fish habitat (Class 2) using the NSW DPI (2013) criteria. Both sites received an RCE score of 43, indicating limited degradation of aquatic habitat. The RCE scores for stream bank structure and riffle/pool sequence descriptors were reduced due to some erosion and limited flow, respectively. Barriers to fish movement in the form of precipitous falls and the dry creek bed were present upstream and downstream.



Plate 7 Dog Creek - DOG 1: Left to right – autumn 2013, spring 2013, autumn 2014: a) Upstream of reach of site looking upstream; b) Upstream of reach of site looking downstream; c) Downstream of reach looking upstream; and d) Downstream of reach looking downstream.



Plate 8 Dog Creek - DOG 2: Left to right – autumn 2013, spring 2013, autumn 2014: a) Downstream of reach of site looking upstream; b) Middle of site looking downstream; c) Upstream of reach looking downstream; and d) Upstream of reach looking upstream.

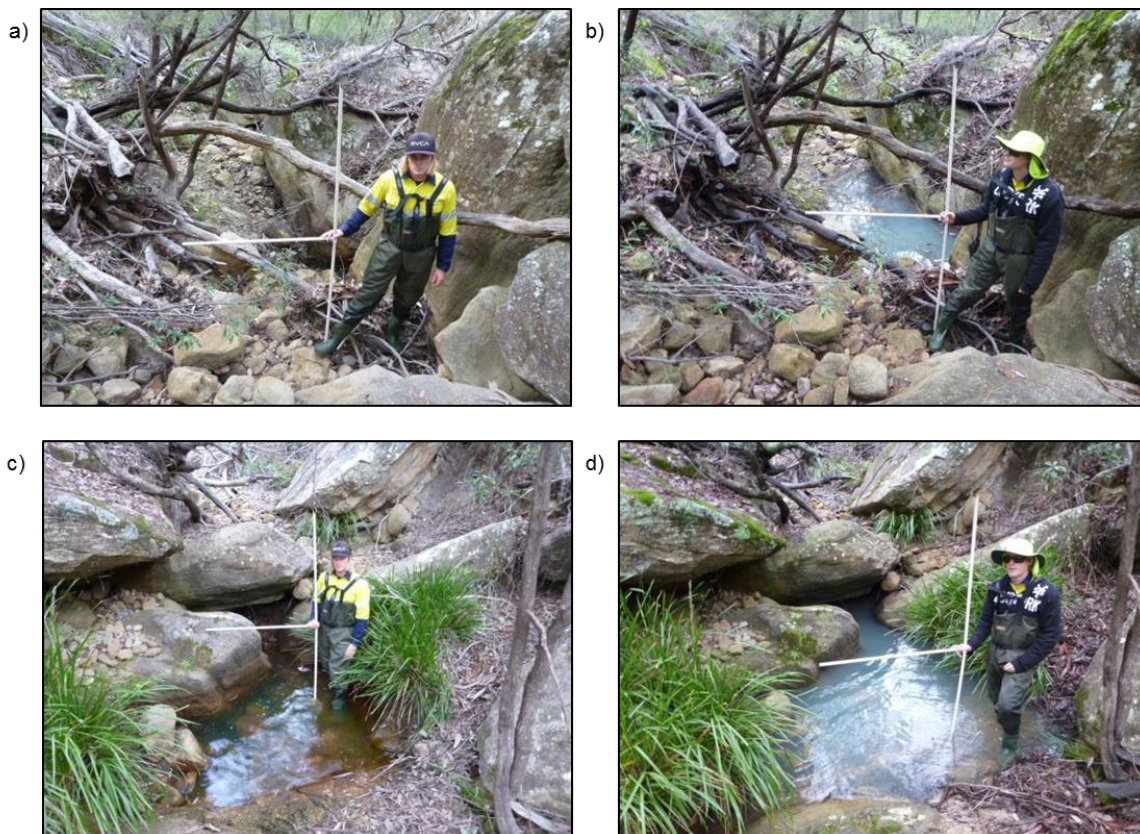


Plate 9 Gap Creek - GAP 1: a) May 2013 looking downstream from near top of site; b) June 2013 looking downstream from near top of site; c) May 2013 looking upstream from near bottom of site; and, d) June 2013 looking upstream from near bottom of site.



Plate 10 Gap Creek - GAP 2: a) May 2013 looking downstream from near top of site; b) June 2013 looking downstream from near top of site; c) May 2013 looking upstream from bottom of site; and, d) June 2013 looking upstream from bottom of site.

4.6.6 Grotto Creek

The sites on Grotto Creek (GRO 1 and GRO 2) were located directly adjacent one another on the upper south-west arm of Genowlan Creek (**Plate 11** and **Plate 12**). The sites were located downstream of the confluence with drainage lines originating from sandstone canyon formations of the centre of Genowlan Mountain, these being 'the Grotto' to the west (**Plate 11c** and **d**) and approximately 30 km (the Lost City) to the south. The upstream site (GRO 1) was located directly downstream of the gauging station (**Plate 11a**). The Genowlan Mountain Fire Trail was approximately ten m to the south-west of the creek channel at this point and crossed the creek at several points further downstream. The creek habitat at both sites consisted of several small pools (**Plate 11a**) connected by runs of low flow over rock or detritus. Many pools were isolated by low flow during the May 2013 sampling and surface flow ceased at several points downstream of the sampling sites. Pools were relatively small (one to three m wide), shallow (20 to 40 cm deep) and contained a thick iron flocculent and/or detritus. Some foaming and algal growth was also noted. Banks were approximately one metre high and consisted mainly of soil with some rock and were stabilised by dense vegetation.

The creek substratum was fairly homogenous, being predominantly sand overlain by fine detritus with some larger rock also present. During the initial site inspection (April 2013), the flow at the gauging station was less than one litre per second. The flow in the creek channel was also low in May and June 2013, but not observed at the gauging station (**Plate 12b**). Upstream of this point the valley sides of the feeder creeks were constricted into canyon formations.

Riparian vegetation was Eucalyptus-dominated forest with a dense understorey of tree ferns and other ferns, similar to that of the Genowlan Creek sites further downstream. Small trees and shrubs were also present, including *Acacia* sp. and *Leptospermum* sp. Moss was observed on several rocks near the creek, but no in-stream aquatic macrophytes were present.

The GRO 1 and GRO 2 sites, being on second order streams, were not considered key fish habitat using the NSW DPI (2013) criteria. Both sites received an RCE score of 47, indicating minimal degradation of aquatic habitat.

4.6.7 Genowlan Creek

The sites on Genowlan Creek (GEN 1 and GEN 2) were located directly adjacent to one another and a short distance downstream of the confluence with the two upper arms of Genowlan Creek (**Plate 13** and **Plate 14**), that originate from the Grotto area to the south-west and the south-eastern sub-catchment known as 'the Oasis'. A four wheel drive track met the main Genowlan Mountain Fire Trail at the confluence point and followed the western bank of the creek along the upstream site (GEN 1), crossing the creek at an old ford between the two sites (**Plate 13c**) and terminating at the downstream site (GEN 2). The creek habitat at both sites consisted of small (one to three m wide), shallow (30 to 40 cm deep) pools (**Plate 14a**) and small (ten to one hundred cm wide), shallow (five to ten cm deep) slow flowing riffle and run sections (**Plate 14a** and **Plate 13c**). Banks were steep to moderately inclined and consisted of rock and soil that was mostly stabilised by vegetation. Little erosion was evident.

The creek substratum was relatively heterogeneous, consisting predominantly of sand with small proportions of boulder, cobble, pebble, gravel and silt. A consistent flow of approximately one to ten litres per second was observed at both sites on all visits. Water clarity was very good and relatively little benthic algae or periphyton were observed. The aquatic habitat along the approximately one hundred m reach downstream of the sites appeared relatively similar, with some log jams and detritus present. The south-eastern 'Oasis' sub-catchment had clear flowing water near the confluence point in April 2013 (**Plate 14a**), but the upper sub-catchment was dry in May and June 2013 (**Plate 14b**). The substratum of the main creek channel in the upper 'Oasis' appeared to be similar to that downstream, although no permanent pools were observed.

Riparian vegetation was Eucalyptus-dominated forest with a large number of tree ferns forming a lower foliage layer. Various native trees and shrubs, including *Leptospermum* sp. and *Acacia* sp. were also present. Moss was abundant on rocks close to the channel and small ferns such as *Sticherus* sp., *Blechnum* sp. and *Todea barbara* were also present. The mat rush *Lomandra* sp. and grasses were relatively dense. In-stream macrophytes were limited to sparse *Isolepis inundata*. Some isolated but dense beds of *Chara* sp. were observed in the larger pools (**Plate 14a**).

The GEN 1 and GEN 2 monitoring sites were classified as highly sensitive (Type 1) major fish habitat (Class 1) using the NSW DPI (2013) criteria. Both sites had an RCE score (47) indicative of minimal degradation of aquatic habitat.



Plate 11 Grotto Creek upstream - GRO 1: a) May 2013 looking upstream from top of site at flow across the weir; b) June 2013 looking downstream from top of site; c) May 2013 looking downstream from near bottom of site; and, d) June 2013 looking downstream from near bottom of site.



Plate 12 Grotto Creek downstream - GRO 2: a) May 2013 looking upstream from top of site; b) June 2013 looking upstream from top of site; c) May 2013 looking upstream from near bottom of site; and, d) June 2013 looking upstream from near bottom of site.



Plate 13 Genowlan Creek - GEN 1: a) May 2013 looking downstream from near top of site; b) June 2013 looking downstream from near top of site; c) May 2013 looking upstream from near bottom of site; and, d) June 2013 looking upstream from near bottom of site.



Plate 14 Genowlan Creek - GEN 2: a) May 2013 looking upstream from near middle of site; b) June 2013 looking upstream from near middle of site; c) May 2013 looking downstream from near middle of site; and, d) June 2013 looking downstream from near middle of site.

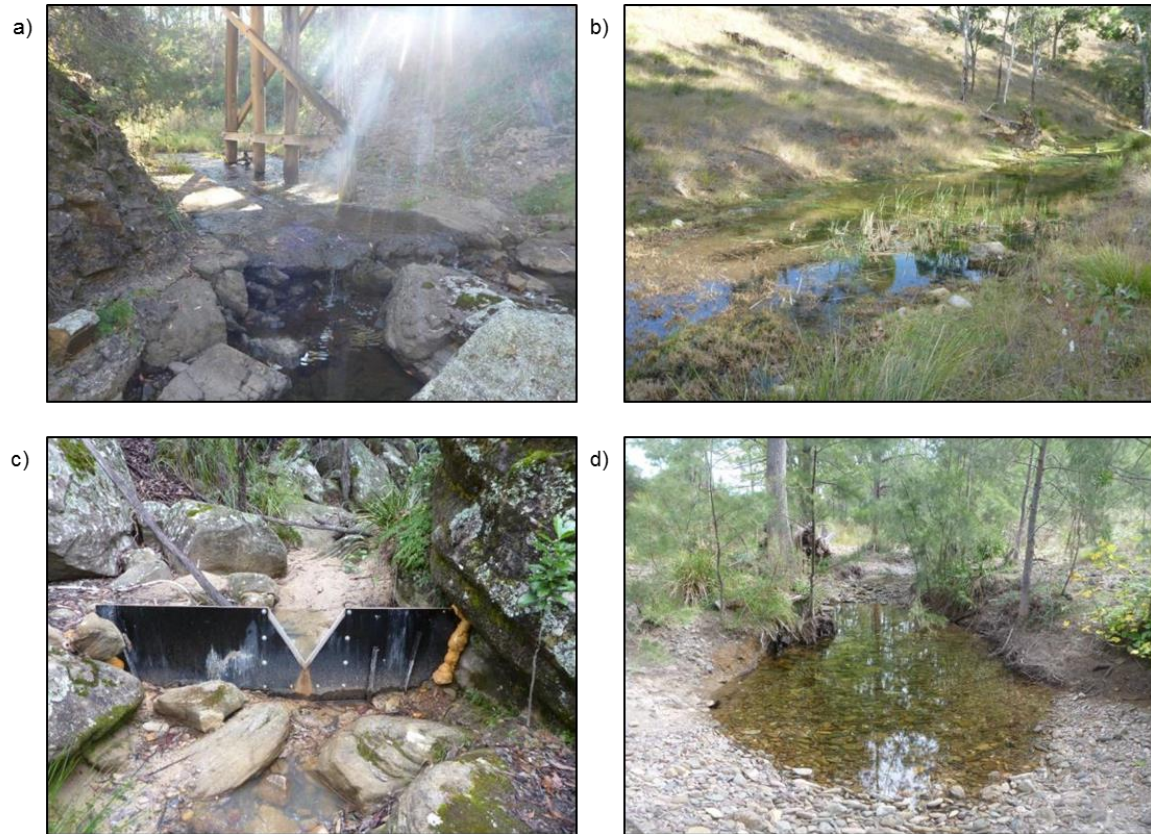


Plate 15 a) bridge at Airly Creek on the Glen Davis Road; b) small artificial impoundment between sites on Dog Trap Creek; c) flow gauging v-notch weir at Gap Creek in June 2013; and d) Coco Creek near the Glen Davis Road with subterranean alluvial flow indicating hyporheic habitat.

4.7 Aquatic Fauna

4.7.1 Macroinvertebrates

Results from the AUSRIVAS analysis from all sampling events are presented in **Figure 4-10**, **Figure 4-11** and **Figure 4-12**. Results from samples collected using the quantitative suction sampler method are summarised in **Figure 4-13** and are illustrated in an MDS plot in **Figure 4-14**. Data from both sampling techniques are presented in **Appendix D**.

4.7.1.1 AUSRIVAS

4.7.1.1.1 Taxon Richness

Mean taxon richness (diversity) varied across the waterways and among sampling seasons (**Figure 4-10**). Of the waterways outside the Project Application Area, Airly Creek had the lowest mean taxon richness (13.5 in autumn 2013) and Dog Trap Creek the highest (27.5, 23.0 and 30.0 in autumn 2013, spring 2013 and autumn 2014, respectively). Samples from the potential 'impact' waterways (Airly and Torbane creeks) both had fewer taxa than those from Dog Trap Creek, the 'control' waterway, irrespective of sampling season. Samples taken from Gap, Grotto and Genowlan creeks during autumn 2013 had similar mean numbers of taxa (16.5, 15 and 16.8, respectively). Variability within each of the waterways was relatively low as indicated by the small standard errors. No threatened macroinvertebrate species were captured or observed during the sampling events.

Taxon richness may be indicative of a range of environmental and habitat variables, including water quality, habitat diversity and the local context of the waterway. These factors are likely to have contributed to the higher taxon richness in Dog Trap Creek. For example, water quality was generally favourable in Dog Trap Creek, with warmer temperature, high dissolved oxygen and low turbidity (**Section 4.5.1**). In contrast, Airly Creek was colder, had reduced dissolved oxygen and was more turbid and saline (**Section 4.5.1**). In-stream aquatic habitat was also relatively diverse in Dog Trap Creek, with abundant submerged macrophyte growth (primarily macroalgae). Dog Trap Creek was also relatively dry above and below the sampling sites and may have acted as a refuge for some species (**Section 4.6.4**).

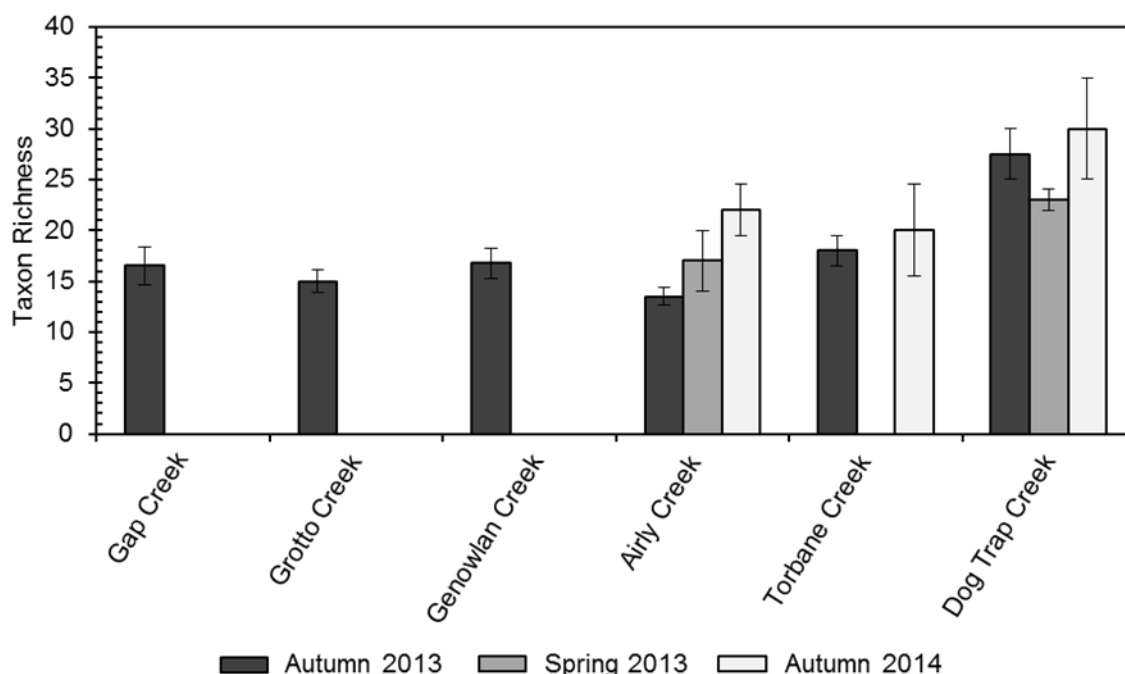


Figure 4-10 Mean macroinvertebrate taxon richness for all samples collected from each waterway. Data presented are the mean and standard error of all samples collected at each waterway over the three sampling events (May and June 2013 combined into autumn 2013) (n = 4 in autumn 2013, and 2 in spring 2013 and autumn 2014). Aquatic fauna were not monitored at Gap, Grotto and Genowlan creeks during spring 2013 and autumn 2014.

Although taxon richness within the Project Application Area was generally lower than outside, this does not mean that these areas have less ecological value. This point is indicated by SIGNAL2 scores depicted in **Figure 4-11**.

4.7.1.1.2 SIGNAL2 Scores

Mean SIGNAL2 scores also varied across the waterways and among sampling seasons (**Figure 4-11**). During the autumn 2013 sampling season, the potential 'impact' waterways (Airly and Torbane creeks) had marginally lower mean SIGNAL2 scores (3.3 and 3.5, respectively) than the 'control' waterway, Dog Trap Creek (3.8). At Airly Creek, the mean score during spring 2013 was similar to autumn 2013, while it had increased to 5.0 by autumn 2014. In contrast, the mean scores at Dog Trap Creek remained similar among sampling seasons, while at Torbane Creek the mean score in autumn 2014 (2.3) was lower than in autumn 2013. Excluding the relatively high autumn 2014 score at Airly Creek, the creeks within the Project Application Area (Gap, Grotto and Genowlan) had the highest mean SIGNAL2 scores of 4.5, 5.0 and 5.2, respectively. Variability within most waterways was relatively low as indicated by the small standard errors. Airly Creek had a greater standard error than the other sites, which was driven by a low score for the AIR 2 sample (2.55) in May 2013.

Although samples from Gap, Grotto and Genowlan creeks taken during autumn 2013 had fewer taxa, a large proportion of these were pollution sensitive. Pollution sensitive taxa and their individual SIGNAL2 scores (in brackets) found in Gap, Grotto and/or Genowlan creeks included Nannochoristidae (9), Telephlebiidae (9), Athericidae (8), Gripopterygiidae (8); Helicopsychidae (8), Hydrobiosidae (8), Leptophlebiidae (8) and Philorheithridae (8). Only two of these taxa, Leptophlebiidae and Hydrobiosidae were found in Dog Trap Creek and only one, Telephlebiidae, was found in Torbane Creek. No pollution sensitive taxa were found in Airly Creek. No pollution sensitive taxa were found during the spring 2013 sampling event, while three, Athericidae and Hydrobiosidae at Torbane Creek and Leptophlebiidae at Dog Trap Creek, were found during autumn 2014.

The individual taxon SIGNAL2 grades are derived from ecotoxicology investigations (Chessman *et al.* 1997; Chessman 2003) and are therefore implicitly linked to water quality attributes. They do not account for assemblage differences due to habitat and other natural physical variables.

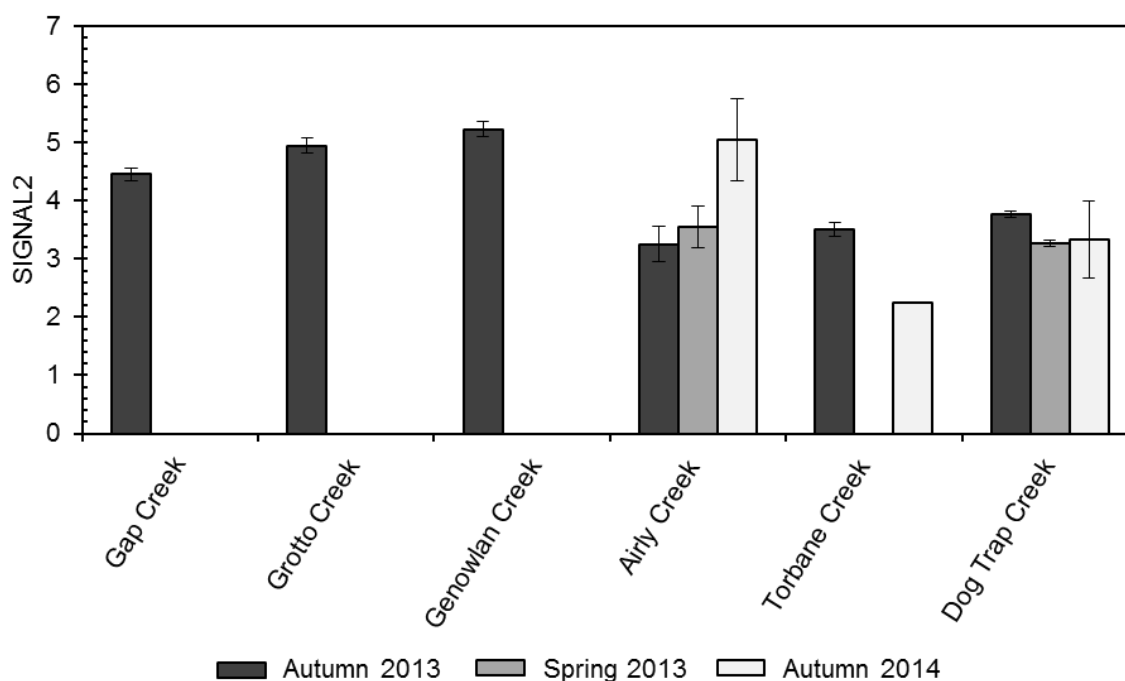


Figure 4-11 Mean SIGNAL2 score for all samples collected from each waterway.

Data presented are the mean and standard error of all samples collected at each waterway over the three sampling events (May and June 2013 combined into autumn 2013) (n = 4 in autumn 2013, and 2 in spring 2013 and autumn 2014). Aquatic fauna were not monitored at Gap, Grotto and Genowlan creeks during spring 2013 and autumn 2014.

4.7.1.1.3 AUSRIVAS OE50 Taxa Scores

The AUSRIVAS model accounts for key habitat variables, so outputs from the model may be useful in understanding biological impairment in relation to this potentially important source of variability. The variability in mean OE50 taxa scores followed a similar pattern to mean taxon richness, with Dog Trap Creek and Airly Creek having the greatest and lowest scores, respectively (**Figure 4-12**). Across all sampling seasons, fauna in Dog Trap Creek ranked in Band A (equivalent to reference condition), whereas fauna in Airly Creek ranked within Band B (significant impairment). Fauna in Gap, Grotto and Genowlan creeks in autumn 2013 ranked in Band B and had mean OE50 taxa scores of 0.57, 0.56 and 0.61, respectively. Variability was relatively low within all waterways except for Airly Creek during the autumn sampling seasons, as indicated by the standard error bars. OE50 taxa scores for both of the Airly Creek samples collected in autumn 2013 from AIR 1 were low (≤ 0.45) and were placed in Band C (severely impaired). OE50 score for the AIR 2 sample taken in autumn 2013 was 0.82, placing it in Band A, however in 2014, AIR 2 was placed in Band C.

The AUSRIVAS model placed Gap, Grotto and Genowlan creeks in the Group 4 reference group and the remaining sites in Group 6 and predicted that more taxa would be observed in Gap, Grotto and Genowlan creeks (16-20 taxa) than in Airly, Torbane and Dog Trap Creek (13-15 taxa). However, similar numbers of invertebrate taxa were found in all the waterways, except Dog Trap Creek (**Figure 4-10**). This is essentially the reason why all sites except Dog Trap Creek had similar OE50 scores and were placed in the 'significant impairment' band.

The AUSRIVAS model predicted more and, notably, different taxa for the two groups due to differences in the input predictor variables. Alkalinity, in particular, was much higher in Airly, Torbane and Dog Trap creeks and is likely to have been a key variable influencing the model predictions. Differences in alkalinity are due to catchment hydrogeology, with waterways derived from marine influenced Shoalhaven Group geology having greater alkalinity than those derived from Narrabeen Group geology (S. Gray, 2013 *pers. comm.*, 25 July).

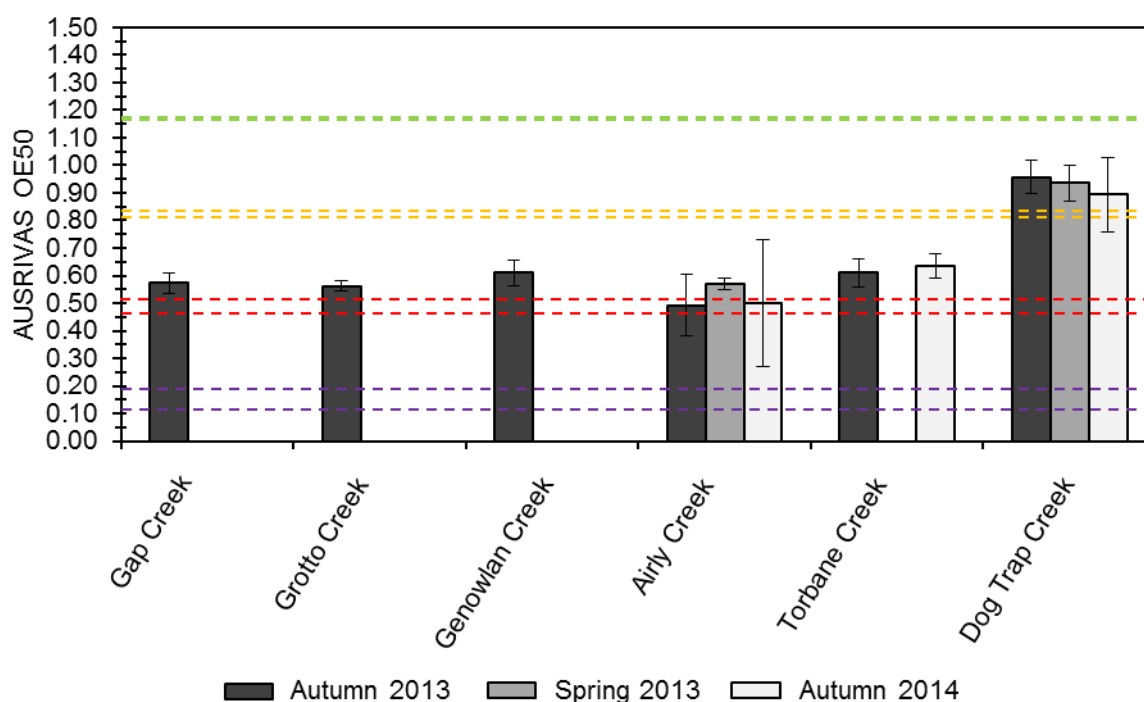


Figure 4-12 Mean AUSRIVAS OE50 and Bands score for all samples collected from each waterway. Data presented are the mean and standard error of all samples collected at each waterway over the three sampling events (May and June 2013 combined into autumn 2013) ($n = 4$ in autumn 2013, and 2 in spring 2013 and autumn 2014). Coloured lines depict Bands for autumn and spring, the upper line being spring. Aquatic fauna were not monitored at Gap, Grotto and Genowlan creeks during spring 2013 and autumn 2014.

AUSRIVAS samples collected in 2005 from edge habitat in the Capertee River downstream of Glen Davis, were ranked within Band A (equivalent to reference condition). Another site on the Capertee River at Glen Davis was slightly below reference condition (Colo River Wild Rivers Assessment 2008).

4.7.1.2 Quantitative Suction Samples

Taxa diversity in the quantitative samples was, on average, greatest at the Dog Trap Creek sites, followed by the Torbane and Airly Creek sites (**Figure 4-13a**), this being consistent with the AUSRIVAS samples collected (**Figure 4-10**). Total macroinvertebrate abundance was, on average, greatest at the Torbane Creek sites in autumn 2013, followed by Dog Trap Creek and Airly Creek, in that order. In spring, abundance was greatest at Airly Creek, while in autumn 2014 Dog Trap Creek had the greatest abundance by an order of magnitude, followed by Torbane then Airly creeks (**Figure 4-13b**). These differences were due primarily to differences in abundance of Oligochaeta and Ceratopogonidae. The 2D stress value for the MDS plot (0.2) indicates a reasonable representation of the quantitative macroinvertebrate data in two dimensions (Figure 4-14). Fauna at the 'impact' sites (Airly and Torbane creeks) was not distinct from that at the 'control' sites (Dog Trap Creek) at the 80% dissimilarity level. As mining has not commenced, the similarity in the assemblages is expected, with any dissimilarities likely to be due to existing differences in water quality, habitat or other environmental variables possibly influenced by previous mining activities.

The Torbane Creek samples showed a greater level of within-site similarity than those collected at the other two creeks, with all but one sample being grouped at <60% dissimilarity (Figure 4-14). Samples from Dog Trap Creek were more distinct from one another in the MDS plot, with six separate groups at 50% similarity (**Figure 4-14**).

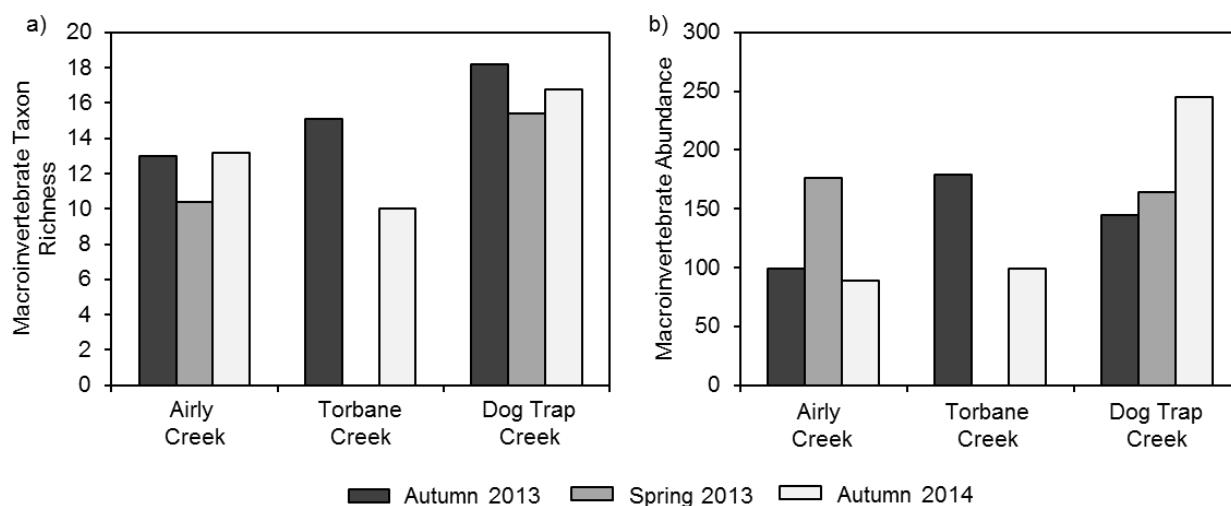


Figure 4-13 Macroinvertebrate a) taxon richness and b) abundance from all quantitative suction samples collected from each creek (n=10)

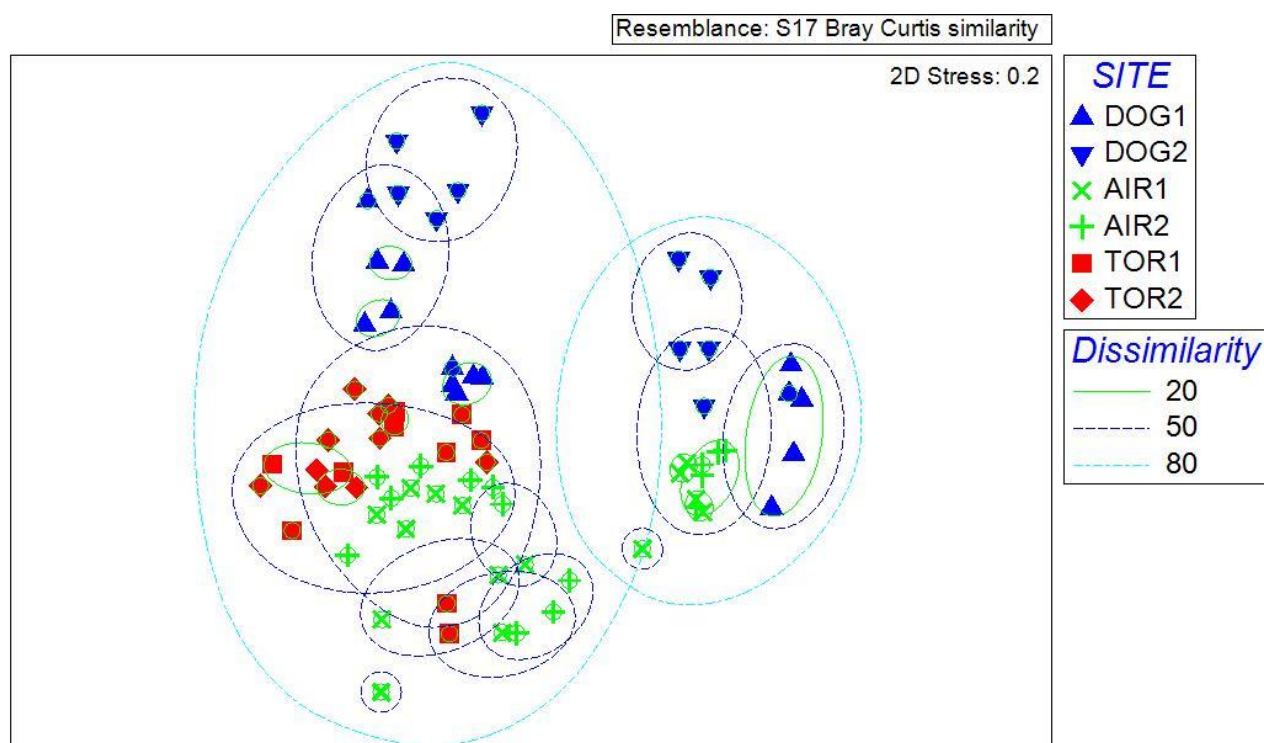


Figure 4-14 MDS diagram for suction sampler data with dissimilarity cluster groupings overlay

4.7.2 Fish

Thirty four individual fish from six species were captured in Airly, Torbane and Dog Trap creeks using the backpack electrofisher in autumn 2013. In contrast, over 200 fish were captured in spring 2013 and only two in autumn 2014. No fish were captured in Gap, Grotto and Genowlan creeks. While fish species diversity was greatest in Dog Trap Creek (four species), most individuals were captured in Airly Creek (over 200 in the spring 2013 sampling season). Tadpoles were observed at all sites.

All of the fishes captured were native species, except for eastern gambusia, which was observed in high abundance at Airly Creek in all three sampling seasons and varied in length from one to three cm. This species is native to the Americas and is listed as a noxious species under the *FM Act*.

Mountain galaxias was the most abundant native species, but was captured only in Torbane Creek. These fish were four to eight cm long with a median length of five cm.

All other fish except the Cox's gudgeon were captured in the central impoundment at Dog Trap Creek. Both of the Australian smelt caught were approximately eight cm long. The long-finned eel captured was approximately twenty five cm long, while both marbled eels were around one metre long. Both eel species have a catadromous life cycle, in which adults migrate to the ocean to spawn and die and young eels (elvers) re-colonise freshwater habitats. Very few fish were observed in the autumn 2014 sampling event.

One specimen of Cox's gudgeon (approximately 13 cm long), was captured in a rocky pool at the upstream end of the DOG 1 site.

None of the fish captured are threatened species under Commonwealth *EPBC Act* (Section 3.1.3) or the NSW *FM Act* (Section 3.2.3), nor were any threatened fish species observed during monitoring events.

Table 4-5 Number and species of fish captured using backpack electrofishing during the three sampling events.

Site	Season	Short-finned Eel	Marbled Eel	Mountain Galaxias	Coxs Gudgeon	Australian Smelt	Eastern Gambusia [†]
		<i>Anguilla australis</i>	<i>Anguilla reinhardtii</i>	<i>Galaxias olidus</i>	<i>Gobiomorphus coxii</i>	<i>Retropinna semoni</i>	<i>Gambusia holbrooki</i>
Airly Creek	Autumn 2013	-	-	-	-		9
	Spring 2013	-	-	-	-		>200
	Autumn 2014	-	-	-	-		1
Torbane Creek	Autumn 2013	-	-	19	-		-
	Spring 2013	-	-	20	-		-
	Autumn 2014	-	-	-	-		-
Dog Trap Creek	Autumn 2013	1	2	-	1		-
	Spring 2013	1	3	-	13		-
	Autumn 2014	-	1	-	-		-

[†] Introduced species listed as a noxious species under the *FM Act*.

4.8 Surface Water Ecosystems Summary

4.8.1 Water Quality Summary

A summary of the water quality data relative to the appropriate ANZECC/ARMCANZ (2000) guidelines and SSTVs is provided in **Table 4-6**.

Table 4-6 Comparison of mean *in-situ* water quality measurements recorded during the three sampling events against ANZECC/ARMCANZ (2000) guidelines and SSTVs.

Site	Electrical Conductivity		pH		Dissolved Oxygen		Turbidity	
Autumn 2013	ANZECC	SSTV	ANZECC	SSTV	ANZECC	SSTV	ANZECC	SSTV
Airly Creek	↑	↑	✓	✓	↓	N/A	✓	✓
Torbane Creek	↑	✓	✓	✓	↓	N/A	✓	✓
Dog Trap Creek	↑	✓	✓	✓	✓	N/A	✓	✓
Gap Creek	✓	✓	✓	✓	↓	N/A	✓	✓
Grotto Creek	✓	✓	↓	↓	↓	N/A	↓	✓
Genowlan Creek	✓	✓	✓	✓	↓	N/A	↓	✓
Spring 2013								
Airly Creek	↑	↑	✓	✓	↓	N/A	✓	✓
Torbane Creek	↑	↑	✓	✓	↓	N/A	✓	✓
Dog Trap Creek	↑	✓	✓	✓	↓	N/A	✓	✓
Autumn 2014								
Airly Creek	↑	✓	✓	✓	↓	N/A	↓	✓
Torbane Creek	↑	✓	✓	✓	↓	N/A	↓	✓
Dog Trap Creek	↑	✓	✓	✓	↓	N/A	↓	✓

Up arrows represent values generally above the relevant ANZECC/ARMCANZ (2000) guidelines, down arrows represent values below the guidelines and ticks represent values within the guidelines. Green highlight represents positive water quality, while orange highlight represents less positive water quality.

The water quality attributes of Gap, Genowlan and Dog Trap Creek suggested that their aquatic ecosystems may be healthier than those in Airly and Torbane Creeks. The quality of water in Airly Creek and Torbane Creek commonly exceeded guidelines for a range of water quality indicators.

Electrical conductivity levels were much greater at lower altitude creeks than those located on top of Mount Airly and Genowlan Mountain. pH and dissolved oxygen were lower in Grotto Creek than at other sites, probably due to natural factors such as greater organic matter content and low light penetration.

4.8.2 Aquatic Habitat Summary

A summary of aquatic habitat characteristics is provided in **Table 4-7**. In all cases, the conclusions reached are indicative only and represent a broad brush approach to aquatic habitat quality.

Table 4-7 Summary aquatic habitat characteristics.

Site	Survey	RCE Score	Fish habitat sensitivity (Type)	Fish habitat class (Class)
Airly Creek	Autumn 2013	37	1	1
	Spring 2013	37	1	2
	Autumn 2014	43	1	2
Torbane Creek	Autumn 2013	38	1	1
	Spring 2013	38	N/A	2
	Autumn 2014	39	1	2
Dog Trap Creek	Autumn 2013	37	1	1
	Spring 2013	37	1	2
	Autumn 2014	38	1	2
Gap Creek	Autumn 2013	43	1	2
Grotto Creek	Autumn 2013	43	N/A	2
Genowlan Creek	Autumn 2013	47	1	1

Green highlight represents a better aquatic habitat condition than the orange highlight.

The modified RCE inventory (Chessman *et al.* 1997) indicated the aquatic habitat in Genowlan Creek was in the best overall condition followed by that in Gap and Grotto creeks. The lower scores for Airly, Torbane and Dog Trap creeks were due to apparent disturbance of the creek channel and riparian zones. Airly scored highly in autumn 2014 due to increase flow and vegetation growth. Most of the creeks were originally classed as highly sensitive, major fish habitat. All creeks, excluding Genowlan were classified as moderate fish habitat once their ephemeral nature became apparent in spring.

4.8.3 Aquatic Fauna Summary

A summary of aquatic fauna is provided in **Table 4-8**. The scores were classified according to the following thresholds to aid interpretation:

- > Macroinvertebrate taxon richness: greater than 20 = high taxa diversity;
- > SIGNAL2 Score: greater than 4 = pollution sensitive taxa present and favourable water quality;
- > AUSRIVAS OE50: greater than 0.81 (Band A) = equivalent to reference condition;
- > Fish: native fish present = healthy fish communities.

Table 4-8 Summary of aquatic fauna characteristics, May and June 2013.

Site	Macroinvertebrate taxa diversity	SIGNAL2 Score	AUSRIVAS OE50 Taxa score	Fish
Autumn 2013				
Airly Creek	13.5	3.26	0.49	Gambusia
Torbane Creek	18	3.5	0.61	Galaxias
Dog Trap Creek	27.5	3.77	0.96	Various Native
Gap Creek	16.5	4.45	0.57	No Fish
Grotto Creek	15	4.95	0.56	No Fish
Genowlan Creek	16.75	5.23	0.61	No Fish
Spring 2013				
Airly Creek	17	3.5	0.57	Gambusia
Torbane Creek	N/A	N/A	N/A	Galaxias
Dog Trap Creek	23	3.3	0.94	Various Native
Autumn 2014				
Airly Creek	14.5	5.0	0.50	Gambusia
Torbane Creek	14.5	2.3	0.64	No Fish
Dog Trap Creek	20	3.3	0.90	Eel

Green and orange highlights represent healthy and impaired aquatic fauna, respectively.

Throughout all sampling seasons, aquatic invertebrate communities at Dog Trap Creek were more diverse and scored better AUSRIVAS scores than those at any of the other sites visited. SIGNAL2 scores were greatest at Gap, Grotto and Genowlan creeks in autumn 2013, and in Airly Creek in autumn 2014, meaning more pollution sensitive taxa were found in these waterways at those times, which is indicative of better water quality. Native fish were found at Torbane Creek and Dog Trap Creek only.

The aquatic fauna characteristics are indicative of water quality and habitat features measured at each of the creeks visited. For example, generally favourable water quality at Gap, Grotto and Genowlan creeks (**Table 4-6**) provide the environmental conditions required to support pollution sensitive taxa, as indicated by the SIGNAL2 scores (**Table 4-8**). Favourable fish habitat was present at Airly, Torbane and Dog Trap creeks (**Table 4-7**), these being the waterways where all fish were captured (**Table 4-8**).

Initial sampling of the aquatic ecosystem indicated that the highest level of biological impairment generally occurred at sites on Airly Creek followed by Torbane Creek. Biological impairment at these sites is likely to be a result of extensive deforestation and use of land in the catchment for agriculture and mining activities. Biological impairment observed at sites on Grotto, Gap and Genowlan creeks may be due to the ephemeral or low flow characteristics of these catchments.

5 Existing Environment – Groundwater Ecosystems

Subterranean aquatic systems often support a diverse group of animals, including crustaceans, worms, snails, insects, other invertebrate groups and fish, referred to collectively as stygofauna (Humphreys 2006a). In this section, a brief description of the aquifers and groundwater systems in the Project Application Area based on the reports prepared by a specialist groundwater consultant (RPS Aquaterra 2012; GHD 2014b) is presented. This information provides a context for the pilot stygofauna study, description of hyporheic fauna and for the impact assessment in **Section 7**.

5.1 Hydrogeology

A description of the main hydrogeological units identified within the Project Application Area is provided by GHD (2014). Listed from surface to depth, these include:

Period	Lithology
Quaternary Alluvium	Silt, clay, sand, gravel
Tertiary	Basalt, dolerite
Triassic	Quartz sandstone, red brown claystone (Narrabeen group) Claystone, shale, quartz sandstone (Caley Formation)
Permian	Coal, lithic sandstone, claystone (Wallerawang Subgroup) Sandstone, claystone, coal, mudstone (Charbon subgroup) Coal, claystone, siltstone, mudstone, conglomerate (Cullen Bullen subgroup) Siltstone, lithic sandstone conglomerate (Shoalhaven Group) Metamorphic rocks: Quartzite, shale, sandstone, limestone, tuff

5.1.1 Alluvial Aquifers

Quaternary alluvium is present in the valley floors and along creek lines (RPS Aquaterra 2012) and sustains minor alluvial aquifers in highland valleys, including tributaries of Gap Creek, Genowlan Creek and the Grotto area. These would be recharged typically by rainfall infiltration and seepage from creeks (RPS Aquaterra 2012).

Hydrological conductivity in this aquifer was measured at the piezometer ARP05 (refer **Figure 5-2**) site at 0.11 m/d (RPS Aquaterra 2012). This was greater than the majority of tests completed for underlying units (RPS Aquaterra 2012) and is indicative of greater porosity in this younger, less consolidated alluvial unit.

Alluvial groundwater quality is characterized by low pH (between 5.8 and 6.6 at ARP05 from *ex-situ* analysis), low salinity (130 to 160 $\mu\text{S}/\text{cm}$ at ARP05, again from *ex-situ* analysis), low levels of total dissolved solids, biological oxygen demand and total organic carbon compared with other groundwater resources in the area (RPS Aquaterra 2012).

5.1.2 Narrabeen Group

The Narrabeen Sandstone that outcrops at the site receives recharge via rainfall. Recharge by direct infiltration of precipitation occurs on the upper slopes and the tops of the mountains. Discharge via seepage takes place on contact with low permeability strata and occurs as spring flow (RPS Aquaterra 2012).

The groundwater systems within this group of sediments are complex with perched water tables and semi-confined leaky aquifers separated by relatively impermeable claystone layers. Interstratified shales, claystones and siltstones act as aquitards and aquicludes (RPS Aquaterra 2012).

Groundwater occurs in all these units, and may form local aquifers where sufficient permeability exists. The flow system in the Narrabeen Group can be characterised as a local flow system. The water bearing units in the Narrabeen Group have a reported low flow inter-granular primary porosity and a greater secondary porosity provided by fractures, fissures, bedding planes and faults within the strata (RPS Aquaterra 2012).

Hydrological conductivity in this aquifer was measured at the ARP01, ARP02A, and ARP03 boreholes (refer **Figure 5-2**) at 0.00168, 0.00225 and 0.15 m/d, respectively. Hydraulic conductivity therefore varied across sites within this aquifer and may have been greater at the ARP03 site due to greater secondary porosity.

Groundwater from the Narrabeen Group, measured from samples collected at the Village Spring (discussed in **Section 5.2.1**) shows higher levels of salinity (average four hundred and nine $\mu\text{S}/\text{cm}$), total dissolved solids ranging from 218 mg/L to 256 mg/L, major cat ion and anion, zinc, nickel and ammonia concentrations than the alluvial groundwater (RPS Aquaterra 2012). The pH at the Village Spring was alkaline and varied from 7.1 to 8.2 between June 2012 and June 2013.

5.1.3 Permian Sediments

The coal measures comprise strata of varying permeability and storage capacity, with the Middle River, Irondale, Lidsdale and Lithgow coals seams being the principal aquifers. The shales, claystones and siltstones between these seams generally act as aquitards/aquicludes. The coal measures outcrop on the slopes around the top of the mountain (RPS Aquaterra 2012).

The regional groundwater flow direction within the Illawarra Coal Measures and the inter-burden sediments is in a north-easterly direction. Regional groundwater flow is generally horizontally through the coal measures in the direction of the dip of the coal seams.

Hydraulic conductivities measured in the aquifers containing coal at ARP01, ARP02A, ARP03 and ARP04 were found to be low to very low (RPS Aquaterra 2012).

No water quality information to date is available for these aquifers; however sampling is now possible due to new boreholes on Genowlan Creek.

5.1.4 Shoalhaven Group

Limited groundwater movement may occur within the Shoalhaven group via fracture flow and inter granular flow within the matrix of the rock.

Hydraulic conductivity measured in the Shoalhaven Group aquifer at the ARP04 bore was very low at 2.92×10^{-4} (RPS Aquaterra 2012).

Groundwater from the Shoalhaven Group is brackish to saline (greater than four thousand $\mu\text{S}/\text{cm}$) and has high concentrations of major cations and anions, dissolved iron, ammonia, zinc and nickel, with the latter three being above the ANZECC guideline values. Turbidity and total dissolved solids ($>4000 \text{ mg/L}$) are significantly higher in the Shoalhaven Group than in the alluvium and Narrabeen Sandstone (RPS Aquaterra 2012).

5.2 Surface Expressions

5.2.1 Springs and Seepage

Several small springs and areas of groundwater seepage were identified within the Project Application Area. The most notable of these are the Village Spring on the north-east side of Mount Airly (**Plate 7c**) and the springs/seepages that occur across the slopes of Mount Airly and Genowlan Mountain. Other sites within the Project Application Area that are either known or expected to have groundwater flowing to the surface include:

- > Westerly/south-westerly flowing tributaries of Gap Creek arising from Mount Airly;
- > North-westerly flowing tributaries of the upper south-east arm of Genowlan Creek; and
- > A westerly flowing tributary of upper Emu Swamp Creek arising from Genowlan Mountain.

The water in these springs and seepages originates from aquifers of the Narrabeen Group (described in **Section 5.1.2**). Chlorofluorocarbon analysis of water samples collected in November 2012 from the Village Spring and the Grotto indicate the water had been contained within these aquifers for approximately 25 and 36 years, respectively before discharge at the surface (U. Krause, 2013, *email comm.*, 23 January).

Flow at the Village Spring has been monitored since January 2011 and is depicted alongside rainfall data from the Glen Alice Weather Station **Figure 5-1**. Data collected from this site indicates that the Village Spring flows permanently and is largely independent of recent antecedent rainfall (**Figure 5-1**).

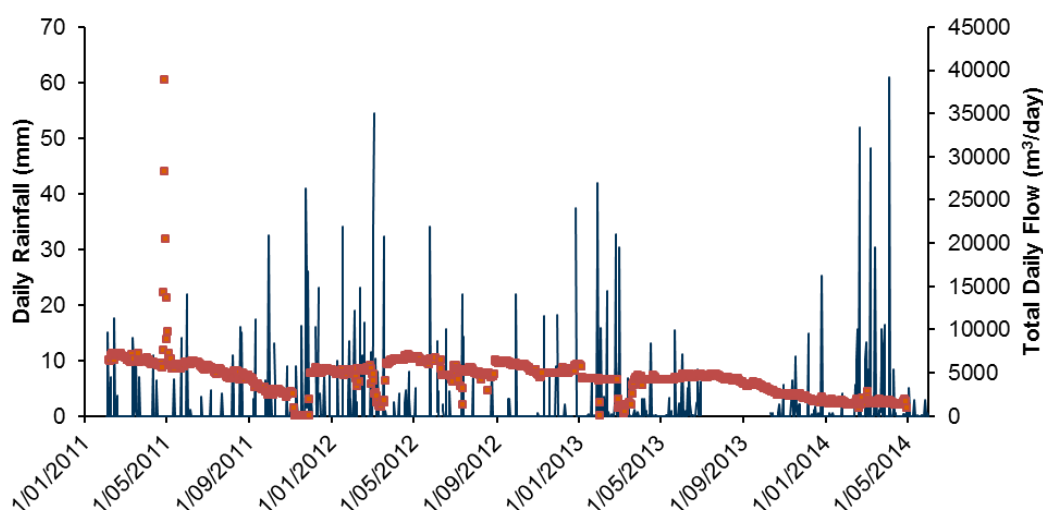


Figure 5-1 Flow at the Village Spring and daily rainfall from the Glen Alice weather station

5.2.2 Groundwater Dependant Vegetation Communities

Two EECs with known or expected groundwater dependence were identified in the literature review, one of which (various swamp communities) does not occur within the Project Application Area. The other (White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland) has been observed within the Project Application Area on low land riparian zones of numerous creeks. Riparian vegetation communities, such as the Sheltered Gully Brown Barrel Ferny Forest and Mountain Gully Grey Myrtle Dry Rainforest present around the slopes of Mount Airly and Genowlan Mountain and Genowlan Creek areas and may have facultative dependence on groundwater, and as such are not considered completely reliant on groundwater for their persistence. These communities occur elsewhere within the PAA, in areas that do not contain shallow aquifers with the potential to be impacted upon (within the proposed GHD (2014a) Scenarios 1 and/or 2) (RPS Aquaterra 2014).

5.3 Stygofauna

5.3.1 Introduction

Stygofauna are groundwater dwelling organisms which belong to the wider community of Groundwater Dependent Ecosystems (GDEs), which include terrestrial vegetation and wetland communities sustained by groundwater. Whilst most stygofauna species spend their entire lives in groundwater, three groups with different degrees of dependence on groundwater are recognised:

- > Stygobites - animals that complete their entire life in subterranean aquatic environments;
- > Stygophiles - animals that spend their entire life in subterranean aquatic habitats but are also capable of living in epigeal habitats;
- > Stygoxenes - animals that use subterranean environments but require access to surface environments to complete part of their lifecycle (Humphreys 2006b).

Stygofauna contribute to the biodiversity of Australia and may also be functionally important, contributing to the maintenance of voids, alteration of redox gradients, enhancing the release of organic carbon and cycling of nutrients, movement and transfer of energy and materials through the sediments and maintenance of community structure (Humphreys 2006b).

Information on the distribution of stygofauna within NSW aquifers is sparse and scattered (Serov *et al.* 2012). Preliminary research indicates stygofaunal diversity could be high and that some species may be locally endemic (i.e. restricted to certain areas or sections thereof) (Eberhard and Spate 1995, Hancock and

Boulton 2008). The highly localised occurrence of some species combined with their high degree of adaptation to life in subterranean aquatic systems suggests that they may be sensitive to changes in the characteristics of the groundwater they inhabit and that disturbance of their habitat could pose a threat to their survival.

Sampling was undertaken to establish whether any stygofauna occur in the aquifers within the Project Application Area and, if so, how abundant and spatially diverse they are.

5.3.2 Methods

Stygofauna samples were collected on 21 May, 11 June, 4 December 2013 from the existing shallow piezometer (ARP05) near Gap Creek, the Production Bore (AM2B) near the coal handling facility and the Old Production Bore (AM2B-1). Since the spring 2013 sampling event (December), three new bores had been drilled as detailed in **Table 5-1** and **Figure 5-2**, and were sampled in autumn 2014 (2-4 June).

Table 5-1 Location and characteristics of the bores sampled for stygofauna and sample volume.

Bore Name	Bore ID	Northing ¹	Easting ¹	Total depth (m)	Aquifer	Volume sampled (l)
Gap Creek Bore	ARP05	6333272	224068	15	Alluvial	50
Grotto Creek Bore	ARP07	6332554	224692	300	Narrabeen	N/A
Genowlan Creek Bore	ARP08	6333826	224967	300	Narrabeen	N/A
Genowlan Creek Bore	ARP09	6332766	225359	20	Alluvial	N/A
Production Bore	AM2B	6332879	220485	84	Shoalhaven	200
Old Production Bore	AM2B-1	6332879	220485	87	Shoalhaven	N/A

¹ Coordinate datum is WGS 84 UTM (Zone 56 H)

The sampling method differed for each bore due to their characteristics. The Production Bore (AM2B) is fully enclosed, so water was extracted using a submersible pump and discharged through a small diameter sampling hose under moderate pressure. This water was passed through a 63 µm sieve to collect the residual sample. For ARP05, water was extracted using a bailer and then passed through a 63 µm sieve. The Old Production Bore (AM2B-1) was open and the metal casing was badly corroded. This bore was sampled by lowering a 150 µm mesh stygofauna sampling net to the bottom of the water column, agitating it and retrieving it three times to collect a single composite sample. A coarser net was used at this site due to the dense particulate matter from well corrosion clogging a fine net and rendering it ineffective. This technique was also suitable for ARP07, ARP08 and ARP09, although a finer net was used as the bores are narrow.

At the ARP05, ARP07, ARP08, ARP09 and AM2B sites, the bore is purged before monthly water quality samples are collected. At ARP05 – ARP09, this process involves removing water using a bailer until consistent pH and EC measurements are collected. The dates and days prior to sampling, that purging occurred are outlined in **Table 5-2**.

Table 5-2 Bore purging dates prior to sampling events.

Bore	Autumn 2013 Purge	Spring 2013 Purge	Autumn 2014 Purge
P. BORE	13 May 2013 (23)	18 November 2013 (21)	12 May 2014 (24)
OLD P. BORE	Not Purged	Not Purged	Not Purged
ARP05	8 April 2013 (42)	18 November 2013 (21)	6 May 2014 (27)
ARP07		Not Purged	12 May 2014 (24)
ARP08		Not Purged	12 May 2014 (24)
ARP09		19 September 2013 (91)	12 May 2014 (24)

Other wells within the Project Application Area were either sealed or lost at the time of sampling. The characteristics of the additional bores being established within the Project Application Area are outlined in **Table 5-3** and their location is depicted in **Figure 5-2**.

Table 5-3 Other bore locations and descriptions

Bore ID	Northing ¹	Easting ¹	Type	Depth (m)	Aquifer	Comments
ARP01	6332695	222365	Vibrating wire piezometer	272	Multiple	Not suitable for stygofauna sampling
ARP02A	6333637	222783	Vibrating wire piezometer	273.8	Multiple	Not suitable for stygofauna sampling
ARP03	6334042	223113	Vibrating wire piezometer	261	Multiple	Not suitable for stygofauna sampling
ARP04	6333150	224001	Vibrating wire piezometer	235	Multiple	Not suitable for stygofauna sampling
ARP06	6331810	225326	Vibrating wire piezometer	300	Multiple	Not suitable for stygofauna sampling

¹ Coordinate datum is WGS 84 UTM (Zone 56 H)

5.3.3 Results

Stygofauna were not found in any of the samples collected. The absence of stygofauna in the samples collected does not necessarily indicate they are absent from the Project Application Area. Sampling effort and representation of subterranean habitats was severely limited by the number (six) and location (four) of bores available for sampling stygofauna at the time of the investigation. Temporal replication was also limited, with only three sampling events undertaken over the course of twelve months. The frequency and timing of bore purging prior to sampling may also have limited the capture of stygofauna.

In eastern Australia relatively diverse stygofauna assemblages have been found in alluvial aquifers in Queensland and the Hunter Region of New South Wales (Tomlinson and Boulton 2010, Hancock and Boulton 2008, 2009). In the latter studies, stygofauna were more common in bores with low electrical conductivity (i.e. EC <1500 µS/cm), shallow water table (10 m below ground and associated with alluvium) and in geological units with cavities, fractures or interstices. A summary of this information is provided in **Table 5-4**.

Table 5-4 Habitat conditions reported to be conducive to stygofauna (Hancock and Boulton 2008)

Characteristic	Reported Conditions (Hancock and Boulton 2008)
Groundwater electrical conductivity	Lower than 1500 μScm^{-1}
Groundwater pH	4.3 to 7.37 units
Depth of groundwater body	Shallower than 10 m below ground level
Geology	Presence of cavities, fractures or interstices

The information presented above suggests that the alluvial aquifer and the Narrabeen Group aquifer are most likely to harbour stygofauna. Both aquifers are understood to contain cavities, fractures and/or interstices and have electrical conductivities of $<1500 \mu\text{S/cm}$. The few studies available indicate that fractured rock supports low levels of stygofauna diversity, while none are known to have been reported from coal seam habitats (Tomlinson and Boulton 2010). The alluvial aquifer is also shallow, measured at approximately 5-7 m below ground level, while the Narrabeen aquifer is also shallow outcropping with springs and seepage across the Project Application Area. Groundwater pH within the alluvial aquifer at ARP05 and the Narrabeen aquifer at the Village Spring is within the range reported for stygofauna.

The precautionary principle has been adopted for this assessment due to the relatively small amount of available stygofauna data. This principle states that, in the case of potential serious or irreversible environmental impacts, the lack of scientific knowledge should not be used as a reason for measures to prevent environmental degradation. Following this principle, all aquifers are assumed to contain some stygofauna species for the purpose of this assessment.

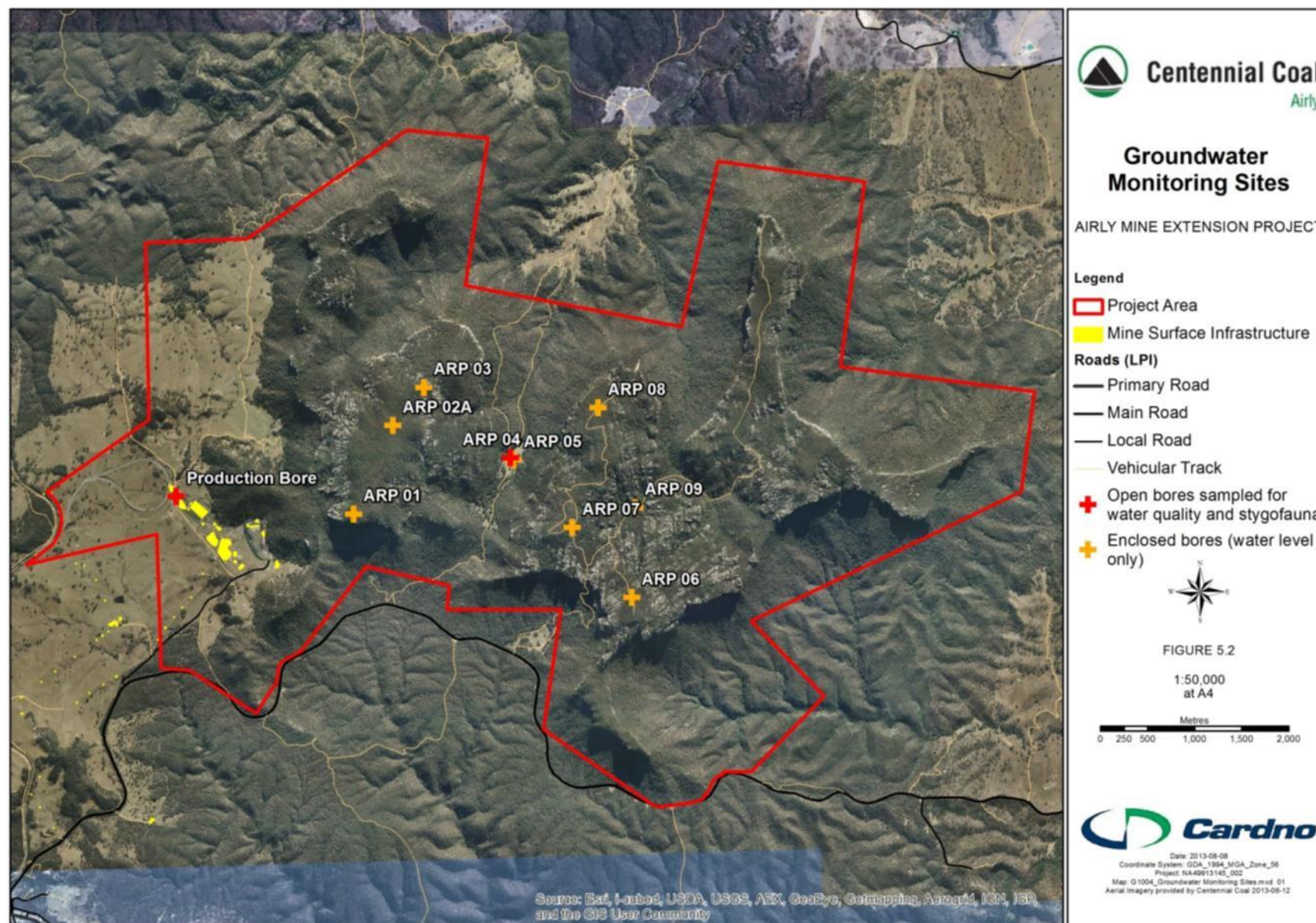


Figure 5-2 Groundwater monitoring locations

5.4 Hyporheic Fauna

Another distinct assemblage known as the hyporheic fauna, inhabit the hyporheic zone, the area of interaction between surface and groundwater. The hyporheic fauna is distinct from surface and groundwater dwelling organisms. Hyporheic habitat is usually associated with stream beds, being the area where water flows through the substrate. Hyporheic habitats can exist in creek beds that cease to flow on the surface, but maintain subterranean flow (Pryce *et al.* 2010).

Hyporheic fauna may occur in alluvial substrata associated with ephemeral creeks within the Project Application Area and are likely to occur in alluvium associated with larger creeks outside of the Project Application Area. Areas of potential hyporheic fauna habitat exist along Gap Creek and Genowlan Creek, where alluvial deposits occur. The larger creeks downstream of the Project Application Area, such as the Airly/Coco Creek, contain likely hyporheic habitat and are therefore likely to harbour hyporheic fauna (**Plate 7d**).

5.5 Summary of Groundwater Ecosystems

Stygofauna were not recorded within the Project Application Area in the current investigation during three sampling efforts undertaken between 21 May 2013 and 4 June 2014. Stygofauna generally occur in aquifers at low densities unless there is localised resource abundance, such as phreatophytes (Hancock and Bolton 2008). The low density of stygofauna further reduces the chance that they would be collected given a sampling effort.

A more extensive sampling program is required to determine if stygofauna are present and if so to estimate their abundance and community composition in aquifers within the Project Application Area. This would require multiple bores per aquifer to be sampled on multiple occasions, with several sampling events per season if seasonal changes are expected to occur (Hancock and Bolton 2009; Hose and Lategan 2012). Greater sampling replication at the existing bores may be needed because of the limited number of available bores. If further drilling is to be completed sampling bores should be located preferentially in the alluvial and Narrabeen Group aquifers, which are more likely to contain stygofauna.

Potential impacts on species which are locally endemic would be greater than those that are widespread. Information on stygofauna composition as well as presence/absence is therefore important in making an assessment of impacts on these organisms. Regional scale surveys are required to establish their distribution patterns and likely conservation significance in this context.

The lack of suitable bores has been recognised as a major constraint on accurate assessment of groundwater invertebrate fauna. Hancock and Boulton (2009) suggest that this problem could be overcome by installing bores that are suitable for multiple-parameter surveys (i.e. fauna, geochemistry, water quality and hydrology). The limitation should be considered if additional bores are constructed on Genowlan Mountain. Newly constructed bores also need to be left for a minimum of three to six months before sampling takes place, because the construction of bores could disturb the aquifer and its associated biota (WA EPA 2007).

Apart from the lack of sampling effort, some limitations also exist with the sampling methodology. Stygofauna samples should be collected from boreholes prior to any recent purging, because purging removes animals and it may take weeks or months for them to re-establish. In some cases this may be longer than the frequency of water quality sampling (Hose and Lategan 2012). Further sampling should ensure that bores are not purged for at least one month before stygofauna sampling is completed.

6 Assessment of Potential Impacts and Mitigation Measures – Surface Water Ecosystems

In this section, the potential direct, indirect and cumulative impacts on aquatic habitats, surface water quality, aquatic biota and threatened aquatic species that may arise during the construction, operation, decommissioning and rehabilitation phases of the Project are described. The assessment of potential impacts of the Project on surface water ecosystems is based on:

- > The description of the Project provided by Centennial Airly;
- > The description of the existing surface water ecosystems presented in **Section 4**;
- > The Subsidence Predictions and Impact Assessment for Airly Mine (Golder Associates 2013);
- > Summary of the assessment of potential impacts on surface water quality (GHD 2014a); and
- > Summary of the assessment of potential impacts on groundwater recharge and discharge to streams and baseflows (GHD 2014b).

The potential impacts of the Project on the aquatic habitats, surface water quality, aquatic biota and threatened aquatic species associated with the construction, operation, and decommissioning and rehabilitation phases are described below. Measures that could be used to avoid, minimise or manage such impacts are also described in each of the relevant sections. The potential impacts of the Project on groundwater ecosystems are described in **Section 7**.

6.1 Construction

The construction phase is defined as initial construction of the proposed surface infrastructure. Construction of underground infrastructure and all mining activities related to the extraction of coal are covered under operational impacts in **Section 6.2**.

6.1.1 Sediment Mobilisation, Suspension and Deposition

6.1.1.1 Potential Impacts

Sediment mobilised from construction areas is the main potential source of impact on creek habitat and aquatic organisms during the construction phase. The potential construction works that may result in sediment mobilisation include:

- > Vegetation clearing, soil stripping and stockpiling;
- > Erosion and runoff from construction work areas;
- > Erosion and runoff from the proposed rejects emplacement area (REA) or coal stockpiles;
- > Discharge of sediment laden water in the event of ineffective capture and/or treatment;
- > Construction of additional dams associated with the REA; and
- > Erosion caused by vehicular movement.

Sediment has its greatest potentially adverse effect on aquatic ecosystems in areas of deposition. This is due to its potential to smother habitat and through sediment interactions with the water column, which can influence nutrient concentrations (Bartley and Rutherford 1999).

Downstream aquatic habitats may be placed at risk from increased concentrations of suspended sediment, which can result in increased turbidity. Suspended sediments have been detected for long distances (several km) downstream of construction sites (Wheeler *et al.* 2005). An increase in suspended sediment load can degrade water quality and important habitat features such as snags and submerged macrophyte beds, resulting in a loss of biodiversity and a shift towards a more pollution-tolerant biotic assemblage. For example, sedimentation and increased concentrations of suspended sediment affects biota by causing:

- > Mortality and decreased growth – Suspended particles could clog respiratory gills and/or feeding apparatus of fish and macroinvertebrates;
- > Degradation of habitat – Siltation could infill deep water refugia and interstitial spaces in the stream bed and smother aquatic macrophytes beds and spawning grounds; and
- > Reduced water quality – Increased light attenuation could decrease primary productivity and nutrients bound in mobilised sediments could increase eutrophication.

The likelihood of such impacts occurring depends on the proximity of the streams and their associated drainage lines to the construction works and whether appropriate management measures are implemented. Airly Creek, the closest watercourse to most of the proposed surface works, and aquatic environments downstream thereof, are the most likely to be affected. The Torbane Creek catchment may be impacted by construction of the proposed REA and associated facilities, if these are constructed here. Gap Creek and Genowlan Creek catchments may be impacted by exploration drilling works, and vehicular movements within their upland catchments. The aquatic flora and fauna in these creeks may experience temporary, localised increases in sediment load and turbidity during construction works. The aquatic flora and fauna living in these creeks are likely to be fairly tolerant of temporary increases in sediment load, as these would occur naturally during significant rainfall events. It is therefore unlikely that any temporary, localised increases in sediment load resulting from the proposed construction works and exploration drilling would have significant effects on aquatic biota.

6.1.1.2 Mitigation Measures

The following measures would be implemented to mitigate potential sediment impacts:

- > An Erosion and Sediment Control Plan, prepared in accordance with the Bluebook (Landcom 2004, DECC 2008) with details of specific work areas, water management structures, erosion and sediment control structures (refer below), and measures required would be used to minimise construction related sediment mobilisation and dispersion;
- > The existing Water Management Plan would be updated to ensure that the sediment and water quality control structures constructed to adequately treat and manage runoff are appropriately sized and located. Basin sizing and treatment efficacy design should include an engineering design factor of at least 20% to account for rainfall and subsequent inflow variability;
- > Water discharge management would be included in the updated Water Management Plan to ensure that storages are maintained with adequate freeboard to accommodate anticipated rainfall inflow during construction;
- > A Vegetation Management Plan with measures that ensure vegetation removal is minimised and controlled;
- > Vegetation clearing, soil stripping and stockpiling should be minimised and limited to the designated construction areas;
- > Construction stockpiles should be covered to prevent erosion and sediment mobilisation and any leachate anticipated should be captured and adequately treated before discharge; and
- > Monitoring of construction related sediment discharge at licenced discharge points.

The Erosion and Sediment Control Plan would be prepared in accordance with the Blue Book – Managing Urban Stormwater: Soils and Construction (Landcom 2004) and Managing Urban Stormwater: Soils and Construction, Volume 2E Mines and Quarries (DECC 2008) and would include a description of the erosion sediment control structures that are to be used to minimise soil erosion and the potential for the transport of sediment to downstream waters. Temporary erosion and sediment control measures such as sediment fences, sandbag weirs, temporary drains, and temporary silt traps should be installed prior to any construction works.

6.1.2 Water Quality

6.1.2.1 Potential Impacts

Water quality constituents (other than sediment) that are harmful to aquatic organisms may be mobilised into the aquatic environment during construction activities. Specific construction works that may result in water quality issues include:

- > Spills during construction;
- > Runoff from construction of the REA and coal stockpiles;
- > Discharge of contaminant laden water in the event of ineffective capture and/or treatment;
- > Passive contamination from vehicles (e.g. tyre wear and oil leakage);
- > Ineffective effluent management (e.g. sewerage effluent system failure); and
- > Compounding sediment related effects (e.g. volume and availability of contaminants in substratum).

Water pollutants can have toxic effects on aquatic biota if concentrations are elevated above an organism's tolerance threshold. Different thresholds apply for different organisms (more or less tolerant) exposed to different compounds (more or less toxic) under different environmental conditions (more or less stressful). Toxicity depends on exposure concentration and exposure time, which can be broadly summarised as occurring at high concentrations over short periods (acute toxicity) or lower concentration over long periods (chronic toxicity). Threshold concentrations for toxicity effects to aquatic ecosystems are outlined in the ANZECC/ARMCANZ (2000) guidelines for a variety of aquatic contaminants.

Potential water quality impacts are dependent on the type, volume and location of the source contaminant, its relevance to the receiving ecosystem and whether appropriate management measures are implemented. As with potential sediment related impacts, water quality impacts would primarily affect Airly Creek and aquatic environments downstream, as it is in this catchment that the majority of the proposed surface works including the establishment of the REA would be undertaken. Gap Creek and Genowlan Creek catchments may be impacted by contaminants arising from increased vehicular movement within their upland catchments for exploration drilling activity. Water quality impacts are likely to be temporary and localised and would not therefore have significant effects on aquatic biota.

6.1.2.2 Mitigation Measures

Measures to mitigate potential sediment related impacts will also assist in the mitigation of water quality impacts. In addition, the following measures would be implemented to reduce water quality related impacts:

- > Storage and handling of fuel and oils and other chemicals within designated, controlled, bunded areas;
- > Preparation of spill response plans;
- > Construction stockpiles should be covered to prevent erosion and contaminant mobilisation and any anticipated runoff should be captured and adequately treated before discharge; and
- > Monitoring of construction related water quality at licenced discharge points.

6.1.3 Hydrology

6.1.3.1 Potential Impacts

Hydrological changes may also occur as a result of construction activities. Specific construction-related hydrological changes include:

- > Water capture, storage and use during construction, including dewatering of existing dams for expansion or additional water use/discharge requirements for construction related works; and
- > Exploration drilling activity could result in changes to surface water ecosystems in the event that these activities directly impact surface water flow or indirectly through changes to groundwater resources feeding creeks and tributaries.

Hydrological changes can impact aquatic organisms through altered habitat availability (flooding/drying) waterway dynamics (altered flow regime) and changes to reproductive cues and logistics (spawning and migration).

The hydrological changes associated with construction works are expected to be minor, short term and largely restricted to Airly Creek and aquatic environments downstream.

6.1.3.2 Mitigation Measures

The update and the continued implementation of the existing Water Management Plan and Site Water Balance would assist in the reduction of hydrological impacts as a result of construction activities through planning and appropriate design of water infrastructure.

Exploration drilling activity should be accompanied by adequate environmental impact assessments and should not be proposed in close proximity to watercourses except when drilling of an alluvial aquifer is undertaken specifically for monitoring purposes. All drilling activities should consider the potential for impacts to surface water resources, either directly or through alteration of source aquifers.

6.1.4 Aquatic Habitat and Invasive Species

6.1.4.1 Potential Impacts

Degradation or loss of aquatic habitat could occur as a result of construction activities through sediment deposition, reduced water quality, changes to hydrology and/or altered geomorphology. Aquatic habitat loss and degradation can occur in a direct physical manner (e.g. piping, culverts, flow restriction, snag removal) or indirectly through processes such as riparian vegetation loss (this resulting in reduced littoral habitat, reduced input of woody debris and/or reduced shading, which can in turn influence water quality and stream biota). The potential for impact is limited to Airly Creek and relates mainly to potential sediment deposition and potential reductions in water quality.

Habitat degradation can result in preferential conditions for the establishment of invasive species. Invasive aquatic and riparian species could also be spread within the Project Application Area, or could become established from external populations during construction, due to increasing potential vectors for their transmission, for example increased vehicular movements and water transfers. Predation by *Gambusia holbrooki*, a KTP listed under the *TSC Act*, could be amplified if this species spreads from Airly Creek into other watercourses as a result of water being transferred between this and other catchments.

6.1.4.2 Mitigation Measures

Any construction works in the vicinity of watercourses should also be done in accordance with the NSW DPI Policy and Guidelines for Fish Habitat Conservation and Management (**Section 2.2.2**) (NSW DPI 2013). These indicate that:

- > Riparian buffer zones should be established and maintained in or adjacent to key fish habitat where practical;
- > Riparian buffer zones should be designed to maintain lateral connectivity between aquatic and riparian habitat;
- > The width of the riparian buffer zone should be based on the habitat type and waterway class, for example, larger buffers and exclusion of stock around sensitive waterways;
- > Existing riparian vegetation should be retained in an undamaged state where possible and disturbed areas should be revegetated with local native species and monitored to ensure revegetation is successful; and
- > If rehabilitation is required this should include native instream vegetation and snags, where appropriate.

Appropriate wash down and decontamination procedures, education of construction staff and limiting non-essential inter-catchment water movements during the construction phase will also assist in the mitigation of the potential spread of invasive aquatic species.

6.2 Operations

The operational phase is defined as activities undertaken for coal extraction, processing and transport and includes potential subsidence related impacts. Mining operations currently undertaken by Centennial Airly extend into the western portion of the Mount Airly area only. Cardno notes that the limited mining operations to date have not resulted in groundwater drawdown within the Lithgow Seam or have impacted overlying aquifers (RPS Aquaterra 2011). Surface water in Gap Creek and Genowlan Creek has also not been impacted (RPS Aquaterra 2011), although these creeks have not yet been undermined.

6.2.1 Proposed Mining Operations

The economically preferable panel and pillar mining method was not suitable for use across the entire Project Application Area, because of the highly variable depth of cover. Centennial Airly therefore plans to use a combination of mining methods to extract coal, with the aim of limiting subsidence to defined levels within five distinct mining zones. The Project has adopted subsidence criteria that would result in 'minimal subsidence impact' (Golder Associates 2013). The mining zones have also been modified to accommodate watercourse features.

The mining zones are outlined in **Figure 6-1** and predicted subsidence effects within each zone are summarised in **Table 6-1**.

Table 6-1 Predicted conventional subsidence parameters for the defined mining zones

Mining Zone	Subsidence (mm)	Tilt (mm/m)	Tensile Strain (mm/m)	Compressive Strain (mm/m)	Fracture Zone Height (m above seam)	Surface Cracking
Shallow Zone	0 to 10	0 to 0.5	0 to 0.5	0 to 0.5	Less than 10	Not expected
Partial Pillar Extraction Zone	10 to 80	0 to 2	0 to 2	0 to 2	20 to 35	Not expected
Cliff Line Zone and Area of First Workings	10 to 30	0 to 1	0 to 1	0 to 1	Less than 10	Not expected
Panel and Pillar Mining Zone	50 to 70 (106 max.)	1 to 2 (3 max.)	0 to 1	0 to 2	60 to 70	Not expected
New Hartley Shale Mine Potential Interaction Zone (first workings)	10 to 30	0 to 1	0 to 1	0 to 1	Less than 10	Not expected
New Hartley Shale Mine Potential Interaction Zone (panel and pillar)	200 ¹	2.5 to 6.7	1.0 to 2.0	0.7 to 3.3	N/A	Expected
New Hartley Shale Mine Potential Interaction Zone (panel and pillar) ²	500 ¹	6.2 to 16.7	2.4 to 5	1.8 to 8.3	N/A	Expected

¹ Indicates new subsidence effects accepting that subsidence has already occurred in this area.

² This scenario assumes sub-critical areas in the old shale working that become super-critical, resulting in remnant pillar collapses with panel and pillar mining.

A variety of mining methods would be utilised to achieve these outcomes. This would involve limiting the resource extraction under environmentally sensitive zones.

Mining methods proposed include:

- > Bord and Pillar Mining - This involves first workings only using a continuous minor, with spans along bords (or roadways) restricted to a maximum of 5.5 m. The intervening pillars would be designed to be 'long-term stable';
- > Pillar Splitting - This involves splitting and quartering pillars on retreat, with the remnants designed to be 'long-term stable';
- > Single-sided Lifting – This involves lifting (removal of material) from one side of the roadway to a maximum depth of 10 m, creating a total span of 15.5 m. The intervening pillars would be designed to be 'long-term stable';
- > Double-sided Lifting – This involves lifting from both sides of the roadway to a maximum depth of 10 m, creating a total span of 25.5 m. The intervening pillars would be designed to be 'long-term stable'; and
- > Panel and Pillar Mining – This system involves a twin entry chain pillar and a fully extracted maximum void width of 61 m. Voids can be extracted by various mining methods. The resulting chain pillars would be designed to be 'long-term stable'.

In addition to the conventional subsidence predictions, the following unconventional subsidence was predicted for the panel and pillar layout, assuming a typical 50 to 70 mm of vertical subsidence (Golder Associates 2013):

- > Valley closure of 90 to 130 mm; and
- > Upsidence of 20 to 25 mm.

Overall, the proposed mining system aims to provide the following advantages:

- > Caving heights restricted to the immediate Permian overburden, with minimal deformation of the Triassic sandstone. This is expected to reduce disturbance to any overlying aquifers, particularly perched aquifers within the Narrabeen Group that feed springs and surface groundwater expressions; and
- > No appreciable adverse surface impacts. In particular, the intent is to avoid surface cracking and minimise mining-related rock falls.

6.2.2 Ground Movements

6.2.2.1 Potential Impacts

The extraction of coal from the Project Application Area may result in vertical and horizontal movements of the rock and soil mass above the extracted coal seam. At the surface the following movements may occur:

- > Vertical (downward) and horizontal displacements of the surface which are referred to as vertical subsidence and horizontal subsidence;
- > Changes in surface slope, which is referred to as tilt; and
- > Changes in the horizontal distance between two points on the surface, referred to as tensile strain if the distance between the two points increases and compressive strain if the distance between the two points decreases.

Ground movements resulting from mining operations can lead to fracturing of stream beds and banks, movements of joint and bedding planes in the stream bed, uplift and buckling of strata in the stream bed (NSW DoP 2008). These physical impacts, in turn, can result in diversions of surface and sub-surface flows, drainage of pools and increases in groundwater inflows. Tilting of stream beds can result in erosion of the stream bed and banks and increased in-stream sediment load, changes in flow rates and migration of stream channels. These physical impacts can have adverse effects on aquatic flora and fauna through loss of aquatic habitat, desiccation of fringing vegetation, reductions in longitudinal connectivity, deterioration of water quality and changes in the diversity of riparian and aquatic plants, aquatic macroinvertebrates and fish.

The analysis completed as part of the subsidence predictions and impact assessment indicated that the mining systems devised would result in minimal surface impacts to aquatic features over the majority of the Project Application Area (Golder Associates 2013). An exception to this is the New Hartley Shale Mine Potential Interaction Zone where existing surface cracking is likely to be reactivated and impact several first

order watercourses. Other potential sensitive aquatic receptors outside the New Hartley Shale Mine Potential Interaction Zone are outlined below:

- > Genowlan Creek becomes a third order stream upstream of the confluence with Grotto Creek and overlies the Shallow Zone, Partial Pillar Extraction Zone and Cliff Line Zone, for 47, 523 and 517 m, respectively within each zone. This reach of Genowlan Creek contains highly sensitive, major fish habitat and shows minimal degradation of aquatic habitat (**Section 4.6.7**). Although subsidence predictions indicate minimal surface impacts within these zones, this section of Genowlan Creek represents a highly sensitive receptor for any potential subsidence-related impacts that may occur.
- > Gap Creek is also a third order stream within the Project Application Area. The subsidence zones have been offset from the creek due to the very low depth of cover below the lower reach of this creek. Gap Creek has been classified as highly sensitive, moderate fish habitat and shows limited degradation of aquatic habitat. Although Gap Creek has less aquatic habitat than Genowlan Creek within the Project Application Area and contains natural barriers to fish passage it still represents a sensitive receptor for any potential subsidence related impacts should these occur.

Potential impacts on aquatic ecosystems associated with mining related ground movements are outlined under the headings of surface hydrological change and surface water quality change below.

6.2.2.1.1 Surface Hydrological Change

Subsidence-related surface cracking is expected to occur in the New Hartley Shale Mine Potential Interaction Zone due to the interactions with the existing shale workings but not in any of the other mining zones within the Project Application Area (Golder 2013). The New Hartley Shale Mine Potential Interaction Zone contains two mapped first order drainage lines with a total length of 634 m. These first order streams are assumed to contain negligible surface aquatic habitat due to a small catchment size, ephemeral nature and expected steep channel gradient. Surface cracking currently exists in the area as a result of the historical shale mining operation, however there is limited understanding on the full nature and extent of the existing cracking with the sub-surface strata (GHD 2014a). This existing surface cracking is likely to have resulted in some historical loss of water and ephemeral aquatic habitat in these small drainage lines.

The proposed mining is likely to induce further cracking of the surface within the New Hartley Shale Mine Potential Interaction Zone, reactivate existing cracks and increase vertical permeability. Further loss of surface water may occur (GHD 2014a), resulting in additional loss of ephemeral surface water habitat in this zone. The existing condition, small and ephemeral nature of these watercourses and assumed minimal to negligible aquatic habitat means that negligible impact to the surface aquatic ecosystem will occur within this zone. Any cracks that do form are also likely to be infilled by sediment during subsequent flow events.

Further surface and subsurface cracking within the New Hartley Shale Mine Potential Interaction Zone has the potential to influence water flow at the Village Spring. Depending on the nature of the further cracking, discharge from the Village Spring may increase, decrease or cease as a result of the proposed mining. No significant surface aquatic ecosystem is associated with the Village Spring, so impacts on this component of the ecosystem due to loss of discharge would be negligible. Indirect impacts on terrestrial flora and fauna may be identified as a result of this loss (RPS Australia East 2014).

The New Hartley Shale Mine Potential Interaction Zone covers approximately 2% of the catchment area of Gap Creek and Genowlan Creek at their confluence. As this mining zone lies within the Gap Creek catchment, this proportion increases to around 4% and 5.5% contribution for its south and south-west arms, respectively (GHD 2014a). These proportions represent the maximum potential loss of surface runoff to the receiving aquatic environment at these points. It should also be noted that water lost within the New Hartley Shale Mine Potential Interaction Zone is likely to reappear downstream (GHD 2014a).

Subsurface cracking is expected within the fracture zone above the extracted seam in other mining zones and may result in the loss of a proportion of creek baseflow due to increased vertical permeability of groundwater within surrounding aquifer(s). Flow in Gap and Genowlan creeks are understood to be fed consistently by interflow emerging from Quaternary colluvium and alluvium, this being derived from catchment rainfall, along with a component of baseflow and direct runoff (GHD 2014a). Under the maximum impact scenarios modelled for locations within the Project Application Area, baseflow would be reduced from 3.8 ML/year to 0.6 ML/year at Gap Creek and from 3 ML/year to 0 ML/year at Genowlan Creek, respectively (GHD 2014a). Note that baseflow derived from the 'Oasis' is not represented in the hydrogeological model

and occurs in addition to the information provided (anecdotally at a constant rate of 1-2.2 L/s or 31.5-69.3 ML/year). From the modelling undertaken (GHD 2014a), flow in Gap and Genowlan Creek would be largely maintained by interflow and direct runoff following rainfall.

From the modelling undertaken, the maximum loss of baseflow as a proportion of total annual flow occurred in sections of Gap Creek and Genowlan Creek (2.2% and 3%, respectively) (GHD 2014a). Loss of base flow further downstream on these and at other creek locations was minimal to negligible as a proportion of the existing baseflow and total annual flow. Although the loss in flow as a proportion of total annual flow is relatively small, flow variability is an important factor influencing potential impact on the aquatic ecosystem. During very dry years rainfall derived runoff and interflow may be negligible at times and in this case, areas of Gap and Genowlan creeks that would have previously received base flow to sustain water movement may be impacted by stagnation and desiccation on occasions.

6.2.2.1.2 Surface Water Quality

Surface water entering mining related fractures within the New Hartley Shale Mine Potential Interaction Zone and re-emerging downstream may result in changes to water chemistry brought about by water-rock interactions along new flow pathways. Fresh rock faces exposed to groundwater flow, or surface water infiltration are subject to a variety of water-rock chemical interactions until a time when the exposed face behaves in a manner chemically approaching the pre-existing condition of weathered rock. The chemistry of these interactions is complex, but commonly involves dissolved ionic constituents entering the water and being transported to an outlet point. This process can target available carbonate or sulfide minerals in sandstones and other strata and can contribute cations such as iron, barium, strontium and calcium together with the bicarbonate anion to the groundwater and eventually to the surface stream flow (NSW DoP 2008).

The dissolution of iron oxy-hydroxides provides a mechanism for increasing the presence of iron in surface waters. Iron sulphide may also contribute to elevated iron, sulphate and increased acidity through oxidative dissolution. The influence of these iron minerals on water quality is reflected in the characteristic bright orange discolouration of subsurface water that returns to the surface. This discolouration can be accompanied by the downstream growth of bacterially-mediated iron mats and blooms in rock pools, which can lead to a reduction in dissolved oxygen and related eco toxic impacts (NSW DoP 2008). These effects are expected to be localised and transient and are unlikely to have a significant impact on aquatic flora and fauna, as there would be little if any aquatic habitat in the first order drainage lines.

6.2.2.2 Mitigation Measures

The mining zones have been designed to cause minimal surface impacts over the majority of the Project Application Area (Golder Associates 2013). To achieve this outcome modifications to the mining zones have been made and are outlined below.

- > Within the Partial Pillar Extraction Zone, it has been recommended that a minimum constrained zone thickness of 12 times the mining height be maintained beneath the creeks to provide them with suitable protection (Golder Associates 2013). This is the equivalent of 34 m of additional cover, resulting in a combined fracture plus constrained zone height of 54 to 69 m. Allowing for a weathered surface zone thickness of 10 to 15 m, it was recommended that mining beneath the creeks at depths of less than 80 m be therefore limited to first workings only, with the zone of first workings defined by an angle of draw equivalent to half the depth (Golder Associates 2013). First working only zones have therefore been delineated within the partial pillar extraction zones along Genowlan Creek below the confluence with Grotto Creek and within tributaries of Gap Creek, as depicted in **Figure 6-1**.
- > Within the Shallow Zone, it has been suggested that a minimum mining depth of 40 m beneath creeks be adopted, based on a criterion of 10 times the minimum mining height (28 m), plus an allowance of 12 m for the thickness of the weathered zone (Golder Associates 2013). These criteria are met along tributaries of Gap Creek and would restrict mining activity in this vicinity, as depicted in **Figure 6-1**. Appropriate setback distances from Gap and Genowlan creeks should also be defined by an angle of draw equivalent to half the depth (Golder Associates 2013).

During resource extraction, main watercourses and drainage lines within and immediately outside the subsidence zones should be periodically inspected by suitably qualified personnel for evidence of subsidence-induced impacts. A Trigger Action Response Plan for surface water and groundwater should be

developed in consultation with the NSW Office of Water. If the changes in quality and quantity of groundwater and surface water that may occur during or after extraction are greater than expected, their effects on downstream aquatic ecology should be investigated immediately. Trigger values (i.e. thresholds that would need to be exceeded) that would result in the initiation of such studies would need to be identified.

Although significant impacts on aquatic ecology are unlikely, continued collection of baseline data on aquatic ecosystems is recommended to ensure data are available in the event of future requirements for responsive monitoring. Sites across the Project Application Area should be monitored twice annually for a minimum 2 years prior to mining to provide for seasonal and annual variation in species composition, as outlined in the aquatic ecology monitoring framework document. The requirement for 2 years of data collection is consistent with Centennial Coal Management Standard 015 on environmental baseline data collection (Centennial Coal 2012).

An adaptive management approach to the mine design should also be implemented in response to ongoing subsidence monitoring. This would ensure that further safeguards are implemented in response to any unforeseen ground subsidence related impacts on creeks and drainages.

If the impacts of resource extraction on aquatic habitats and biota are greater than predicted, the following contingent measures should be considered:

- > Stream remediation measures, such as backfilling or grouting, should be used in areas where fracturing of controlling rock bars and/or stream bed leads to protracted diversion of stream flow and drainage of pools;
- > Appropriate control measures should be implemented to limit the potential for deposition of eroded sediment into watercourses (e.g. installation of sediment fences down slope of areas where subsidence has led to erosion, and use of rocks, brush matting or vegetation to stabilise areas prone to erosion and soil slumping); and
- > Soft engineering techniques, such as coir logs, jute matting, hay bales, water dissipaters constructed from timber logs and rocks and revegetation using tube stock or direct seeding, could be used to minimise erosion, slumping and/or scouring.

6.2.3 Operational Water Quality and Sedimentation

6.2.3.1 Potential Impacts

An increase in plant and machinery operation, including vehicular movements will occur during mine production and has the potential to impact water quality and sediment mobilisation, suspension and deposition. These processes have been covered under construction related impacts in **Section 6.1.1.1**. Operational processes may lead to increased spill potential, wash-down activities, servicing and maintenance requirements, erosion and diffuse sources of contaminants. The most likely water quality constituents that would impact aquatic ecosystems during operation are likely to be sediments, petroleum hydrocarbons (fuel, oil and grease), nutrients and metals. Contaminants arising from coal handling and reject materials management are covered in **Section 6.2.4**.

6.2.3.2 Mitigation Measures

The ingress of sediments into watercourses and the potential for impacts on instream ecology would be minimised by implementing appropriate measures specified in an Erosion and Sediment Control Plan. These would include temporary erosion and sediment controls such as sediment fences, sandbag weirs, temporary drains and temporary silt traps. Runoff from rehabilitated areas may also be directed to sediment control retention ponds for treatment. Impacts to surface water ecology would also be minimised by the generally small amount of proposed works on the surface.

Operational water quality impacts will be mitigated through the capture and treatment of runoff arising from site related plant and machinery use. Wash-down facilities will be located within the dirty water capture areas to ensure this water is treated and in most cases the water used would be reused in site operations.

In addition, the following actions would be taken to reduce operational water quality impacts:

- > Wash-down facilities and service bays for plant and machinery would be bunded and runoff treated to separate excessive oil and grease. Oil and grease would be removed from site for treatment at an appropriate liquid waste facility; and
- > Spill response plans have been developed to ensure any spills are appropriately managed.

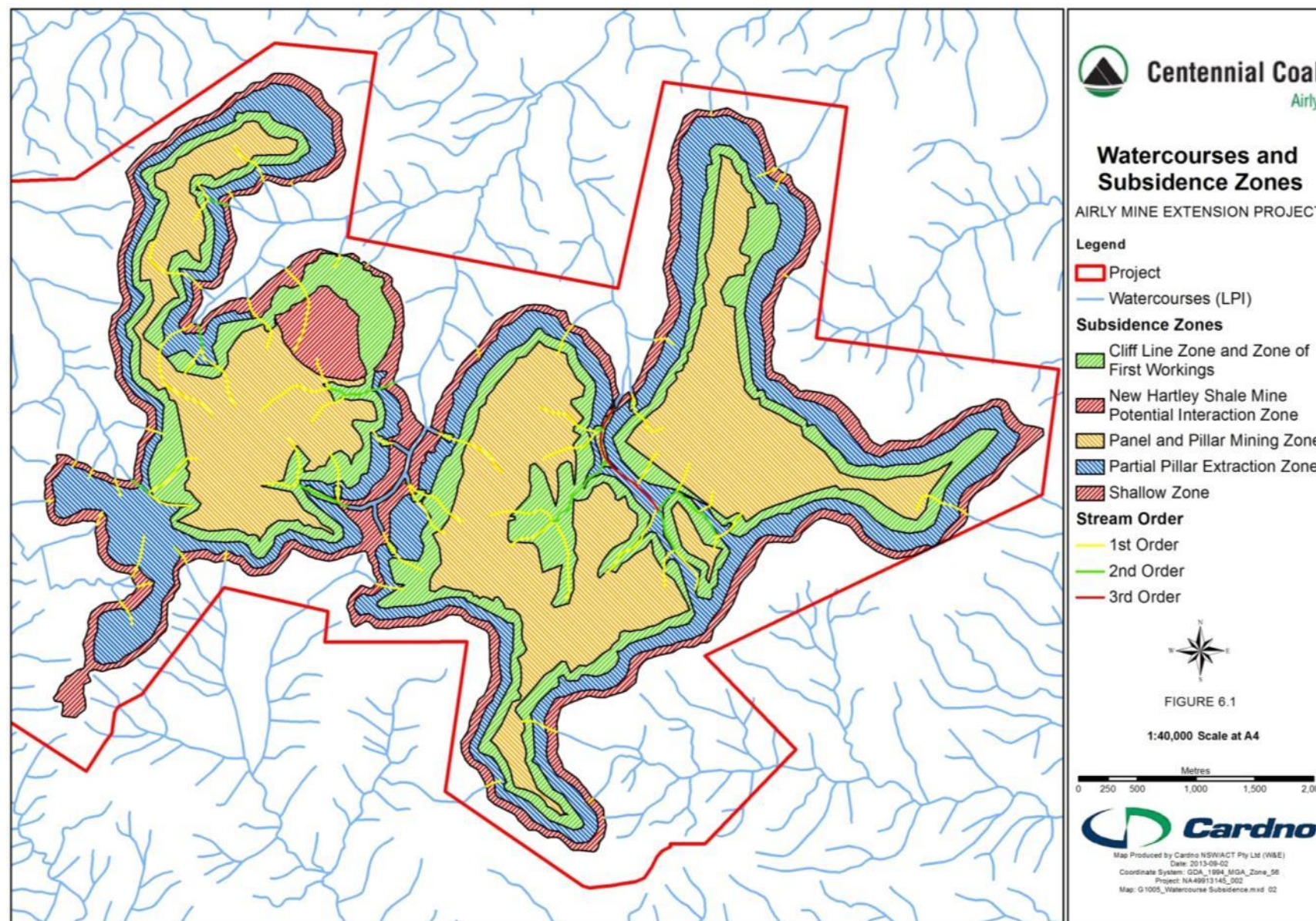


Figure 6-1 Subsidence prediction zones overlaid with surface water features

6.2.4 Coal Management and Rejects Emplacement

6.2.4.1 Potential Impacts

The Project includes the construction of a Coal Preparation Plant (CPP) and an REA and will therefore result in the generation of more runoff that has been in contact with coal and coal reject. This runoff may contain elevated concentrations of aquatic contaminants. These could include increased suspended particulates, acidity and concentrations of metal ions and other compounds. The location of the REA will be close to the existing surface infrastructure in the vicinity of the existing water management structures. Similarly, the CPP will be located near existing infrastructure in the vicinity of the water management structures. Both the REA and the CPP locations fall within the Airly Creek catchment.

A geochemical assessment was undertaken at Baal Bone Colliery (GHD 2011) to determine the potential for acid and metalliferous runoff from the REA (GHD 2014a). As the Lithgow Seam is the main coal seam mined at Baal Bone Colliery the geochemistry of the mine waste runoff is likely to be representative of that which will be generated at Airly Mine in the future. Given the predominant use of surface water for CPP uses, the assessment suggests that the future operation of the CPP and REA at Airly Mine is unlikely to result in deterioration in water quality at LDP001, particularly in terms of acidity and metals (GHD 2014a).

Operation of the REA will result in runoff being removed from the Airly Creek catchment through a reduction in the effective catchment area. The reduction in total Airly Creek catchment area would be approximately 3%, the total catchment area being defined approximately at the aquatic ecology sampling locations on these creeks. The percentage provides an indication of the likely reduction in flow into Airly Creek at the aquatic ecology sampling locations. As indicated, the percentage flow reduction at the monitoring points resulting from the REA runoff capture will be minimal.

As the operation of the REA and CPP using mainly surface water supply would have minimal impacts on water quality and hydrology there are unlikely to be detectable impacts on aquatic ecosystems.

6.2.4.2 Mitigation Measures

All runoff from the proposed CPP and existing coal handling, stockpiling and transportation infrastructure will be routed through settlement basins and would be reused on site and discharged as required at existing LDPs. The impact of such discharges on aquatic ecology would be minimised by ensuring it meets the conditions specified in the Airly Mine Environment Protection Licence.

Settlement ponds are proposed to be constructed to treat runoff at the proposed REA (within the Airly catchment). The settlement ponds are designed to collect runoff events up to the 100 year, 72 hour event and are designed to capture and treat contaminants arising from the REA (GHD 2014a). The runoff would be recirculated into the water management system at the surface facilities site, reducing the likelihood of contaminants being discharged to receiving aquatic environments.

Appropriate management of the REA, settlement ponds and any other construction stockpiles and related water treatment infrastructure is required to ensure that runoff is captured and adequately treated before discharge. This will include management of storage capacities to ensure adequate volume is retained to capture runoff during large rain events. Management of water within the site will be achieved via the site water balance and Water Management Plan.

6.2.5 Operational Water Discharges

6.2.5.1 Potential Impacts

Water seeping into mine workings from overlying aquifers and through upwelling from regional aquifers will require removal and treatment and may require discharge to surface water ecosystems. The discharge is proposed to occur through the existing licenced discharge points (LDPs), located along Airly Creek, following treatment in the water management dams. Dirty water from all disturbed areas and coal stockpiles would pass through settling ponds prior to discharging into the 109 ML Dirty Water Dam. Surface water runoff that enters the 7 ML Dam and Train Loader Dam would be pumped into the 109 ML Dirty Water Dam. Water from the 109 ML Dirty Water Dam will be transferred by pipe or overflows into the 35 ML Discharge Dam and this clean water would then either used for in CPP operations or discharged at LDP001.

Outcomes of the modelling show that discharges from LDP001 currently occur during periods of high rainfall (5.5 ML/yr average). Due to grey water and sewage generated from the bathhouse and amenities at Airly

Mine, discharges through LDP001 are expected to increase to an average of 76 ML/yr with discharges predicted to occur in 2030 on less than 9% of days or approximately 31 days per year. The maximum discharge through LDP001 under proposed conditions is approximately 84.6 ML/yr due to increased groundwater make (GHD 2014a). Water make from the mine workings is likely to contain similar constituent concentrations of water of the Permian aquifer, with contribution from overlying (Narrabeen) and underlying (Shoalhaven) aquifers.

Additional water required during the mine operational phase will be sourced from the Production Bore, which is screened within the Shoalhaven Group aquifer. Water from this aquifer is in the brackish to saline range and contains ammonia, nickel and zinc concentrations in excess of the ANZECC/ARMCANZ (2000) default trigger values. Water produced from this source may therefore result in an increase in salinity and ammonia, nickel and zinc concentrations at the licensed discharge point. Overall, the salt water balance due to mine operations is expected to result in minimal increase in net salt load (GHD 2104c). The proportion of water sourced from the production bore that is present in a given discharge will influence the level of impact on the receiving aquatic ecosystem. It is likely that this proportion would be low as discharges are likely to occur during rainfall events when contaminants would be diluted. Water in Airly Creek has also been shown to be moderately brackish and to have relatively high concentrations of nutrients and some metals. Therefore, the likelihood of major impacts on the receiving aquatic ecosystem arising from the contribution of discharge water from the Production Bore are considered low if this water is suitably diluted during rainfall events before being discharged.

Potential impacts arising from the discharge of mine make water on aquatic ecosystems therefore includes:

- > Hydrological change in Airly Creek through either increased flow, due to an increase in mine make water and the requirement to discharge or reduce flow due to additional operational use of mine make water on site;
- > Reduction in flow in Airly or Torbane Creek through removal of water from the new REA catchment area that would be re-used and recirculated on site;
- > Increase in flow to Airly Creek through increased discharge resulting from water obtained from the production bore;
- > Changes in water quality in Airly Creek through increased contribution of mine make water and production bore groundwater at the discharge point.

6.2.5.2 Mitigation Measures

Operational water, stored and treated in the water management dams (refer Section 6.2.2.5), can be discharged through LDP001. The impact of such discharges on aquatic ecology would be minimised by ensuring they meet the conditions specified in the Airly Mine Environment Protection Licence.

Runoff diverted from the REA constitutes a relatively small proportion of the total catchment in the Airly Creek catchment. The impacts associated with this loss are expected to be low to negligible. This water would be captured in the settlement ponds for reuse on site, reducing the likelihood of direct impacts on receiving aquatic ecosystems. In the event that discharges are to occur treatment prior to discharge will mitigate any potential impact on the aquatic ecology.

In terms of the potential increase in water sourced from the Production Bore and the potential impact on aquatic ecosystems from salinity and water quality issues, water quality should be managed to limit the requirement for extraction. Discharges should also be managed where feasible and reasonable to do so, to ensure water quality is within acceptable limits. Should dissolved metal concentrations in Airly Creek exceed SSTVs due to site discharges, it will be necessary to undertake appropriate toxicity testing of the discharge and determine the size of the downstream mixing zone in accordance with ANZECC/ARMCANZ (2000) methodology (GHD 2014a).

6.3 Decommissioning and Rehabilitation Phase

The decommissioning phase of the Project would involve permanent sealing of underground access points, dismantling and removal of surface infrastructure and services and rehabilitation of the underlying land to ensure that it is appropriate for the proposed final land use. Mining related monitoring bores and any new access roads constructed on the Mount Airly and Genowlan Mountain mesas would be decommissioned as

soon as practicable after they are no longer required and fully rehabilitated to enable rehabilitation of the land.

The areas that have been disturbed during the life of the mine will need to be returned to a stable, productive and/or self-sustaining condition similar to pre-mining conditions. Rehabilitation would be an ongoing process that takes place progressively as soon as each disturbed area is no longer required, or in the case of the REA as emplacement of the reject materials occur. Rehabilitation works typically involve clearing and grading of land, spreading of topsoil, seeding and/or revegetation, application of fertilisers and control of weeds. Land contamination issues would need to be addressed and managed prior to rehabilitation. Once rehabilitation has been completed, monitoring is required to ensure erosion is not occurring and that seeding and/or revegetation is successful. The above works would be undertaken in accordance with the updated Mining Operations Plan.

6.3.1 Potential Impacts

During the rehabilitation phase, there is a potential for erosion of denuded areas to occur and for runoff containing sediments and contaminants such as fertilisers, herbicides and weeds to enter watercourses during rainfall events. An increase in sediment load and input of contaminants could potentially have adverse effects on aquatic flora and fauna. The potential for such effects would depend on the residence time of the sediment and contaminants within particular areas of the watercourses.

6.3.2 Mitigation Measures

The input of sediments into watercourses during the decommissioning and rehabilitation phase and potential for impacts on instream ecology would be minimised by implementing appropriate measures specified in the Sediment and Erosion Control Plan prepared in accordance with Managing Urban Stormwater: Soils and Construction, Volume 2E Mines and Quarries (DECC 2008). The measures may include temporary erosion and sediment controls such as sediment fences, sandbag weirs, temporary drains and temporary silt traps. Runoff from rehabilitated areas may also be directed to sediment control retention ponds for treatment prior to discharge.

6.4 Potential Impacts on Threatened Species, Populations and Communities

Assessments of significance for Macquarie perch, giant dragonfly and Adam's emerald dragonfly have been prepared in accordance with the Threatened Species Assessment Guideline – The Assessment of Significance (NSW DPI 2008). These guidelines specify the important factors that must be taken into consideration when assessing potential impacts on threatened species, populations or ecological communities listed under Schedules 4, 4A and 5 of the *FM Act*. The factors are:

1. Whether the proposed action is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction;
2. The extent to which the species habitat is likely to be removed or modified as a result of the action proposed, whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and whether the habitat to be removed, modified, fragmented or isolated is important to the long-term survival of the species in the locality;
3. Whether the proposed action is likely to have an adverse effect on critical habitat (either directly or indirectly);
4. Whether the proposed action is consistent with the objectives or actions of a recovery plan or threat abatement plan; and
5. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

6.4.1.1 Assessment of Significance for Macquarie perch

(a) Is the proposed mine extension likely to have an adverse effect on the life cycle of Macquarie perch that would result in a risk of extinction of a viable local population of the species?

Macquarie perch are found in rivers and lakes, but particularly the upper reaches of rivers and their tributaries. This species prefers clear water and deep, rocky holes with lots of cover in the form of aquatic vegetation, large boulders, debris and overhanging banks (DSEWPAC 2010). They spawn in spring or

summer and lay their eggs in shallow, fast-flowing water over stones and gravel in shallow upland streams or flowing parts of rivers. Areas of Genowlan Creek within the Project Application Area are considered marginal habitat fitting this description.

The life cycle of Macquarie perch could be affected if the construction, operation, decommissioning and/or rehabilitation phases of the Project resulted in loss or modification of its habitat or reduced the quality of the water downstream of the Project Application Area. The Project Application Area does not contain habitat that would be suitable for Macquarie perch spawning, assuming adult fish could navigate up the Capertee River to this point. The subsidence impact assessment indicates habitat loss is unlikely to occur within Genowlan Creek (Golder Associates 2013). Water quality impacts from the Project are unlikely to extend downstream of the Project Application Area to the area downstream of Glen Davis where Macquarie perch have been observed.

(b) Is the habitat of Macquarie perch likely to be (i) removed or modified, (ii) become fragmented or isolated from other areas of habitats by the proposed mine extension and (iii), if so how important is the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species?

The subsidence impact assessment indicates habitat loss, modification or fragmentation is unlikely to occur within Genowlan Creek (Golder Associates 2013).

(c) Is the proposed mine extension likely to have an adverse direct or indirect effect on critical habitat?

Critical habitat for this species has not been declared under the FM Act.

(d) Is the proposed mine extension consistent with the objectives or actions of a recovery plan or threat abatement plan?

There is no recovery plan or threat abatement plan for this species at present.

(e) Does the proposed mine extension constitute or is it part of a key threatening process or is it likely to result in the operation of, or increase the impact of, a key threatening process?

Underground coal mining is not classed as a Key Threatening Process (KTP) under the FM Act under which Macquarie perch is listed as endangered. Alteration of natural flow regimes and degradation of riparian vegetation are both listed as KTPs although it is considered unlikely that these processes would be accelerated as a result of Project related works.

Conclusion

It is highly unlikely Macquarie perch would inhabit waterways within the Project Application Area and it is unlikely that the Project would have a significant effect on known Macquarie perch populations within the Capertee River, downstream of the Project Application Area. There is, however, a potential that the cumulative impacts of coal mining (from other mining activities such as the Charbon, Clarence, Angus Place, and Springvale Collieries) in the upper Colo River catchment could have an impact on this species with respect to water quality and hydrological pressure in this unregulated and relatively undisturbed catchment of the Hawkesbury-Nepean system.

6.4.1.2 Assessment of Significance for the giant dragonfly

(a) Is the proposed mine extension likely to have an adverse effect on the life cycle of giant dragonfly that would result in a risk of extinction of a viable local population of the species?

The giant dragonfly is typically found in permanent swamps and bogs containing some free water and open vegetation (NSW Scientific Committee 2011). The giant dragonfly is considered to be an obligate groundwater dependent mire (peat-forming wetland) dwelling species, because its breeding success is dependent on sites with a groundwater regime that provides enough surface moisture to minimise desiccation of eggs and early larval instars, supports peat land soils suitable for burrowing by larvae, and that have a water table height that allows larvae to access or extend their burrows (Benson and Baird 2012). The larval stage is unusually long, from at least 10 to 30 years. Adults emerge in October – November and fly until late January. They are poor flyers and do not readily disperse (NSW Scientific Committee 2011).

The life cycle of the giant dragonfly could be adversely affected if the construction, operation, decommissioning and/or rehabilitation phases of the Project resulted in loss or modification of its habitat or reduced the quality of the water. If fracturing of the surface watercourses occurs during mining, it could lead to drainage of habitat that could be used by the giant dragonfly. Considering the type of aquatic habitat

found within the Project Application Area, it is considered unlikely that this species would occur and therefore unlikely that any changes to the surface water features, if they did occur, would adversely affect the life cycle of this species.

(b) Is the habitat of giant dragonfly likely to be (i) removed or modified, (ii) become fragmented or isolated from other areas of habitats by the proposed mine extension and (iii), if so how important is the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species?

Giant dragonfly larvae inhabit swamps and this habitat type was not found within the Project Application Area. It is therefore considered that habitat for this species would not be removed, modified, fragmented, or isolated.

(c) Is the proposed mine extension likely to have an adverse direct or indirect effect on critical habitat?

Critical habitat for this species has not been declared under the TSC Act, although numerous swamp communities are provided legislative protection under state and federal Acts.

(d) Is the proposed mine extension consistent with the objectives or actions of a recovery plan or threat abatement plan?

There is no recovery plan or threat abatement plan for this species at present.

(e) Does the proposed mine extension constitute or is it part of a key threatening process or is it likely to result in the operation of, or increase the impact of, a key threatening process?

Longwall mining is listed as a Key Threatening Process under the TSC Act although the Project does not involve longwall mining, only panel and pillar mining. Some alteration of flow regimes may occur within Airly Creek due to discharge of operational water or retention of water for on-site use. Although unlikely, some modification of natural flow regimes could occur in the upper catchment if subsidence related fracturing occurs.

Conclusion

It is unlikely that the giant dragonfly would inhabit waterways within the Project Application Area or within the larger systems downstream as these organisms are primarily swamp dwelling during larval life stages. It is therefore unlikely that the Project would have a significant impact on known giant dragonfly populations.

6.4.1.3 Assessment of Significance for the Adam's emerald dragonfly

(a) Is the proposed mine extension likely to have an adverse effect on the life cycle of Adam's Emerald Dragonfly that would result in a risk of extinction of a viable local population of the species?

The Adam's emerald dragonfly has a predominantly aquatic life cycle, with larvae living for approximately seven years before metamorphosing into adults, which fly away from water to mature (NSW DPI 2012). Larval Adam's emerald dragonfly have been found in small creeks with gravel or sandy bottoms and narrow shaded riffle zones with moss and extensive riparian vegetation. The adults return to water to breed, with males congregating at breeding sites and guarding a territory and females laying their eggs into the water. The adults are believed to live for only a few months. This species appears to have a low natural rate of recruitment and limited dispersal abilities.

The life cycle of Adam's emerald dragonfly could be adversely affected if the construction, operation, decommissioning and/or rehabilitation phases of the Project resulted in loss or modification of its habitat or reduced the quality of the water. If fracturing of the Genowlan Creek bed does occur during mining it could lead to drainage of overlying pools, reduced flow resulting in loss of riffle zones, loss of aquatic habitat and changes in water quality. The subsidence impact assessment indicates habitat loss is unlikely to occur within Genowlan Creek (Golder Associates 2013).

(b) Is the habitat of Adam's emerald dragonfly likely to be (i) removed or modified, (ii) become fragmented or isolated from other areas of habitats by the proposed mine extension and (iii), if so how important is the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species?

Larval Adam's emerald dragonfly are aquatic and inhabit small creeks with gravel or sandy bottoms and narrow shaded riffle zones with moss and extensive riparian vegetation (NSW DPI 2012). The adults are terrestrial, but return to water to breed. Potential habitat for the larvae of this species occurs in Genowlan Creek within the Project Application Area. Potential habitat for the larval stage could be lost or become

isolated, if fracturing of the river bed in Genowlan Creek results in drainage of pools or reduced flow resulting in loss of riffle zones. The subsidence impact assessment indicates habitat loss is unlikely to occur within Genowlan Creek (Golder Associates 2013).

(c) Is the proposed mine extension likely to have an adverse direct or indirect effect on critical habitat?

Critical habitat for this species has not been declared under the *FM Act*.

(d) Is the proposed mine extension consistent with the objectives or actions of a recovery plan or threat abatement plan?

There is no recovery plan or threat abatement plan for this species at present.

(e) Does the proposed mine extension constitute or is it part of a key threatening process or is it likely to result in the operation of, or increase the impact of, a key threatening process?

Underground coal mining is not classed as a Key Threatening Process under the *FM Act* under which Adam's emerald dragonfly is listed as a threatened species. Some alteration of flow regimes may occur within Airly Creek due to discharge of mine make water or retention of water for on-site use. Although unlikely, some modification of natural flow regimes could occur in the upper catchment if subsidence related fracturing occurs.

Conclusion

It is considered possible, although unlikely that the Adam's emerald dragonfly would inhabit waterways within the Project Application Area. Genowlan Creek is considered a potential habitat for this species, although subsidence related impacts to this creek are not expected (Golder Associates 2013). It is therefore unlikely that the Project would have a significant impact on Adam's emerald dragonfly populations. There is, however, a potential that the cumulative impacts of coal mining in the upper Colo River catchment could have an impact on this species with respect to water quality and hydrological pressure in this unregulated and relatively undisturbed catchment of the Hawkesbury-Nepean system.

6.5 Potential Impacts on the Mugii Murum-ban State Conservation Area Relating to Aquatic Ecology

The main issue relating to impacts on aquatic ecology in the Mugii Murum-ban SCA involves the disturbance of top soil associated with road usage, leading to increased sedimentation and decreased water quality in creeks within the SCA. Mine operations would not contribute to increased road usage within the reserve compared to anticipated increase in recreational vehicle usage, and mine-associated traffic would be confined to sealed roads. As such traffic associated with mine operations would not impact on the condition of creeks and their biota.

The predicted area of maximum groundwater drawdown is small and confined to one area of Gap Creek, with a second, less intense, small area of groundwater drawdown expected in Genowlan Creek. As riparian vegetation in these areas is not understood to be dependent on groundwater supply, no impact on riparian vegetation is predicted (RPS Australia East 2014).

6.6 Cumulative Impacts

The term cumulative impacts refers to the total impact on the environment in a defined area that results from incremental direct and indirect impacts of the Project combined with past, present, and reasonably foreseeable future actions. This section consequently addresses the possibility of cumulative impacts on surface aquatic ecosystems arising due to multiple types of disturbances associated with the Project, expansion of existing underground mining and activities of other activities in the catchment.

6.6.1 Area Limitation and Context

The area of assessment for surface cumulative impacts has been limited to the upper Colo River catchment, defined by the Capertee River, which flows in a south-east direction to its confluence with the Wolgan to form the Colo River.

Historical mining works in the local Capertee River catchment were completed in the late 1800s to early 1900s on the northern and north-western side of Mount Airly, these being the New Hartley shale oil mine and historic torbanite mine workings around the Carinya settlement. Gold and diamond mining activities have

also been completed more recently on the southern side of Genowlan Mountain by Airly Diamond Syndicate. Mining of the western section of the Mount Airly has also been completed by Centennial Airly as part of the first stage of the Airly project.

The regional coal mining activities summarised in the Western Coalfield Water Balance (Centennial Coal 2013a) have been separated into a northern and southern study area. The Airly Mine along with two other Centennial Coal projects, Charbon Colliery and the Inglenook Exploration Project, lie within the northern study area. Airly is the only mine situated within the Colo River catchment within the northern study area. The southern study area includes numerous mines, power plants and coal works, owned by Centennial Coal and other organisations. Clarence, Angus Place and Springvale Collieries have underground operations within the Cocks River catchment and all three discharge water to this catchment. Extensive historical mining activities have also been completed around the townships of Glen Davis and Newnes within the upper Colo River catchment.

Current sand mining operations also exist within the Colo River catchment, including those near Bungleboori and Bell creeks on the Newnes Plateau (Wollongambe River catchment) and at Melong Swamp in the Wollemi Creek catchment on the eastern side of the Colo River catchment (DECCW 2008). Development of a large sand-kaolin mine has also been approved at Newnes Junction in the Wollongambe River catchment.

Mining activities that are currently operating, have historically operated or are proposed within these areas could potentially produce cumulative effects to aquatic ecosystems within the Colo River catchment and further downstream.

6.6.2 Subsidence

Subsidence related impacts at Airly are predicted to be minimal for the majority of the Project Application Area (Golder Associates 2013). As such, the Project is not expected to contribute to cumulative subsidence related impacts within the region.

6.6.3 Mine Retention and Discharge

The site water balance modelling undertaken for the Project (GHD 2014c) show that discharges from Airly Mine occur occasionally during high rainfall events. This pattern of discharge is likely to continue into the future, however discharge events may occur slightly more or less frequently, but are likely to be of a similar magnitude to those occurring at present (GHD 2014c).

Due to the relatively small anticipated discharge and retention of water at the Airly site (GHD 2014c), the cumulative hydrological and water quality impacts on the receiving waters of the Colo River are anticipated to be minor to negligible. This assessment assumes that discharge from the Project continues to occur occasionally during high rainfall events and that water quality constituent concentrations do not deviate substantially from the historical discharges.

6.6.4 Other Activities

Track management has historically been completed across the Mount Airly/Genowlan Mountain mesas and will continue or increase during operation of the Project. Recreational activities, such as four wheel driving and trail bike riding can have an impact on aquatic ecosystems, through track maintenance and wear, which can increase sediment mobilisation. These activities produce impacts on aquatic ecosystems through increased sediment mobilisation and deposition, water quality effects and degradation of habitat. Activities undertaken as part of the Project have the potential to produce cumulative impacts on receiving aquatic ecosystems in conjunction with these other activities.

7 Assessment of Potential Impacts and Mitigation Measures – Groundwater Ecosystems

Stygofauna are the only potential GDE suspected within the Project Application Area and have not been found in sampling campaigns to date. Stygofauna are threatened by activities that change the quality or quantity of groundwater, disrupt the connectivity between different aquifers and between aquifers and surface systems or remove soil pores. Aquifers of the Narrabeen Group and associated alluvial aquifers are the most likely of those within the Project Application Area to harbour stygofauna, if these are present (**Section 5.3**), although stygofauna may also be present in the Permian and Shoalhaven Group aquifers. Aquifers of the Narrabeen Group within the Project Application Area are isolated from regional aquifers of this geological unit by the regional topography (isolated mesas) and are also likely to be isolated within the unit by the stratigraphy of the unit (i.e. perched aquifers and aquicludes). Aquifers of the Narrabeen Group are therefore more likely to contain endemic species than the regionally connected aquifers (Hancock and Boulton 2008).

In this section, the potential impacts of the various phases of the Project on the stygofauna associated with groundwater systems below the Project Application Area are described in the context of the worst case scenario of significant disturbance to aquifer habitat and degradation of groundwater quality. The potential impacts described are those that could occur in the absence of appropriate mitigation measures designed to avoid, minimise or manage such impacts. The assessment of potential impacts on stygofauna arising from the Project is based on:

- > The description of the Project provided by Centennial Airly;
- > The description of the existing groundwater systems presented in Section 5;
- > The Subsidence Predictions and Impact Assessment for Airly Mine (Golder Associates, 2013);
- > Summary of the assessment of potential impacts on surface water quality (GHD 2014a); and
- > Summary of the assessment of potential impacts on groundwater recharge and discharge to streams and baseflows (GHD 2014b).

Due to the limited sampling effort and representation of subterranean habitats, and paucity of information on the distribution of stygofauna within NSW aquifers, the precautionary principle has been adopted. In the following assessment of potential impacts it has been assumed that stygofauna occur in all aquifers below the Project Application Area with the majority occurring in the alluvial and Narrabeen Group aquifers. The precautionary approach is considered justified as stygofauna have been recorded in sandstone aquifers in the region (Cardno 2013). Adoption of the precautionary approach is also in line with the philosophy of the Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities (DEC 2004). It is important to note that the assessment of potential impacts is hindered by our general lack of knowledge about stygofauna and natural changes in groundwater characteristics.

The potential impacts associated with the construction, operation, decommissioning and rehabilitation phases and measures that could be used to avoid, minimise or manage such impacts are described in each of the relevant sections below. The possibility of cumulative impacts on these assets arising due to multiple types of disturbances associated with the Project, extension of existing mining operations and activities of others in the catchment is also addressed.

7.1 Construction

The construction phase is defined by initial construction of surface infrastructure only. Construction of underground infrastructure and all mining activities related to the extraction of coal using panel and pillar extraction are covered under operational impacts in **Section 7.2**.

7.1.1 Potential Impacts – Production Bore Construction

Groundwater extraction from the Production Bore for construction use could impact on groundwater ecosystems within the Shoalhaven Group aquifer by altering groundwater hydrodynamics around the extraction point, for example through groundwater drawdown and loss of subterranean aquatic habitat. Up to

278 ML per annum is proposed to be extracted from the production bore under the Bore Licence No 10BL603503. Initial investigations during commissioning of this bore indicated that 9 L per second could be extracted from the bore at a continuous rate, this equating to approximately 283 ML per annum (AGC 1991) and therefore sufficient to meet site demand.

Groundwater drawdown impacts around the Production Bore are predicted to be localised around the pit top footprint (GHD 2014b). Groundwater in the Shoalhaven Group aquifer is considered less likely to contain stygofauna than the Alluvial and Narrabeen Group aquifers and stygofauna that are contained in this aquifer are less likely to be endemic due to the regional connectivity of this aquifer. For this reason, the impact on stygofauna associated with extraction from the Production Bore during construction activities is considered to be low.

Excavations that penetrate the surface to the groundwater table, especially where these are constructed from the surface to the resource depth (e.g. boreholes piercing the Narrabeen Group Aquifer) could also potentially interfere with groundwater hydrodynamics and subsequently impact stygofauna (if present). The impact assessment prepared for the drilling of existing bores across Genowlan Mountain (ARP06 to ARP09) considered the overall risk to the environment as negligible (RPS Australia East 2014). Considering limited further drilling is required, that existing drilling has often failed to intercept aquifers in alluvium or Triassic strata and assuming that further drilling is completed in non-sensitive areas, the risk of further damage to stygofauna from drilling during construction is considered low.

The construction of monitoring boreholes is the activity most likely to impact on any stygofauna associated with alluvial and Narrabeen Group aquifers. The potential for cross contamination between aquifers depends on the permeability of the strata and quantity of groundwater that may enter the borehole during drilling. The machinery used to construct underground roadways is likely to compact sediment, which could in turn reduce the size of interstitial spaces and voids in the underlying strata where stygofauna live, if present. Any such compaction of strata and impact on groundwater quality is likely to be minor and localised and as such is unlikely to affect stygofauna, if present.

7.1.2 Avoidance, Mitigation and Management Measures

Impacts to groundwater arising from extraction from the production bore have been assessed by groundwater specialists (GHD 2014b). Water required for use during construction works should be preferentially sourced from recycled water collected at the designated clean water surface storage as opposed to water extracted from the Production Bore. Water management at the site should follow the Water Management Plan and site water balance, once these documents have been revised.

Temporary erosion and sediment control measures such as sediment fences, sandbag weirs, temporary drains, and temporary silt traps should be installed where appropriate along roads and drilling sites to prevent sediment mobilisation and infiltration during rainfall events.

Drilling methods employed should aim to prevent shallow aquifers from draining into deeper aquifers or underground, cross contamination of aquifers differing in water quality and to minimise inflows to the bores during drilling.

7.2 Operation

The operation phase is defined by operational activities undertaken for coal extraction, processing and transport and includes potential subsidence related impacts. Mining operations currently undertaken by Centennial Coal extend into the western side of the Mount Airly mesa. The assessments below acknowledge that the limited mining operations to date have not resulted in groundwater drawdown within the Lithgow Seam or impacted overlying aquifers (RPS Aquaterra 2011).

7.2.1 Potential Impacts

7.2.1.1 Ground Movements

The extraction of coal using the proposed mining methods will result in vertical and horizontal movements of the rock and soil mass above the extracted coal seam, which may, in turn, affect groundwater systems. Physical impacts, such as fracturing of confining units, reduced or increased hydrological conductivity, tensile cracking and tensile/shear movement of near-surface strata, bending of strata and horizontal separation of bedding planes, could lead to:

- > Redirection of sub-surface flows to the surface;
- > Reduction or loss of surface expressions of groundwater, such as springs and seepage;
- > Mixing of aquifers or groundwater with surface water;
- > Changes in the characteristics of aquifer storages; and
- > Depressurisation of strata overlying extracted coal seams.

These, in turn, could lead to cross-aquifer contamination, mine water inflows and loss of groundwater resources. The chemical interaction between freshly broken rock faces and percolating groundwater could also change groundwater quality, through elevated levels of ionic constituents as outlined in **Section 6.2.2.1.2**. Sub-surface fractures resulting from subsidence can result in breaching of deep aquifers within the fractured zone and drainage of groundwater into mine workings, and could change their storage capacity.

Changes in groundwater quantity (i.e. levels, pressures and fluxes) and quality, the physical disruption of aquifers, clogging of pore spaces by compaction and mobilisation of fine sediment activated by vibrations produced by mining equipment could potentially affect the distribution of stygofauna, should they be present.

The analysis completed as part of the subsidence predictions and impact assessment indicated that the mining systems devised would result in minimal surface impacts over the majority of the Project Application Area (Golder Associates 2013). Additionally, this document notes that the mining system is designed to reduce disturbance to any overlying aquifers, particularly within the Narrabeen Group and that the predicted levels of subsidence would not result in impacts to this aquifer except for those described for the New Hartley Shale Mine Interaction Zone in **Section 6.2.2.1.1**.

Groundwater drawdown within the shallow alluvial aquifer of Gap Creek is expected to occur to a maximum depth of approximately 2.5 m (GHD 2014a). Although subsidence predictions indicate minimal impacts in other zones, fracturing of aquifers within the Narrabeen Group is possible but unlikely. If stygofauna exist in isolated groundwater within the Mount Airly and Genowlan Mountain mesas and significant disturbance of alluvial and Narrabeen Group aquifers occurred, local loss of stygofauna populations and loss of genetic diversity could also occur. Note that no stygofauna have been found in the current, albeit limited sampling undertaken and that groundwater impacts are expected to be minimal in extent and magnitude throughout the alluvial and Narrabeen Group aquifers across the majority of the Project Application Area. Hence the likelihood of loss of stygofauna populations due to groundwater drawdown in alluvial aquifers is considered unlikely.

7.2.1.2 Groundwater Drawdown

Groundwater drawdown has been summarised in the hydrogeological impact assessment summary (GHD 2014a). Gap Creek is subject to the greatest level of drawdown due to the very low depth of cover, this being approximately 2.5 m at maximum (GHD 2014a). A smaller level of groundwater drawdown is predicted around the lower section of Genowlan Creek, close to the Project Application Area boundary, this being 0.1-1 m at maximum (GHD 2014a). Groundwater drawdown around Gap and Genowlan creeks has the potential to affect stream baseflow, which has been discussed in **Section 6.2.2.1.1**.

A maximum drawdown from the Permian aquifer is predicted to be limited to small areas around Gap Creek and Genowlan Creek (GHD 2014a). It is assumed that extraction of this volume of water at this rate would not adversely impact upon the regional aquifer to an extent that causes substantial regional loss of subterranean aquatic habitat and associated impacts to stygofauna.

There is a potential for subsidence related ground movements to impact on the aquifer that feeds springs and other surface expressions of groundwater, in particular the Village Spring and Grotto Creek. These two areas are considered sensitive receptors to the potential impacts of subsidence. Disruption of aquifers that lead to redirection of groundwater flow or depressurisation of aquifers could result in a reduction or elimination of water flow to these surface expressions from groundwater sources.

There is minimal potential for groundwater drawdown to have an impact on the GDE listed in **Section 3.8**, however it is unlikely that these vegetation communities are completely dependent on groundwater, rather they may rely on groundwater on seasonally or during extended periods of drought (RPS Australia East 2014). Due to these communities having the tolerance to persist in the absence of groundwater, they are unlikely to be significantly impacted upon as a result of the Project.

7.2.1.3 Dewatering of Boreholes

Groundwater impacts associated with the extraction of water from the Production Bore have been outlined for construction impacts in **Section 7.1.1**. These are anticipated to continue throughout the operation phase.

7.2.2 Mitigation Measures

The mining zones have been designed to cause minimal impacts over the majority of the Project Application Area (Golder Associates 2013) and employs an adaptive management approach, allowing for modifications in the operational phases of the mine's life. A similar adaptive management approach will also be implemented in response to ongoing subsidence monitoring. This would ensure that further safeguards are implemented in response to any unforeseen ground subsidence related impacts on aquifers.

If the impacts of resource extraction on aquifers are greater than predicted, the mine layout and subsidence zone extents should be reviewed for applicability and modified as appropriate. A Trigger Action Response Plan for groundwater should be developed in consultation with the NSW Office of Water. If the changes in quality and quantity of groundwater and surface water that occur during or after extraction are greater than expected, an independent, external hydrogeologist should be asked to review the monitoring data and determine whether a response action needs to be implemented.

Ongoing monitoring of groundwater level and quality should be implemented to ensure any unforeseen changes are identified and mitigated as appropriate as early as possible in accordance with adaptive management practices. Stygofauna sampling should also be continued twice annually with further spatial replication, if available, for a period of two years prior to mining, after which the program could be discontinued if no fauna are detected. The requirement for 2 years of data collection is consistent with Centennial Coal Management Standard 015 on environmental baseline data collection (Centennial Coal 2012).

7.3 Decommissioning and Rehabilitation Phases

7.3.1 Potential Impacts

Decommissioning of bores used for monitoring and water extraction should be completed as soon as practicable after they are no longer required. The decommissioning of boreholes is unlikely to have any impact on stygofauna if they are permanently sealed by full grouting from the top to the bottom of the bore.

Although possible, rehabilitation works such as clearing and grading of land, spreading of topsoil, seeding and/or revegetation, application of fertilisers and control of weeds are unlikely to impact on any stygofauna that may exist in the aquifers below the Project Application Area. During rainfall events, there is a possibility of stygofauna associated with shallow aquifers being impacted by runoff laden with sediment and contaminants such as fertilisers and herbicides.

7.3.2 Avoidance, Mitigation and Management Measures

No practical mitigation measures can be recommended for impacts that may arise during the decommissioning phase.

Temporary erosion and sediment control measures such as sediment fences, sandbag weirs, temporary drains, and temporary silt traps should be installed prior to any rehabilitation construction works in the vicinity of the shallow alluvial aquifers around Genowlan and Gap creeks to prevent the input of sediment into the aquifer system during rainfall events.

The decommissioning of boreholes would be undertaken in accordance with the Minimum Construction Requirements for Water Bores in Australia (National Uniform Drillers Licensing Committee 2011). This requires all bores and test holes to be permanently sealed. The preferred decommissioning method is full grouting from the top to the bottom of the bore.

7.4 Cumulative Impacts

Cumulative impacts associated with regional disruption to groundwater may occur in response to other mining and quarrying activities within the regional groundwater resource. Other mines and quarries in the region have been outlined in **Section 6.6**. A considerable distance separates the Airly Mine from other

mines and quarries within the region and the level of extraction from the regional aquifer at Airly is low in a regional context. Cumulative impacts of this nature are therefore expected to be minimal.

Cumulative impacts associated with groundwater hydrodynamics may occur in response to groundwater extraction from the mine site in combination with other groundwater users. Cumulative groundwater impacts of this nature are covered in the groundwater impact assessment report (GHD 2014b).

8 Conclusions and Recommendations

The Project Application Area is located in a precipitous surface environment with limited surface water and a complex groundwater environment. Although the extent of the surface watercourses is limited, they are important resources for local aquatic and terrestrial fauna, providing habitat for aquatic species, water supply for terrestrial fauna and aesthetics for recreational activities. Groundwater habitats are similarly important, and have potential to support locally and regionally important stygofauna populations and diversity, although none have been identified to date.

The mine plan has been designed to minimise impacts on the surface waters of Gap and Genowlan creeks and consequently impacts on their aquatic ecology are unlikely. Similarly, predicted impacts on Alluvial and Narrabeen Group aquifers are predicted to be localised and minimal with implementation of recommended mitigation measures. Impacts to any stygofauna that may be present are unlikely because the mining plan design will avoid disturbance to the upper aquifers, the most likely location of stygofauna, if present.

The assessment of both the surface aquatic environment and groundwater aquifers within the Project Application Area is limited by the lack of data currently available. This is particularly the case for stygofauna, where sampling is limited both spatially and temporally. Continued baseline data collection is recommended to build a sufficient dataset, although low volume of water in bores sampled to date may indicate low probability of stygofauna.

The following recommendations for ongoing monitoring have been made to add value to aquatic ecology monitoring and adaptive management:

- > Continue to monitor key components of the aquatic ecosystem bi-annually in spring and autumn AUSRIVAS seasons. This will increase the baseline dataset and/or provide ongoing biological data through the construction and operation phases of the Project.
- > Visual assessment of creek beds to assess for physical damage at a frequency/intensity appropriate under the mining plan. This can be undertaken during either the aquatic ecology monitoring or the terrestrial ecology monitoring. A more extensive stygofauna sampling program is required to determine if stygofauna are present and, if so, to estimate their abundance and community composition in aquifers within the Project Application Area. This would require additional bores in areas of maximum predicted alluvial drawdown (Gap Creek and Genowlan Creek) to be sampled on multiple occasions, with several sampling events per season if seasonal changes are expected to occur (Hancock and Bolton 2008). The new bores being installed across Genowlan Mountain were reported as being dry following drilling (P. Van-Rooyen, 2013 *pers. comm.*, 25 July) and sampling from these locations may therefore not be possible during further baseline data collection. Water level should be monitored in these bores and they should be sampled for stygofauna in the event that water is available after a suitable stabilisation period.

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APPENDIX A
DETAILED METHODS DESCRIPTION

Aquatic Habitat Assessment

Aquatic habitat was assessed at each site using the NSW AUSRIVAS method described by Turak *et al.* 2004. This involved recording information on site location and access, site boundaries, topography, water level, shading, riparian vegetation, macrophytes, width and depth, water quality and land use as well as providing sketches of the site from both plan and cross-sectional views. Attributes of the habitats sampled were also recorded, including substrate description, and general habitat features, e.g. detritus cover, snags and trailing bank vegetation.

Aquatic habitat was also assessed using a modified version of the Riparian, Channel and Environmental (RCE) method (Chessman *et al.* 1997). This assessment involved evaluation and scoring of characteristics of adjacent land, the condition of riverbanks, channel and bed of the watercourse, and degree of disturbance evident at each site. The characteristics and scoring system for this process are outlined in **Appendix B**.

The quality of aquatic habitat for sustaining fish populations was classified according to the NSW DPI Policy and Guidelines for Fish Habitat Conservation and Management (2013) as described in **Section 2.2.2** and outlined in **Appendix B**. Barriers to fish passage that were observed within or near each site were also recorded.

A comprehensive photographic record of each site was made using a 2 m tall x 1 m wide T-bar. Photographs were taken near the top of the site looking downstream, near the middle of the site looking upstream, near the middle of the site looking downstream, and near the bottom of the site looking upstream. Taking standardised photographs in this way each survey is useful in understanding environmental variation within the watercourses.

Water Quality

At each site, two replicate measurements of dissolved oxygen (DO), electrical conductivity (EC), oxidation-reduction potential (ORP), pH, temperature and turbidity of the water were taken from just below the surface of the water using a fully calibrated multi-sensor water quality probe. Total carbonate alkalinity was also measured at each site using a field titration kit. The EC, DO, pH and turbidity measures were compared with the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia as outlined in **Table 9-1**.

Table 9-1 ANZECC/ARMCANZ (2000) default trigger values for south-east Australian upland rivers

Parameter	Trigger value	Comments
DO	90-110%	Daytime measurements
pH	6.5-8 units	
EC	30-350 μ S/cm	High values in NSW
Turbidity	2-25 NTU	Higher in high flow

The ANZECC/ARMCANZ (2000) trigger values are indicators of concentrations below which there is a risk of adverse biological effects. These values are not designed to be used as a definitive reference from which an environmental problem is inferred if they are exceeded. Rather, they are designed to be used in conjunction with professional judgement, to provide an initial assessment of the waterway (ANZECC/ARMCANZ 2000).

Turbidity data was adjusted to account for negative values by increasing all data by the largest negative value (-0.7). Negative values were recorded when the water sampled was clearer than the zero reference solution to which the probe was calibrated.

Only one replicate water quality measurement was collected at Grotto Creek in autumn 2013 and Torbane Creek in spring 2013 due to lack of water at the sampling sites. The mean values depicted are representative of these two values only, not the four collected for other sites.

AUSRIVAS Aquatic Macroinvertebrate Sampling

At each site, the aquatic macroinvertebrates associated with pool edge habitat were sampled using the NSW AUSRIVAS Rapid Biological Assessment method (Turak *et al.* 2004). Samples were collected with dip nets (250 μ m mesh) from a 10 m length of pool edge habitat. Each sample was rinsed from the net onto a white sorting tray from which live animals were picked using forceps and pipettes. Animals were extracted for a

minimum period of forty minutes and maximum period of one hour according to the NSW live sort protocol (Turak *et al.* 2004). Care was taken to collect cryptic and fast moving animals in addition to those that are conspicuous or slow. The animals collected at each site would be placed into a labelled jar containing 70% alcohol.

In the laboratory, each sample was sorted under a binocular microscope (at 40 X magnification); macroinvertebrates were removed and identified to family level, except for Oligochaeta and Polychaeta (to class), Ostracoda (to subclass), Nematoda and Nemertea (to phylum), Acarina (to order) and Chironomidae (to subfamily). As larvae of the threatened giant dragonfly, Adam's emerald dragonfly and Sydney hawk dragonfly could potentially occur within the Project Application Area, any dragonfly larvae collected would be identified to family level and individuals of the genus *Petaluridae*, *Gomphomacromiidae* or *Austrocorduliidae* would be identified to species level, if possible. Identifications would be confirmed using standard references. The animals belonging to each taxon identified (i.e. family or coarser taxonomic level) would be counted. In the case of AUSRIVAS samples, only up to ten animals of each family would be counted, in accordance with the AUSRIVAS protocol. Data on taxa abundance derived from the AUSRIVAS live-pick method is not appropriate for analysis and therefore, only presence/absence was reported.

The identification of a randomly chosen 10% of the samples was verified by a second experienced scientist. After confirmation of sample identifications, samples were stored in 70% alcohol in containers appropriate for long-term storage.

The data obtained from AUSRIVAS samples were analysed using the autumn or spring AUSRIVAS predictive models for edge habitats in New South Wales (Coysh *et al.* 2000). These models generate a number of indices, including:

- > OE50Taxa Score - The ratio of the number of macroinvertebrate families with a greater than 50% predicted probability of occurrence that were actually observed (i.e. collected) at a site to the number of macroinvertebrate families expected with a greater than 50 % probability of occurrence. OE50 taxa values range from 0 to 1 and provide a measure of the impairment of macroinvertebrate assemblages at each site, with values close to 0 indicating an impoverished assemblage and values close to 1 indicating that the condition of the assemblage is similar to that of the reference streams.
- > Overall Bands derived from OE50Taxa scores which indicate the level of impairment of the assemblage, with bands being graded as follows:
 - Band X = Richer invertebrate assemblage than reference condition (greater than 1.17);
 - Band A = Equivalent to reference condition (0.82 to 1.17);
 - Band B = Sites below reference condition (0.47 to 0.81);
 - Band C = Sites well below reference condition (0.12 to 0.46);
 - Band D = Impoverished (equal to or less than 0.11).

It should be noted that outputs from the AUSRIVAS model were outside the experience of the model for Torbane Creek and Dog Trap Creek sites in autumn 2013 due to high total alkalinity values (200-350 mg/L). To produce an output for these sites, total alkalinity was reduced to 200 mg/L for these sites only in all AUSRIVAS analysis.

The revised SIGNAL2 biotic index (Stream Invertebrate Grade Number Average Level) developed by Chessman (2003) was also used to determine the "environmental quality" of sites on the basis of the presence or absence of families of macroinvertebrates. This method assigns grade numbers to each macroinvertebrate family or taxa found, based largely on their responses to chemical pollutants. The sum of all grade numbers for a site was divided by the total number of families recorded at that site to calculate the SIGNAL2 index. The SIGNAL2 index therefore uses the average sensitivity of macroinvertebrate families to present a snapshot of biotic integrity at a site.

Quantitative Aquatic Macroinvertebrate Sampling

Quantitative samples of aquatic macroinvertebrates were collected using a suction sampler device described by Brooks (1993). The device isolated a 10 x 10 cm area of the stream substrata for sampling and used a pump (12 volt bilge pump, 4400 litres per hour capacity) to pass water isolated in the device through a net

(250 µm mesh size) to collect organisms, while the operator disturbed the substrata. The pump was operated continuously for one minute for each replicate sample. A sponge rubber sealed the device against the substratum, while a net cover prevented extraneous organisms being collected. Five replicate samples were collected at each site. These were collected in pool habitats at depths between approximately 10-50 cm. Stream width, depth and substratum composition were recorded on the data sheet for each sample.

In the laboratory, samples were rinsed through sieves (less than or equal to 250 µm) to remove some fine particulate matter before sorting, identification and counting under a binocular microscope (at 40 X magnification). All organisms collected were identified to family level except for Oligochaeta and Polychaeta (to class), Ostracoda (to subclass), Nematoda and Nemertea (to phylum), Acarina (to order) and Chironomidae (to subfamily). A maximum of 50 organisms were counted from each sample.

Statistical analysis of data collected will be completed following the collection of sufficient baseline and post mining data from control and impact sites. Detailed statistical analysis will be achievable when a minimum of two years' of data have been collected from both before and after mining commencement datasets.

Multivariate Statistical analysis will be performed using the statistical software package PRIMER (Plymouth Routines in Multivariate Ecological Research) version 6.1.1.1 (Clarke and Gorley 2006). Multivariate analysis that may be appropriate for comparing and visualising the data include PERMANOVA, BIOENV, SIMPER and representation of the data using Multi-Dimensional Scaling (MDS).

Fish

Fish occurring in the watercourses were sampled using a back-pack electrofisher (model LR-24 Smith-Root). Backpack electrofishing is a commonly used, non-destructive sampling method that is useful for collecting fish in shallow freshwater pools and riffles. The back-pack electrofisher was operated around the edge of pools and in riffles. Fish stunned by the electrofisher were collected in a scoop net and then placed in a container filled with aerated stream water for handling. At the end of sampling of each site, all the fish caught were identified, counted and any abnormalities noted, before being released as quickly as practicably possible. Native species were released unharmed. Non-native species were humanely disposed of, as per NSW DPI guidelines. All fish captured and their fates were reported to DPI and the Director General's Ethics Committee as per the conditions of our permit to sample fish.

Stygofauna

Stygofauna samples were collected from all available sampling wells within the Project Application Area on four occasions, May, June and December 2013 and June 2014. Other wells within the Project Application Area were either sealed, lost or under construction at the time of sampling. Wells sampled included the existing shallow piezometer (ARP05) near Gap Creek, ARP07, ARP08, ARP09, the Production Bore (AM2B) near the coal handling facility and the Old Production Bore (AM2B-1). The sampling methods differed at each bore due to different bore characteristics and are outlined below.

The Production Bore (AM2B) is fully enclosed, with water extracted via a submersible pump and discharged through a small diameter sampling hose under moderate pressure. This water was passed through a 63 µm sieve to collect the residual sample. The ARP05 bore is an open (capped) PVC bore that is sampled for water quality using a bailer. Water was extracted from this bore using the bailer and again passed through a 63 µm sieve.

The Old Production Bore (AM2B-1) was open (loosely capped) and the metal casing was badly corroded. A 150 µm stygofauna sampling net was used to collect samples from this site, this being lowered to the bottom of the water column, agitated and retrieved three times to collect a single composite sample. A coarser net was used at this site due to dense particulate matter from well corrosion clogging the net and rendering it ineffective. This technique was also utilized at ARP05, ARP07, ARP08 and ARP09.

Monthly water quality sampling is completed at the ARP05, ARP07, ARP08 and ARP09 and AM2B sites and involves purging the bore before sample collection. At the ARP05 site, this process involves removing water using a bailer until consistent pH and EC measurements are collected. The dates of this process and days prior to sampling can be found in **Table 5-2**.

The material from each sample retained on the sieve or net was washed carefully into an appropriately labelled jar and then topped-up with 100% ethyl alcohol.

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APPENDIX B
AQUATIC HABITAT CLASSIFICATION
CRITERIA

A. Modified version of the RCE inventory (Chessman *et al.* 1997).

Descriptor and category	Score	Descriptor and category	Score
1. Land use pattern beyond the immediate riparian zone		8. Riffle / pool sequence	
Undisturbed native vegetation	4	Frequent alternation of riffles and pools	4
Mixed native vegetation and pasture/exotics	3	Long pools with infrequent short riffles	3
Mainly pasture, crops or pine plantation	2	Natural channel without riffle / pool sequence	2
Urban	1	Artificial channel; no riffle / pool sequence	1
2. Width of riparian strip of woody vegetation		9. Retention devices in stream	
More than 30 m	4	Many large boulders and/or debris dams	4
Between 5 and 30 m	3	Rocks / logs present; limited damming effect	3
Less than 5 m	2	Rocks / logs present, but unstable, no damming	2
No woody vegetation	1	Stream with few or no rocks / logs	1
3. Completeness of riparian strip of woody vegetation		10. Channel sediment accumulations	
Riparian strip without breaks in vegetation	4	Little or no accumulation of loose sediments	4
Breaks at intervals of more than 50 m	3	Some gravel bars but little sand or silt	3
Breaks at intervals of 10 - 50 m	2	Bars of sand and silt common	2
Breaks at intervals of less than 10 m	1	Braiding by loose sediment	1
4. Vegetation of riparian zone within 10 m of channel		11. Stream bottom	
Native tree and shrub species	4	Mainly clean stones with obvious interstices	4
Mixed native and exotic trees and shrubs	3	Mainly stones with some cover of algae / silt	3
Exotic trees and shrubs	2	Bottom heavily silted but stable	2
Exotic grasses / weeds only	1	Bottom mainly loose and mobile sediment	1
5. Stream bank structure		12. Stream detritus	
Banks fully stabilised by trees, shrubs etc.	4	Mainly unsilted wood, bark, leaves	4
Banks firm but held mainly by grass and herbs	3	Some wood, leaves etc. with much fine detritus	3
Banks loose, partly held by sparse grass etc.	2	Mainly fine detritus mixed with sediment	2
Banks unstable, mainly loose sand or soil	1	Little or no organic detritus	1
6. Bank undercutting		13. Aquatic vegetation	
None, or restricted by tree roots	4	Little or no macrophyte or algal growth	4
Only on curves and at constrictions	3	Substantial algal growth; few macrophytes	3
Frequent along all parts of stream	2	Substantial macrophyte growth; little algae	2
Severe, bank collapses common	1	Substantial macrophyte and algal growth	1
7. Channel form			
Deep: width / depth ratio < 7:1	4		
Medium: width / depth ratio 8:1 to 15:1	3		
Shallow: width / depth ratio > 15:1	2		
Artificial: concrete or excavated channel	1		

B. NSW DPI fish habitat assessment criteria (DPI 2013).

Type	Characteristics of waterway type
Type 1 - Highly sensitive key fish habitat:	- Freshwater habitats that contain in-stream gravel beds, rocks greater than 500 mm in two dimensions, snags greater than 300 mm in diameter or three m in length, or native aquatic plants. - Any known or expected protected or threatened species habitat or area of declared 'critical habitat' under the <i>FM Act</i>. - Mound springs.
Type 2 – Moderately sensitive key fish habitat:	- Freshwater habitats and brackish wetlands, lakes and lagoons other than those defined in Type 1. - Weir pools and dams up to full supply level where the weir or dam is across a natural waterway.
Type 3 – Minimally sensitive key fish habitat may include:	- Coastal and freshwater habitats not included in Types 1 or 2. - Ephemeral aquatic habitat not supporting native aquatic or wetland vegetation.
Not considered key fish habitat ¹	- First and second order gaining streams (based on the Strahler method of stream ordering). - Farm dams on first and second order streams or unmapped gullies Agricultural and urban drains. - Urban or other artificial ponds (e.g. evaporation basins, aquaculture ponds) Sections of stream that have been concrete-lined or piped (not including a waterway crossing). - Canal estates.

¹ Note that if any of these habitats are found to be habitat of a listed threatened species, population or ecological community or 'critical habitat', then they would be considered 'key fish habitat' for the purposes of Tables 1 and 2 and these policies and guidelines

C. Classification of waterways for fish passage (NSW DPI 2013).

Classification	Characteristics of waterway type	Minimum recommended crossing type	Additional design information
Class 1 – Major fish habitat	Marine or estuarine waterway or permanently flowing or flooded freshwater waterway (e.g. river or major creek), habitat of a threatened or protected fish species or 'critical habitat'.	Bridge, arch structure or tunnel.	Bridges are preferred to arch structures.
Class 2 – Moderate fish habitat	Non-permanently flowing (intermittent) stream, creek or waterway (generally named) with clearly defined bed and banks with semi-permanent to permanent waters in pools or in connected wetland areas. Freshwater aquatic vegetation is present. Type 1 and 2 habitats present.	Bridge, arch structure, culvert or ford ¹ .	Bridges are preferred to arch structures, box culverts and fords (in that order).
Class 3 – Minimal fish habitat	Named or unnamed waterway with intermittent flow and sporadic refuge, breeding or feeding areas for aquatic fauna (e.g. fish, yabbies). Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or other Class 1 - three fish habitats.	Culvert ² or ford.	Box culverts are preferred to fords and pipe culverts (in that order).
Class 4 – Unlikely fish habitat	Waterway (generally unnamed) with intermittent flow following rain events only, little or no defined drainage channel, little or no flow or free standing water or pools post rain events (e.g. dry gullies or shallow floodplain depressions with no aquatic flora present).	Culvert ³ , causeway or ford.	Culverts and fords are preferred to causeways (in that order).

¹ High priority given to the 'High Flow Design' procedures presented for the design of these culverts—refer to the "Design Considerations" section of Fairfull and Witheridge (2003).

² Minimum culvert design using the 'Low Flow Design' procedures; however, 'High Flow Design' and 'Medium Flow Design' should be given priority where affordable—refer to the "Design Considerations" section of Fairfull and Witheridge (2003).

³ Fish friendly waterway crossing designs possibly unwarranted. Fish passage requirements should be confirmed with NSW DPI.

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APPENDIX C
WATER QUALITY DATA

A. *In-situ* water quality data from the autumn (May) 2013 sampling event.

Parameter	Unit	Gap Creek				Grotto Creek		Genowlan Creek			
Date		GAP1		GAP2		GRO1		GEN1		GEN2	
Depth (m)	m	0.4	0.2	0.1	0.2	0.1	0.15	0.1	0.4	0.3	0.2
Temperature (°C)	°C	11.83	11.53	10.99	11.19	11.41	11.64	11.76	11.56	11.76	11.83
Conductivity (µS/cm)	µS/cm	182	179	172	172	66	44	116	55	55	55
Salinity (ppt)	Ppt	0.09	0.09	0.08	0.08	0.03	0.02	0.06	0.03	0.02	0.03
pH	Units	7.02	6.8	6.81	6.91	6.38	5.93	7.87	7.32	7.18	6.97
ORP (mV)	mV	92.7	87.6	64.6	57.8	80.4	102.1	85.5	103.1	103.6	104.9
DO (%sat'n)	% sat'n	61.7	89.3	75.3	88.8	27.9	61.1	66.6	79	72.6	67.3
DO (mg/L)	mg/L	6.65	9.73	8.28	9.74	3.04	6.63	7.21	8.6	7.83	7.26
Turbidity (NTU)	ntu	1	12.3	3.1	1.2	0.1	-0.5	0.4	-0.1	0.9	0.2
Turbidity (NTU)	ntu	1	12.3	3.1	1.2	0.1	-0.5	0.4	-0.1	0.6	0.2
Turbidity (NTU)	ntu	1	12.3	3	1.2	0	-0.5	0.3	-0.1	0.6	0.1
Alkalinity (mg/L)	Units	35	35	35	35	<10	<10	<10	<10	<10	<10

A (cont.). *In-situ* water quality data from the autumn (May) 2013 sampling event.

Parameter	Unit	Torbane Creek				Airly Creek				Dog Trap Creek			
Date		TOR1		TOR2		AIR1		AIR2		DOG1		DOG2	
Depth (m)	m	0.3	0.3	0.05	0.1	0.2	1	0.3	0.1	0.1	0.1	0.15	0.25
Temperature (°C)	°C	8.78	8.22	8.48	8.61	8.23	8.09	8.69	8.88	15.7	16.34	13.23	11.53
Conductivity (µS/cm)	µS/cm	2840	2778	2855	2797	3404	3403	3420	3397	1321	1308	1262	1271
Salinity (ppt)	Ppt	1.48	1.45	1.49	1.46	1.79	1.79	1.8	1.79	0.66	0.66	0.63	0.64
pH	Units	7.69	7.75	7.65	7.81	3.68	7.65	7.59	7.44	7.65	7.47	8.02	8.05
ORP (mV)	mV	50.2	52.8	29.5	33.4	68	70.8	72.4	26.2	75.1	45	78.5	78.7
DO (%sat'n)	% sat'n	84.6	81.5	93.8	87.9	87	85.5	74.3	71	60	73.6	113	110.7
DO (mg/L)	mg/L	9.72	9.49	10.88	10.16	10.12	9.99	8.54	8.14	5.91	7.17	11.78	12.06
Turbidity (NTU)	ntu	3.8	2	1.3	0.9	1.7	4	3.6	1.3	-0.6	13.4	-0.7	-0.6

Turbidity (NTU)	ntu	3.7	1.9	1.3	0.9	1.7	3.9	3.6	1.3	-0.6	13.9	-0.7	-0.6
Turbidity (NTU)	ntu	3.7	1.8	1.3	0.9	1.7	3.7	3.6	1.3	-0.6	13.7	-0.7	-0.7
Alkalinity (mg/L)	Units	350	350	350	350	170	170	170	170	350	350	400	400

B. *In-situ* water quality data from the autumn (June) 2013 sampling event.

Parameter	Unit	Gap Creek				Grotto Creek				Genowlan Creek			
Date		GAP1	GAP2			GRO1	GRO2			GEN1	GEN2		
Depth (m)	m	0.4	0.2	0.1	0.05	0.05	0.05	0.1	0.1	0.1	0.15	0.2	0.1
Temperature (°C)	°C	11.67	10.59	10.27	10.73	12.14	11.7	10.99	11.33	11.5	11.36	11.6	11.71
Conductivity (µS/cm)	µS/cm	185	177	186	188	44	41	42	40	56	55	79	55
Salinity (ppt)	Ppt	0.09	0.08	0.09	0.09	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.03
pH	Units	6.92	6.83	7.59	7.22	5.58	5.6	6.92	6.62	7.67	7.44	8.42	7.93
ORP (mV)	mV	1.8	19.9	5	-31.5	149.2	148.2	102.3	111.3	82.9	94	77.9	78.7
DO (%sat'n)	% sat'n	54.1	50.8	76.6	68.5	28.4	65.8	36.1	61.5	73.6	75.8	67.7	62.4
DO (mg/L)	mg/L	5.82	4.78	8.56	7.59	3.05	7.13	3.93	6.7	8	8.29	7.33	6.76
Turbidity (NTU)	ntu	4	9.4	2.5	1	-0.7	-0.4	1	-0.3	-0.1	-0.1	0.1	0
Turbidity (NTU)	ntu	4	9.4	2.4	1	-0.7	-0.4	1	-0.3	-0.1	-0.1	0.1	0
Turbidity (NTU)	ntu	4	9.4	2.4	1	-0.6	-0.4	1	-0.3	-0.1	-0.1	0.1	0
Alkalinity (mg/L)	Units	35	35	35	35	<10	<10	<10	<10	<10	<10	<10	<10

B (cont.). *In-situ* water quality data from the autumn (June) 2013 sampling event.

Parameter	Unit	Torbane Creek				Airly Creek				Dog Trap Creek			
Date		TOR1	TOR2			AIR1	AIR2			DOG1	DOG2		
Depth (m)	m	0.3	0.2	0.15	0.2	0.2	0.4	0.3	0.5	0.2	0.2	0.1	0.1
Temperature (°C)	°C	9.19	9.76	10.79	10.76	7.96	7.99	8.05	8.01	14.49	15.14	11.54	11.87
Conductivity (µS/cm)	µS/cm	2601	2578	3196	3193	2787	2805	2566	2535	1301	1314	1255	1273
Salinity (ppt)	Ppt	1.35	1.34	1.68	1.68	1.45	1.46	1.33	1.31	0.65	0.66	0.63	0.64
pH	Units	6.93	7.39	7.78	7.88	6.62	6.87	6.05	6.38	7.52	7.49	6.9	7.36
ORP (mV)	mV	109.7	97.6	94.6	93.6	158.5	150.1	177.7	168.1	124.8	123.6	143.6	128.8
DO (%sat'n)	% sat'n	91.1	94.5	92.5	92.1	85.3	85	86.9	87.2	88.2	83.2	104.9	105.4
DO (mg/L)	mg/L	10.38	10.64	10.16	10.11	10.02	9.96	10.19	10.23	8.93	8.32	11.4	11.36
Turbidity (NTU)	ntu	2	-0.1	0	16.8	7	7.3	26.2	28	-0.5	-0.6	0.3	0.7

Turbidity (NTU)	ntu	1.9	-0.1	0	16.7	7.2	7.5	27.1	27.7	-0.5	-0.6	0.2	0.6
Turbidity (NTU)	ntu	1.9	-0.1	0	16.8	7.1	7.6	28.4	27.5	-0.5	-0.6	0.2	0.6
Alkalinity (mg/L)	Units	270	270	225	225	130	130	130	130	>100	>100	>100	>100

C. *In-situ* water quality data from the spring 2013 sampling event.

Parameter	Unit	Airly Creek				Torbane Creek		Dog Trap Creek		
		AIR1		AIR2		TOR2	DOG1		DOG2	
Depth	m			0.2	0.2	0.2	0.5	5	0.6	0.35
Temperature	°C	20.06	16.76	19.91	19.21	18.22	1796	17.99	19.96	20.57
Conductivity	µS/cm	2661	3000	3026	3316	3176	1375	1347	1302	1264
Salinity	Ppt	1.38	1.57	1.58	1.74	1.67	0.69	0.69	0.65	0.63
pH	Units	7.66	7.72	7.65	7.61	7.35	6.5	6.68	6.99	7.18
ORP	mV	52.2	63	31.9	43.7	28.1	-29.9	-51.7	-146	-105.2
DO	% sat'n	80.2	104.2	38.5	83.2	76.6	38.6	43.6	22.5	54.4
DO	mg/L	7.21	10.03	3.43	7.59	7.16	274	209	1.87	4.85
Turbidity	ntu	6.9	5	7.3	12.2	11.8	14	14.9	1.7	2
Turbidity	ntu	6.8	5.1	7.3	12.4	11.8	14.7	14.9	1.5	1.9
Turbidity	ntu	6.8	5.3	7.3	11.7	11.7	11.05	14.8	1.4	1.3
Alkalinity	Units	160		220					11	

Aquatic Ecology and Stygofauna
Assessment

APPENDIX D
MACROINVERTEBRATE DATA

A. Macroinvertebrate taxa found in AUSRIVAS edge samples collected at study sites on Dog Trap Creek, Genowlan Creek, Grotto Creek, Gap Creek, Torbane Creek and Airly Creek May 2013 (May 2013 sites on Dog

SITE CODE	DOG 1	DOG 2	GEN 1	GEN 2	GRO 1	GRO 2	GAP 1	GAP 2	TOR 1	TOR 2	AIR 1	AIR 2
DATE	May-13	May-13	May-13	May-13	May-13	May-13	May-13	May-13	May-13	May-13	May-13	May-13
Order or Family												
Hydridae		✓										
Dugesidae	✓											
Nematoda		✓							✓	✓		
Lymnaeidae												✓
Ancylidae							✓	✓				
Planorbidae												
Physidae	✓	✓							✓	✓	✓	✓
Hirudinidae										✓		
Oligochaeta	✓							✓	✓			✓
Cladocera		✓									✓	
Copepoda		✓				✓				✓		
Ostracoda	✓	✓		✓				✓	✓		✓	✓
Parastacidae											✓	
Araneae			✓			✓						
Hydracarina				✓	✓	✓		✓	✓	✓	✓	✓
Hypogastruridae										✓		
Caenidae		✓										
Baetidae	✓	✓									✓	
Leptophlebiidae	✓	✓	✓	✓			✓	✓				
Coenagrionidae	✓	✓						✓	✓		✓	✓
Lestidae												
Megapodagrionidae	✓	✓					✓	✓	✓	✓	✓	
Gomphidae	✓	✓								✓		

SITE CODE	DOG 1	DOG 2	GEN 1	GEN 2	GRO 1	GRO 2	GAP 1	GAP 2	TOR 1	TOR 2	AIR 1	AIR 2
DATE	May-13	May-13	May-13	May-13	May-13	May-13	May-13	May-13	May-13	May-13	May-13	May-13
Order or Family												
Aeshnidae	✓	✓									✓	✓
Telephlebiidae			✓	✓		✓	✓	✓	✓	✓		
Hemicorduliidae	✓	✓					✓	✓	✓		✓	✓
Synthemistidae				✓			✓	✓				
Gripopterygiidae				✓		✓						
Hydrometridae												
Veliidae		✓			✓	✓		✓				
Nepidae		✓										
Corixidae		✓			✓				✓	✓	✓	✓
Notonectidae	✓	✓					✓	✓	✓	✓		✓
Corydalidae	✓	✓		✓	✓	✓	✓	✓		✓		
Halplidae									✓			
Dytiscidae	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Gyrinidae	✓		✓	✓								
Hydrochidae							✓					
Hydrophilidae	✓	✓				✓			✓	✓		✓
Hydraenidae		✓	✓	✓	✓	✓						
Scirtidae				✓	✓							
Psephenidae												
Nannochoristidae												
Dixidae	✓						✓					
Culicidae	✓											
Chironomidae/Chironominae	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Chironomidae/Orthoclaadiinae	✓	✓	✓	✓			✓			✓		
Chironomidae/Tanypodinae	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	

SITE CODE	DOG 1	DOG 2	GEN 1	GEN 2	GRO 1	GRO 2	GAP 1	GAP 2	TOR 1	TOR 2	AIR 1	AIR 2
DATE	May-13	May-13	May-13	May-13	May-13	May-13	May-13	May-13	May-13	May-13	May-13	May-13
Order or Family												
Ceratopogonidae	✓	✓			✓		✓	✓	✓	✓		
Tipulidae		✓	✓		✓	✓			✓	✓	✓	
Athericidae			✓	✓				✓				
Stratiomyidae	✓	✓								✓	✓	
Empididae			✓									
Hydrobiosidae		✓		✓								
Hydroptilidae	✓	✓		✓			✓	✓	✓	✓		
Polycentropodidae				✓								
Ecnomidae	✓	✓		✓				✓	✓			
Helicopsychidae				✓								
Philorheithridae			✓		✓							
Calamoceratidae	✓	✓										
Leptoceridae	✓	✓	✓	✓	✓	✓	✓	✓				
Pyrilidae	✓					✓						
Taxa Richness	29	33	14	21	13	15	17	21	20	21	15	12
SIGNAL2	3.69	3.93	5.31	5.55	4.75	4.69	4.50	4.33	3.47	3.84	3.75	2.55
OE50	0.87	1.13	0.51	0.73	0.58	0.58	0.65	0.62	0.52	0.7	0.35	0.35
Band	A	A	B	B	B	B	B	B	B	B	C	C

Macroinvertebrate taxa found in AUSRIVAS edge samples collected at study sites on Dog Trap Creek, Genowlan Creek, Grotto Creek, Gap Creek, Torbane Creek and Airly Creek June 2013 (✓ indicates present)

SITE CODE	DOG 1	DOG 2	GEN 1	GEN 2	GRO 1	GRO 2	GAP 1	GAP 2	TOR 1	TOR 2	AIR 1	AIR 2
DATE	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13
Order or Family												
Hydridae												
Dugesidae		✓				✓						
Nematoda												
Lymnaeidae	✓											
Ancylidae							✓					
Planorbidae										✓	✓	
Physidae	✓	✓								✓		
Hirudinidae												
Oligochaeta	✓				✓	✓	✓	✓				
Cladocera												
Copepoda		✓				✓						
Ostracoda		✓					✓		✓	✓		✓
Parastacidae											✓	
Araneae	✓											
Hydracarina	✓				✓	✓			✓		✓	
Hypogastruridae												
Caenidae	✓	✓										
Baetidae	✓	✓										
Leptophlebiidae	✓	✓	✓	✓	✓		✓	✓				
Coenagrionidae	✓	✓							✓	✓		✓
Lestidae		✓										
Megapodagrionidae	✓						✓	✓		✓	✓	
Gomphidae	✓	✓								✓		

SITE CODE	DOG 1	DOG 2	GEN 1	GEN 2	GRO 1	GRO 2	GAP 1	GAP 2	TOR 1	TOR 2	AIR 1	AIR 2
DATE	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13
Order or Family												
Aeshnidae	✓								✓		✓	✓
Telephlebiidae			✓		✓	✓	✓	✓		✓		
Hemicorduliidae	✓	✓							✓		✓	
Synthemistidae			✓	✓					✓			
Gripopterygiidae												
Hydrometridae												✓
Veliidae			✓							✓		✓
Nepidae												
Corixidae	✓	✓							✓	✓	✓	✓
Notonectidae	✓	✓	✓	✓			✓	✓	✓	✓		✓
Corydalidae		✓	✓	✓	✓	✓	✓	✓				
Haliplidae												
Dytiscidae	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Gyrinidae	✓											
Hydrochidae									✓			
Hydrophilidae		✓						✓				✓
Hydraenidae					✓	✓			✓			✓
Scirtidae			✓	✓	✓	✓						
Psephenidae			✓									
Nannochoristidae					✓	✓						
Dixidae				✓			✓					
Culicidae	✓											
Chironomidae/Chironominae	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Chironomidae/Orthoclaadiinae		✓		✓	✓				✓	✓	✓	
Chironomidae/Tanypodinae	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

SITE CODE	DOG 1	DOG 2	GEN 1	GEN 2	GRO 1	GRO 2	GAP 1	GAP 2	TOR 1	TOR 2	AIR 1	AIR 2
DATE	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13
Order or Family												
Ceratopogonidae	✓	✓					✓	✓	✓	✓		
Tipulidae				✓	✓	✓						✓
Athericidae			✓	✓		✓						
Stratiomyidae	✓										✓	✓
Empididae												
Hydrobiosidae												
Hydroptilidae	✓		✓	✓		✓	✓					
Polycentropodidae				✓								
Ecnomidae	✓									✓		
Helicopsychidae			✓	✓			✓					
Philorheithridae			✓									
Calamoceratidae	✓	✓				✓						
Leptoceridae	✓	✓	✓	✓	✓	✓	✓	✓				✓
Pyralidae	✓					✓						
Taxa Richness	27	21	16	16	14	18	16	12	15	16	12	15
SIGNAL2	3.65	3.79	5.12	4.94	5.29	5.06	4.75	4.23	3.29	3.40	3.73	3.00
OE50	0.87	0.96	0.56	0.64	0.58	0.51	0.51	0.51	0.52	0.7	0.45	0.82
Band	A	A	B	B	B	B	B	B	B	B	C	A

Numbers of each macroinvertebrate taxon found in quantitative suction samples collected at Airly Creek sites

SITE	AIR 1	AIR 1	AIR 1	AIR 1	AIR 1	AIR 2	AIR 2	AIR 2	AIR 2	AIR 2
DATE	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13
Replicate	1	2	3	4	5	1	2	3	4	5
Order or Family										
Hydridae	0	3	0	0	2	3	2	0	2	8
Nemertea	7	19	1	4	14	5	4	9	36	13
Nematoda	1	7	1	6	3	2	2	1	8	14
Ancylidae	0	0	0	0	0	0	0	0	0	0
Planorbidae	5	2	0	1	19	18	2	0	0	0
Physidae	0	1	11	0	0	7	0	1	1	1
Glossiphoniidae	0	0	0	0	0	0	0	0	0	0
Oligochaeta	0	16	22	12	5	28	6	50	15	50
Cladocera	0	0	0	0	0	0	0	0	0	0
Copepoda	0	2	0	1	6	14	9	1	1	1
Ostracoda	5	5	22	4	11	25	7	10	50	16
Hydracarina	2	2	1	2	8	0	1	0	0	6
Hypogastruridae	2	0	0	0	0	1	1	0	1	1
Entomobryidae	0	0	0	0	0	0	0	0	1	0
Caenidae	0	0	0	0	0	0	0	0	0	0
Baetidae	0	2	0	0	0	0	0	0	0	0
Leptophlebiidae	0	0	0	0	0	0	0	0	0	0
Coenagrionidae	0	0	0	0	0	1	0	0	0	0
Megapodagrionidae	0	0	0	0	0	2	0	0	0	0
Gomphidae	0	0	0	0	0	1	0	0	0	0
Hemicorduliidae	0	0	0	0	1	2	1	1	0	1
Corixidae	0	0	2	0	1	0	0	0	0	0
Notonectidae	0	0	0	0	0	0	0	0	0	0

SITE	AIR 1	AIR 1	AIR 1	AIR 1	AIR 1	AIR 2	AIR 2	AIR 2	AIR 2	AIR 2
DATE	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13
Replicate	1	2	3	4	5	1	2	3	4	5
Order or Family										
Corydalidae	0	0	0	0	1	0	0	0	0	0
Sialidae	0	0	0	0	0	0	0	0	0	0
Dytiscidae	5	4	6	4	4	1	7	3	3	3
Hydrophilidae	0	0	0	0	0	0	0	0	0	0
Scirtidae	0	0	0	0	0	0	0	0	0	0
Tanyderidae	0	0	0	0	0	0	0	0	0	0
Chironomidae/Chironominae	7	5	14	42	37	26	50	10	7	9
Chironomidae/Orthocladiinae	1	0	0	0	0	1	0	0	0	4
Chironomidae/Tanypodinae	0	5	2	5	4	7	0	1	5	0
Ceratopogonidae	2	1	0	2	4	0	0	0	2	4
Tipulidae	0	0	0	0	0	0	0	0	0	0
Stratiomyidae	0	0	0	0	0	0	0	0	0	0
Empididae	0	0	1	0	0	0	0	0	0	0
Dolichopodidae	0	0	0	0	0	0	0	0	0	0
Hydroptilidae	0	0	0	0	0	0	1	0	0	0
Ecnomidae	0	0	0	0	0	0	0	1	3	0
Calamoceratidae	0	0	0	0	0	0	0	0	0	0
Leptoceridae	0	0	0	0	0	0	0	0	0	0
Taxa Diversity	10	14	11	11	15	17	13	11	14	14
Total Abundance	37	74	83	83	120	144	93	88	135	131

Numbers of each macroinvertebrate taxon found in quantitative suction samples collected at Torbane Creek sites

SITE	TOR 1	TOR 1	TOR 1	TOR 1	TOR 1	TOR 2	TOR 2	TOR 2	TOR 2	TOR 2
DATE	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13
Replicate	1	2	3	4	5	1	2	3	4	5
Order or Family										
Hydridae	4	2	3	22	1	3	2	1	6	0
Nemertea	1	0	1	2	2	8	5	7	0	1
Nematoda	7	18	13	32	8	4	1	3	3	4
Ancylidae	0	0	0	0	0	0	0	0	0	0
Planorbidae	0	0	0	0	0	0	0	5	0	2
Physidae	0	1	0	2	1	8	4	0	3	0
Glossiphoniidae	0	0	0	0	0	0	0	0	0	0
Oligochaeta	50	30	50	50	50	6	18	6	0	5
Cladocera	0	0	0	0	0	0	0	0	0	0
Copepoda	0	2	0	3	4	5	6	7	6	1
Ostracoda	1	7	7	19	0	6	50	10	3	3
Hydracarina	0	1	0	0	0	1	0	0	0	0
Hypogastruridae	0	0	1	1	1	1	1	1	1	1
+Entomobryidae	0	0	0	0	0	0	0	0	0	0
Caenidae	0	0	0	2	0	0	0	0	0	0
Baetidae	0	0	0	0	0	0	0	0	0	0
Leptophlebiidae	0	0	0	0	0	0	0	0	0	0
Coenagrionidae	0	0	0	0	0	0	0	1	0	0
Megapodagrionidae	0	1	0	1	0	1	0	0	2	1
Gomphidae	0	0	0	0	0	0	0	0	0	0
Hemicorduliidae	0	2	1	2	0	4	0	0	2	0
Corixidae	0	0	0	0	0	1	0	0	0	0
Notonectidae	0	0	0	0	0	0	0	0	0	0

SITE	TOR 1	TOR 1	TOR 1	TOR 1	TOR 1	TOR 2	TOR 2	TOR 2	TOR 2	TOR 2
DATE	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13
Replicate	1	2	3	4	5	1	2	3	4	5
Order or Family										
Corydalidae	0	0	0	0	0	1	1	1	0	0
Sialidae	0	0	0	0	0	0	0	0	0	0
Dytiscidae	0	0	0	2	1	9	0	3	2	1
Hydrophilidae	0	0	0	0	0	1	0	2	2	1
Scirtidae	0	0	0	0	0	1	0	0	0	0
Tanyderidae	0	0	0	0	0	1	0	0	0	0
Chironomidae/Chironominae	14	50	43	48	13	41	37	36	50	40
Chironomidae/Orthocladiinae	1	0	0	0	2	7	23	0	6	1
Chironomidae/Tanypodinae	15	50	50	50	34	32	17	29	50	19
Ceratopogonidae	0	33	21	50	36	50	45	39	30	32
Tipulidae	1	0	0	0	0	0	0	0	0	0
Stratiomyidae	0	0	0	0	0	1	0	0	0	0
Empididae	0	0	1	1	0	0	0	1	1	0
Dolichopodidae	0	0	0	0	0	1	0	0	0	0
Hydroptilidae	0	0	0	1	0	2	1	0	4	0
Ecnomidae	0	0	0	0	0	4	4	1	0	1
Calamoceratidae	12	0	0	0	0	0	0	0	0	0
Leptoceridae	0	0	0	0	0	0	0	0	1	0
Taxa Diversity	10	12	11	17	12	25	15	17	17	15
Total Abundance	106	197	191	288	153	199	215	153	172	113

Numbers of each macroinvertebrate taxon found in quantitative suction samples collected at Dog Trap Creek sites

SITE	DOG 1	DOG 1	DOG 1	DOG 1	DOG 1	DOG 2	DOG 2	DOG 2	DOG 2	DOG 2
DATE	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13
Replicate	1	2	3	4	5	1	2	3	4	5
Order or Family										
Hydridae	0	0	0	0	0	0	0	0	0	0
Nemertea	0	0	0	1	0	0	0	0	0	1
Nematoda	1	1	1	1	1	0	0	0	0	0
Ancylidae	19	14	11	14	2	0	0	0	0	0
Planorbidae	0	0	0	0	0	0	0	0	0	0
Physidae	0	13	6	2	2	0	2	1	0	1
Glossiphoniidae	0	0	0	0	1	1	0	0	0	0
Oligochaeta	0	5	0	2	1	1	1	0	0	0
Cladocera	0	0	0	0	0	1	0	1	0	1
Copepoda	0	3	8	3	2	4	0	8	2	3
Ostracoda	2	4	2	2	3	2	0	0	1	0
Hydracarina	0	0	0	0	0	0	0	0	0	0
Hypogastruridae	0	0	0	0	0	0	0	0	0	0
Entomobryidae	0	0	0	0	0	0	0	0	0	0
Caenidae	1	2	4	7	2	7	3	10	1	14
Baetidae	20	10	20	9	9	3	5	13	5	35
Leptophlebiidae	43	43	36	50	22	15	7	9	8	18
Coenagrionidae	7	9	15	8	7	2	1	1	4	4
Megapodagrionidae	1	1	2	2	2	0	0	0	0	0
Gomphidae	1	0	1	1	1	3	2	6	3	28
Hemicorduliidae	0	5	6	6	2	4	0	2	0	10
Corixidae	0	0	0	0	0	0	0	0	0	0
Notonectidae	0	0	0	0	0	0	0	0	0	2

SITE	DOG 1	DOG 1	DOG 1	DOG 1	DOG 1	DOG 2	DOG 2	DOG 2	DOG 2	DOG 2
DATE	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13	Jun-13
Replicate	1	2	3	4	5	1	2	3	4	5
Order or Family										
Corydalidae	0	0	0	1	0	0	0	0	0	1
Sialidae	1	0	0	0	0	0	0	0	0	0
Dytiscidae	0	1	0	0	2	0	0	2	2	4
Hydrophilidae	15	10	17	15	6	1	4	4	2	17
Scirtidae	0	0	0	0	0	0	0	0	0	0
Tanyderidae	0	0	0	0	0	0	0	0	0	0
Chironomidae/Chironominae	11	50	24	23	50	7	5	8	1	11
Chironomidae/Orthocladiinae	0	0	0	1	0	0	1	0	0	0
Chironomidae/Tanypodinae	32	50	50	50	50	12	4	4	3	40
Ceratopogonidae	0	4	1	0	0	1	0	1	0	0
Tipulidae	0	0	0	0	0	0	1	0	0	0
Stratiomyidae	0	0	0	0	0	0	0	0	0	0
Empididae	0	0	0	0	0	0	0	0	0	0
Dolichopodidae	0	0	0	0	0	0	0	0	0	0
Hydroptilidae	4	10	10	1	4	2	0	0	0	2
Ecnomidae	1	1	0	3	1	2	1	0	1	5
Calamoceratidae	1	2	0	5	4	5	1	8	1	10
Leptoceridae	3	4	1	4	8	1	0	0	0	2
Taxa Diversity	17	21	18	23	22	19	14	15	13	20
Total Abundance	163	242	215	211	182	74	38	78	34	209

APPENDIX E

TEMPERATE HIGHLAND SWAMPS LOCATION INFORMATION

Temperate Highland Peat Swamps on Sandstone

The following table outlines the extent of this threatened ecological community

Name	Altitude (m)	Location		Land Tenure
		Latitude	Longitude	
Blue Mountains Swamps	800-950	Blue Mountains - based around 33°40'	150°30'	Freehold; National Park
Butler's Swamp	620	34°31'30"	150°35'20"	Crown land; Freehold
Jackson's Bog (Mila Swamp)	780	37°07'	149°09'	Freehold; State Forest
Newnes Plateau Swamps	1000-1100	33°20' to 33°23'	150°12' to 150°15'	State Forest
Paddy's River Swamps (Hanging Rock, Mundego, Long and Stingray Swamps)	600-650	34°36' to 34°41'	150°07' to 150°15'	Flora Reserve; Freehold; State Forest
Wildes Meadow Swamp	670	34°37'30"	150°30'30"	Crown land
Wingecaribee Swamp	680	34°34'	150°30'	Crown land; Freehold

