Longwalls 20 and 21 Subsidence Management Plan

Aquatic Flora and Fauna Assessment

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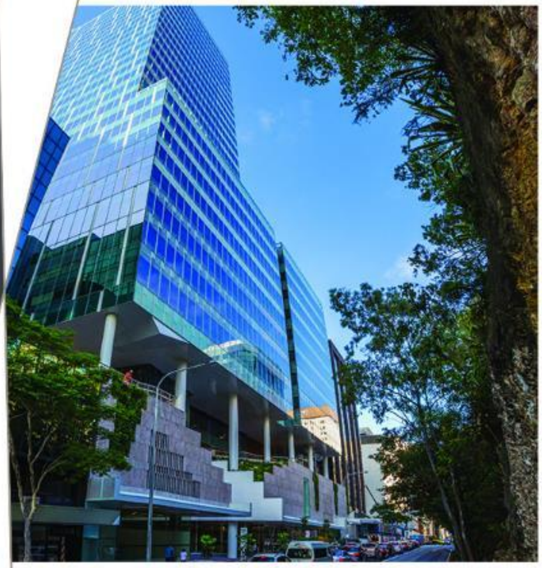

Prepared for
Illawarra Coal Holdings Pty Ltd

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Executive Summary

Introduction

South32 – Illawarra Coal (South32) plans to extract coal from two additional Longwalls 20 and 21, in DA3B of the Dendrobium Mine Area (the Project). Longwall 20 would be located between Wongawilli Creek and Donalds Castle Creek and Longwall 21 to the east of Wongawilli Creek, north of DA3B Longwall 9 and south of Fire Trail 6A. This Aquatic Flora and Fauna Assessment (AFFA) has been prepared to support the Subsidence Management Plan (SMP) for Longwalls 20 and 21. The AFFA focuses on the sections of Wongawilli Creek, Donalds Castle Creek and their drainage lines that may be affected by mining induced ground movements due to longwall extraction. Potential impacts to aquatic flora and fauna are associated with subsidence and fracturing of bedrock resulting in water diversion, groundwater depressurisation and consequent loss of aquatic habitat and biota in watercourses. Lake Avon and Lake Cordeaux are located some distance away from the longwalls and would not be affected by extraction. The AFFA includes:

> A review and synthesis of existing information on the aquatic flora and fauna of Wongawilli Creek, Donalds Castle Creek and their drainage lines in the Study Area (area within 600 metres (m) of Longwalls 20 and 21);

> A field survey in sections of Donalds Castle Creek and Wongawilli Creek and their drainage lines within the Study Area to provide detailed local information on aquatic habitat and biota present;

> Assessment of the potential impacts on aquatic flora and fauna (including threatened species) arising directly and indirectly from the proposed mining; and

> Recommendations on impact mitigation measures and monitoring for inclusion within the SMP.

Existing Environment

Aquatic habitat in Wongawilli Creek, Donalds Castle Creek and their drainage lines within the Study Area for Longwalls 20 and 21 is largely undisturbed. Wongawilli Creek provides substantial aquatic habitat in the form of pools (up to 100 long) with important fish habitat such as large boulders and wood debris. Stream banks consisted mainly of well vegetated sandy soil with little erosion or undercutting evident and extensive overhanging vegetation along the stream margin. The main channel of Donalds Castle Creek consists of a series of relatively small permanent pools with sand substratum and some areas of bedrock, boulder and gravel. These pools are connected by narrow sandy channels with small sections of gravel riffles, sandstone rockbars and small cascades up to 1 m in height. Aquatic habitat in drainage lines include small, disconnected and ephemeral pools with limited habitat potential for aquatic flora and fauna. Wongawilli Creek, but not Donald Castle Creek and drainage lines, is mapped as Key Fish Habitat. Suitable habitat for three threatened species, Adams emerald dragonfly (*Archaeophya adamsi*), Sydney hawk dragonfly (*Austrocordulia leonardi*) and Macquarie perch (*Macquaria australasica*) occurs in the Study Area, however, none were detected in the current or previous surveys. Macquarie perch are potentially unable to access Wongawilli Creek in the Study Area due to the presence of natural barriers to fish passage downstream.

Impact Assessment

The mine has been designed to minimise potential impacts to natural features, including watercourses. This includes setting the longwalls back from Wongawilli Creek by 125 m and from Donalds Castle Creek by 490 m. The mine has also been designed to reduce the rate of rockbar fracture resulting in flow diversion in Wongawilli and Donalds Castle creeks to less than 10 %. The assessment of potential impacts on aquatic ecology arising from the extraction of Longwalls 20 and 21 is based on the maximum residual predicted ground movements (including subsidence) and their predicted impacts on physical structure, water availability and water quality characteristics of the above watercourses. Based on these predictions, it is expected that a reduction in the amount and connectivity of aquatic habitat in Wongawilli Creek and drainage lines would occur due to fracturing of bedrock. An increase in the number of zero flow days in Wongawilli and Donalds Castle creeks following mining induced groundwater depressurisation is also expected to occur and would also result in some reduction in the connectivity of aquatic habitat. Such changes are expected to also impact aquatic biota via reduction in the amount of available habitat and due to habitat fragmentation. Although impacts to aquatic habitat and biota would be severe at the scale of individual pools in isolation, impacts associated with extraction of Longwalls 20 and 21 would be relatively minimal at the scale of individual watercourses and in the context of the upper Avon River and Cordeaux River catchments.

Predictions indicate that although the risk of rockbar fracturing in Wongawilli Creek is low (less than 10 %), it is expected that some minor impacts to rockbars in the section of creek within the Study Area could occur and result in drainage of the associated upstream pool. Associated pools are 3 m to 100 m long with the total length of pool and total watercourse habitat within the Study Area of 365 m and 2,800 m, respectively. The drainage of a smaller pool represents a relatively minimal impact to aquatic habitat and associated biota, while the potential drainage of the largest pool represents a relatively greater impact to pool habitat and associated biota in the section of creek within the Study Area. It is noted that submerged rockbars that have not been mapped may limit pool drainage and habitat loss, if present. There is likely to be a reduction in longitudinal connectivity resulting from the full or partial drainage of pools. This should only be temporary and occur during low flow events. Fracturing and flow diversions are also predicted to occur in drainage lines. However, the aquatic habitat provided by these watercourses is very limited (in terms of permanence and quality) and also abundant in the Study Area and Dendrobium Mine Area. Thus, associated impacts to aquatic habitat and biota would be minimal at the scale of the Study Area. Fracturing is not predicted to occur in Donalds Castle Creek and so impacts to aquatic habitat and biota would not be expected.

Mining induced groundwater depressurisation is expected to reduce baseflow to creeks and result in an increase in the number of zero flow days in Wongawilli Creek from 10 % (natural condition) to between 12 % and 15 %. On Donalds Castle Creek it is predicted to increase from 2 % to 3 % to up to 5 %. On average, these equate to an additional 17 days and 11 days of zero flow, respectively, on these watercourses. These are cumulative impacts associated with extraction of DA3B longwalls and Longwalls 20 and 21. These changes represent relatively minimal changes to natural conditions on these watercourses. Assuming flow returns soon after, reductions in habitat availability and connectivity would be temporary and are not expected to result in substantial impacts to aquatic biota. Impacts to water quality due to mining of Longwalls 20 and 21 are expected to be minor in stream reaches within subsidence affected areas. This prediction is consistent with changes in water quality observed during extraction of DA3B longwalls. Thus, associated risks to aquatic habitat and biota is expected to be low.

Although in isolation impacts due to extraction of Longwalls 20 and 21 represent a relatively minimal impact to these watercourses, cumulative impacts associated with existing impacts and habitat loss, particularly upstream in Wongawilli Creek, should be considered. This has occurred following reductions in baseflow due to mining induced groundwater depressurisation (albeit manifesting during periods of low rainfall only) associated with mining in Dendrobium DA3B. By May 2018 approximately 1.4 km of Wongawilli Creek (representing about 10 % of its 12 km total length) had been affected by reduction in flow and pool drainage associated with extraction of coal at Dendrobium Mine. Although these impacts may only be evident during low rainfall, with flow and pool water levels returning after rainfall periods, even a temporary loss of habitat and the loss of connectively of remaining habitat here would likely have resulted in a reduction in the population size of aquatic biota in Wongawilli Creek. Extraction of Longwalls 20 and 21 would exacerbate the impacts due to groundwater drawdown currently experienced in Wongawilli Creek. The predicted increases in zero flow days was based on the cumulative effect of DA3B longwalls and Longwalls 20 and 21 and applicable to flow at the gauging station located approximately 1 km downstream of the Study Area near Fire Road 6, it is unclear how this may vary along sections of watercourse, in particular Wongawilli Creek. The fewer longwalls that would be extracted compared with the number in DA3B and the relatively small predicted increase in number of zero flow days that would occur suggests that impacts associated with extraction of Longwalls 20 and 21 should be less severe than those currently and expected to be experienced in DA3B,

Recommendations and Management

Potential impacts on aquatic habitat and biota within the Study Area would be managed by:

> Impact minimisation, including setback of longwalls from Wongawilli Creek and Donalds Castle Creek and identification of triggers that would prompt surveys to assess any impacts on aquatic habitats and their biota identified during and after extraction of the longwalls;

> Monitoring of aquatic habitat and biota during and after mining to determine the nature and extent of any subsidence-induced impacts on aquatic ecology and responses of aquatic ecosystems to any remediation or management works implemented;

> Undertaking additional aquatic ecology studies in response to specific impacts on water quality and availability of aquatic habitats within the watercourses; and

> Implementation of contingent measures such as review of mine layout and appropriate offset distances from creeks, watercourse remediation measures, appropriate control measures to limit deposition of any eroded sediment into the watercourses, and appropriate offset and compensatory measures.

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1 Introduction

1.1 Background

South32 – Illawarra Coal (South32) is using longwall mining to extract coal from the Dendrobium Coal Mine, situated near Cordeaux approximately 20 km west of Wollongong. Consent for the mine, granted in November 2001, allows extraction from three longwall domains, known as Dendrobium Areas (DA) DA1, DA2 and DA3. DA3, situated to the west of Lake Cordeaux, is currently being mined. A modification to the mine layout of DA3 approved in December 2008 allowed the mine to be expanded and Area 3 to be sub-divided into three smaller domains, DA3A, DA3B and DA3C. DA3A currently comprises Longwalls 6, 7, 8 and 19, which are situated between Wongawilli and Sandy Creeks. Longwalls 6, 7 and 8 were completed from 2010 to 2012. The Subsidence Management Plan (SMP) for DA3B was submitted in 2012 (BHPBIC 2012). Mining of DA3B Longwalls 9 to 18 commenced in 2013 and Longwall 15 in DA3B is currently being extracted.

South32 are proposing to extract coal from two further longwalls, Longwalls 20 and 21, in DA3 (the Project). Longwall 20 would be located between Wongawilli Creek and Donalds Castle Creek and Longwall 21 to the east of Wongawilli Creek, north of DA3B Longwall 9 and south of Fire Trail 6A. Longwall mining is the most common form of coal mining in the Illawarra Region. Longwall mining contrasts with open-cut mining, with the former being undertaken by extracting coal accessed via tunnels. The coal seams are progressively accessed and extracted by longwalls. Longwall mining can affect the surface, principally by the effects of subsidence. Physical impacts such as subsidence induced fracturing of creek beds can cause diversions of surface and sub-surface flows, drainage of pools and increases in groundwater inflows.

The Dendrobium Mine consent conditions require that prior to carrying out any underground mining operations that could cause subsidence a SMP should be prepared and approved by the Department of Planning and Environment (DPE). The overall objective of the SMP is to manage any impacts to watercourses, other natural features and built features associated with mine-induced subsidence.

South32 has commissioned Cardno (formerly trading as Cardno Ecology Lab and The Ecology Lab Pty Ltd) to undertake the Aquatic Flora and Fauna Assessment (AFFA) to support the SMP for Longwalls 20 and 21.

1.2 Scope of Works

The work undertaken for the AFFA by Cardno included the following:

> Desktop review and compilation of existing information on aquatic habitat, vegetation and macroinvertebrates, fish, and any listed threatened species and populations, in the Donalds Castle Creek and Wongawilli Creek catchments adjacent to Longwalls 20 and 21. This information was obtained from investigations that have been underway for several years, as part of existing mining operations in DA3B.

> A field survey in sections of Donalds Castle Creek and Wongawilli Creek and their drainage lines adjacent to proposed Longwalls 20 and 21. The aim was to obtain further local information on aquatic habitat and biota that may be affected by any subsidence associated with extraction of these longwalls and place it in context of the wider Dendrobium Mine and Metropolitan Catchment Areas.

> Assessment of the potential impacts of the Project on aquatic ecology, including threatened species, and any cumulative impacts, in Donalds Castle Creek and Wongawilli Creek and their tributaries that may experience impacts associated with potential mining subsidence.

> Provide recommendations on measures to avoid and mitigate potential impacts on aquatic ecology and the form and content of the requisite aquatic ecology monitoring plan for these longwalls. This would be implemented to determine the nature and extent of any subsidence induced impacts on aquatic ecology and assess the response of aquatic ecology to any subsequent remediation and management works.

2 Relevant Management, Policies and Guidelines

2.1 Dendrobium Mine Consent

Schedule 3 of the Dendrobium Mine consent includes several conditions concerning management of potential environmental impacts associated with mine subsidence. These include preparation of a SMP that integrates monitoring and management of potential impacts to natural (e.g. watercourses, swamps), built (e.g. electrical, communications and other infrastructure) and cultural (e.g. aboriginal heritage) features of the environment. With relevance to aquatic ecology the SMP should:

> Identify and assess the significance of all natural features located within 600 m of the edge of secondary extraction;

> Include a minimum of two years of baseline data, collected at appropriate frequency and scale, for all significant natural features;

> Address third and higher order streams individually and address first and second order streams collectively;

> Include a detailed subsidence impact assessment, clearly setting out all predicted subsidence effects, subsidence impacts and environmental consequences;

> Describe a monitoring and reporting program addressing aquatic flora and fauna including any threatened aquatic species and their habitats and ecosystem function; and

> Provide a management plan for avoiding, minimising, mitigating and remediating impacts on watercourses, including a contingency plan focusing on measures for remediating both predicted and unpredicted impacts.

Several conditions also relate specifically to swamps, these are considered by other specialists.

Appendix 4 of the Dendrobium Mine consent also provides a statement of commitments relating to longwall layouts, impact monitoring, avoidance, mitigation and any rehabilitation in DA3. These include a commitment to avoid significant impact to major natural features such as creeks, and a commitment to avoid mining under Wongawilli Creek to minimise the potential for major fracturing and loss of surface flow and any associated impacts to aquatic ecology. Pre, during and post mining subsidence impact monitoring of aquatic flora and fauna will also be undertaken in accordance with the approved SMP.

NSW Resources and Energy (formerly the Division of Resources and Energy (DMR)) has prepared guidelines for SMP (now known as Extraction Plan (EP)) applications (DMR 2003). A key component of the application is characterisation of each of the identified surface and sub-surface features that may be affected by the proposed mining. Results of a minimum of one-year pre-mining base-line monitoring of relevant environmental values in areas of environmental sensitivity that may be affected by the proposed mining with reference to applicable guidelines published by the NSW Government should also be included. The applicant should provide the results of a risk assessment, where appropriate, with an emphasis on identifying those subsidence impacts with high-risk levels and/or potentially severe consequences. Areas requiring attention by the applicant when conducting risk assessment include potential subsidence impacts on:

> Wetlands, swamps and water related ecosystems;

> Significant watercourses including surface flows, water quantity and quality and ecological integrity; and

> Threatened and protected species.

2.2 Fisheries Management Act 1994

The *Fisheries Management Act 1994* (FM Act) contains provisions for the conservation of fish stocks, key fish habitat (KFH), biodiversity, threatened species, populations and ecological communities. The FM Act regulates the conservation of fish, marine vegetation and some aquatic macroinvertebrates and the development and sharing of the fishery resources of NSW for present and future generations. The FM Act lists threatened species, populations and ecological communities under Schedules 4, 4A and 5. Schedule 6 lists key threatening processes (KTPs) for species, populations and ecological communities in NSW waters and declared critical habitat are listed in a register kept by the Minister of Primary Industries. Impacts to these species, population, communities, processes and habitats due to the Project need to be considered. Assessment guidelines to determine whether a significant impact is expected are detailed in Section 220ZZ and 220ZZA of the FM Act.

Another objective of the FM Act is to conserve KFH. 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 KFH. 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. At a broad scale, KFH relevant to the Project includes the following:

> Permanently flowing rivers and creeks including those where the flow is modified by upstream dam(s), up to the top of the natural bank regardless of whether the channel has been physically modified;

> Intermittently flowing rivers and creeks that retain water in a series of disconnected pools after flow ceases including those where the flow is modified by upstream dam(s), up to the top of the natural bank regardless of whether the channel has been physically modified; and

> Any waterbody if it is known to support or could be confidently expected (based on predictive modelling) to support threatened species, threatened populations or threatened communities listed under the provisions of FM Act.

2.3 NSW DPI (Fisheries) Policy and Guidelines for Fish Habitat Conservation and Management

The NSW Department of Primary Industries (DPI) Policy and Guidelines for Fish Habitat Conservation and Management (Update 2013) (NSW DPI 2013a) replaces the Policy and Guidelines for Aquatic Habitat Management and Fish Conservation (NSW DPI 1999) and the former Fisheries NSW Policy and Guidelines for Fish Friendly Waterway Crossings (NSW DPI 2003). These updated policies and guidelines are applicable to all planning and development proposals and various activities that affect freshwater, estuarine and marine ecosystems. 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 to ensure their actions comply with 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 an outline of the information that NSW DPI requires to be included in development proposals that affect fish habitat;

> Specific policies and guidelines aimed at maintaining and enhancing the free passage of fish through instream structures and barriers;

> Specific policies and guidelines for foreshore works and waterfront developments; and

> Specific policies and guidelines for the management of other activities that affect waterways.

NSW DPI considers the ‘sensitivity’ of any KFH that would be affected by the Proposal (NSW DPI 2013a). The term ‘sensitivity’ refers to the importance of the habitat to the survival of fish and its ability to withstand disturbance. In freshwater ecosystems, instream gravel beds, rocks greater than 500 mm in two dimensions, snags greater than 300 mm in diameter or 3 m in length, native aquatic plants, and areas known or expected to contain threatened and protected species are considered highly sensitive KFH. Other freshwater habitats plus weir pools and dams across natural waterways are considered to be moderately sensitive KFH. 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 (excluding waterway crossings) and artificial ponds are not regarded as KFH 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), which in turn determines the appropriate type of any waterway crossings.

2.4 Key Threatening Processes

A Key Threatening Process (KTP) is a process that threatens, or may have the capability to threaten, the survival or evolutionary development of species, population or ecological community. KTPs are listed under the FM Act, *Biodiversity Conservation Act 2017* (BC Act) and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). There are eight listed KTPs under the FM Act, 38 listed under the BC Act and 21 listed under the EPBC Act. Broadly, the KTPs include threats to threatened species, population and ecological communities as well as cause species, population or ecological communities to become threatened.

One KTP listed under the BC Act is directly applicable to the Project: *Alteration of habitat following subsidence due to longwall mining.*

In the final determination for this KTP, the NSW Scientific Committee found that:

> Mining subsidence following longwall mining is frequently associated with cracking of valley floors and creek lines and with subsequent effects on surface and groundwater hydrology.

> Subsidence-induced cracks occurring beneath a stream or other surface water body may result in the loss of water to near-surface groundwater flows. If the water body is located in an area where the coal seam is less than approximately 100 to 120 m below the surface, longwall mining can cause the water body to lose flow permanently. If the coal seam is deeper than approximately 150 m, the water loss may be temporary unless the area is affected by severe geological disturbances such as strong faulting.

> In the majority of cases, surface waters lost to the sub-surface re-emerge downstream. The ability of the water body to recover is dependent on the width of the crack, the surface gradient, the substrate composition and the presence of organic matter. An already-reduced flow rate due to drought conditions or an upstream dam or weir will increase the impact of water loss through cracking.

> Subsidence can cause decreased stability of slopes and escarpments, contamination of groundwater by acid drainage, increased sedimentation, bank instability and loss, creation or alteration of riffle and pool sequences, changes to flood behaviour, increased rates of erosion with associated turbidity impacts, and deterioration of water quality due to a reduction in dissolved oxygen and to increased salinity, iron oxides, manganese, and electrical conductivity.

> Loss of native plants and animals may occur directly via iron toxicity, or indirectly via smothering. Long-term studies in the United States indicate that reductions in diversity and abundance of aquatic invertebrates occur in streams in the vicinity of longwall mining and these effects may still be evident 12 years after mining.

> In the Southern Coalfields, substantial surface cracking has occurred in watercourses within the Upper Nepean, Avon, Cordeaux, Cataract, Bargo, Georges and Woronora catchments, including Flying Fox Creek, Wongawilli Creek, Native Dog Creek and Waratah Rivulet. The usual sequence of events has been subsidence-induced cracking within the streambed, followed by significant dewatering of permanent pools and in some cases complete absence of surface flow.

> Subsidence associated with longwall mining has contributed to adverse effects on upland swamps. The conversion of perched water table flows into subsurface flows through voids, as a result of mining-induced subsidence may significantly affect the water balance of upland swamps. The timeframe of

these changes is likely to be long-term. While subsidence may be detected and monitored within months of a mining operation, displacement of susceptible species by those suited to altered conditions is likely to extend over years to decades as the vegetation equilibrates to the new hydrological regime.

The Department of Environment and Conservation (now Office of Environment and Heritage [OEH]) has identified several priority actions to promote the abatement of this KTP, including:

> Examine the effects of subsidence from longwall mining on priority ecosystems including streams, wetlands and threatened species, populations and ecological communities.

> Prepare guidelines outlining key factors that should be considered when assessing impacts of new longwall mines on biodiversity.

> Develop recommendations for monitoring impacts of new longwall mines on biodiversity and mitigation methods.

> Ensure rigorous assessment of new mines continues through existing approval processes including the preparation of SMPs.

Consideration of the effect of exacerbation of any KTP on a listed threatened species, population or ecological community must be taken into consideration during any assessment.

3 Existing Information

3.1 Physical Setting and Study Area

The proposed Longwalls 20 and 21 are located within the Metropolitan Catchment Area, which is a special declared area controlled by Water NSW (previously the Sydney Catchment Authority (SCA)) (**Figure 3-1**). The Study Area for the aquatic ecology assessment is the area encompassing 600 m of Longwalls 20 and 21. The main watercourses within the vicinity of these longwalls are Wongawilli Creek and Donalds Castle Creek, which flow in a northerly direction west and east of the longwalls, respectively. Wongawilli Creek is a 3rd order (Strahler stream order) creek that is 12 km long from its confluence with the Cordeaux River to its headwater, with 2.8 km within the Study Area. The majority of Donalds Castle Creek is 3rd order, though the majority of the creek within the Study Area and upstream of its confluence with drainage line DC13 is 2nd order. There are also several other 1st and 2nd order drainage lines and upland swamps that flow into these watercourses.

Lake Cordeaux is located 1.5 km to the east and Lake Avon is located 2.5 km to the south-west of the proposed longwalls. Avon River, Cordeaux River and their upstream lakes have a very low risk of being affected by the Project and are not included in this assessment. Swamps and associated flora and fauna in the Study Area will be assessed by other specialists.

3.2 Overview of Previous Studies

Numerous studies of aquatic habitat, flora and fauna in the Dendrobium Mine area have been undertaken by Cardno (formerly Cardno Ecology Lab and The Ecology Lab). These included studies in:

> DA1: AEA studies (The Ecology Lab 2001a, b and 2003) and monitoring studies ((The Ecology Lab 2005).

> DA2: AEA studies (The Ecology Lab 2006) and monitoring studies (Cardno Ecology Lab 2009). and

> DA3: AEA studies (The Ecology Lab 2007), including the DA3B AEA (Cardno Ecology Lab 2012a), baseline studies (Cardno Ecology Lab 2011) and ongoing monitoring studies (Cardno Ecology Lab 2012b. 2013. 2014. 2015 and 2016; Cardno 2018a); and

> Areas 5 and 6 AEA studies (Cardno 2018b): Investigation in Donalds Castle Creek were also undertaken in September 2016 as part of the baseline studies for the proposed Area 5 and Area 6 (Cardno 2018b) and in Wongawilli Creek and Donalds Castle Creek in 2017 as part of the ongoing monitoring for DA3B.

In these studies, the primary watercourses considered were in the Wongawilli, Native Dog, Donalds Castle and Sandy Creek Catchments. In particular, investigations of Wongawilli Creek and Donalds Castle Creek within the Study Area were undertaken as part of the initial aquatic ecology assessment for Dendrobium Area 3 (The Ecology Lab 2007) and subsequent SMP for DA3B (Cardno Ecology Lab 2012a). These studies also assessed impacts of predicted mine subsidence on aquatic ecology, including threatened species, in DA3. Information on aquatic ecology in the Study Area and adjacent areas available from these previous studies is reviewed in **Sections 3.3** to **3.8**. This included the findings of surveys undertaken at existing DA3B Sites 14 and X1 on Donalds Castle Creek and Site 5 on Wongawilli Creek that are within the Study Area for Longwalls 20 and 21. Information from DA3B sites further upstream on Wongawilli Creek and outside the Study Area (Sites 1 to 4 and X4 to X6) has also been reviewed. Investigations in June 2017 included additional surveys of sections of these creeks as part of this assessment. Two additional sites on Wongawilli Creek and two on Donalds Castle Creek were established and the findings are presented in **Section 4**.

3.3 Aquatic Habitat and Vegetation

3.3.1 Wongawilli Creek

Detailed investigations of Wongawilli Creek within the Study Area were undertaken as part of the initial investigations for DA3 in July 2007. Four zones with similar habitat characteristics were identified within Wongawilli Creek. The Study Area is located within Zones 1 and 2. Zone 1 is located from the confluence with the Cordeaux River to approximately 3 km upstream (approximately at the current Site 19 location) and

Zone 2 extends from here upstream to the inflow of drainage line WC16. The aquatic habitat within Zones 1 and 2 is characterised as follows:

> Riparian vegetation consisting primarily of sawgrass (*Gahnia* sp.), wattle (*Acacia* sp.), tea-tree (*Leptospermum* sp.) and ferns along the creek banks, surrounded by dry eucalypt forest. There is extensive overhanging vegetation along the stream margin. Stream banks composed of well vegetated sandy soil with little erosion or undercutting. The channel within Zone 2 is far more incised and steep than that in Zone 1 and with sections of exposed sandy soil with signs of erosion including undercutting and scouring.

> A main channel providing substantial aquatic habitat including a series of large deep pools, some of which are over 100 m in length, over 10 m wide and up to 4 m deep. In the large pools, the dominant substratum is sand, with significant areas of bedrock, and boulders. Small gravel beds are present in the upstream sections of some of the pools. The pools also have accumulation of detritus, including leaf litter and woody debris. In Zone 1 the pools are separated by sandstone rock bars ranging in height from 1 to 15 m and up to 50 m in length. The largest of the rock bars (WC RB 1) is situated just upstream of the confluence with the Cordeaux River. There are numerous in-stream habitat features, including large snags, tree roots, sandstone rock walls, caves, boulders and aquatic macrophytes. In Zone 2 the pools are shallower and interspersed by small sandstone rock bars, sandbars, debris dams and small boulder fields. The substratum consists of large areas of sand deposit and small amounts of boulders, cobbles, pebbles and gravel. The pools contain leaf litter and woody debris. Large snags and tree roots are also present.

> There are three significant barriers to fish passage in Zone 1. The largest being rockbar-waterfall (WC RB 1) located just upstream of the confluence with Cordeaux River. This waterfall has a series of sandstone steps up to 2 m high and a total fall in elevation of approximately 15 m and would therefore pose a hindrance to the upstream passage of species such as Macquarie perch, but less so freshwater eels and galaxids which are more adapted passing such barriers. The other barriers are the rockbars (WC-RB 11 & 12) located upstream of Fire Road 6. During periods of low to moderate flow, the shallow flow and vertical fall of these rockbars would create a major barrier to the upstream passage of Macquarie perch. During large floods, these rockbars are likely to be submerged for short periods, so it is possible that Macquarie perch and over fish are able to move further upstream at these times.

> The distribution of aquatic plants is patchy, with green and brown algae present. The only other submerged plant found was Watermilfoil (*Myriophyllum* sp.) at Site 5. Three emergent plants were recorded in Wongawilli Creek, rush (*Juncus* sp.) at Sites 1 and 3, sedge (*Cyperus* sp.) and *Lomandra* sp. at Site 3. The baseline monitoring (Cardno Ecology Lab 2011) indicated that aquatic macrophytes were relatively scarce covering ≤ 5% of the surface area at the majority of monitoring sites, except for Site 5, where the percentage cover varied from 10% to 40% in spring and 15 % to 80 % in autumn. The percentage cover of aquatic macrophytes at the other sites exceeded 5% on only two occasions in September 2011 and April 2009 at Sites X6 and 3, respectively. Algae were more common, covering ≥ 20% of the area on occasion at all of the sites. Mosses were present on bedrock, boulders and large woody debris and appeared to be more prevalent in spring. The Ecology Lab (2001a) also noted small beds of *Myriophyllum* sp. in most pools and extensive algal growth on hard surfaces.

A description of Wongawilli Creek and Donalds Castle Creek drainage lines is provided in **Section 3.3.3**.

3.3.2 Donalds Castle Creek

Aquatic ecology investigations undertaken for Donalds Castle Creek as part of the DA3B Aquatic Flora and Fauna Assessment (Cardno Ecology Lab 2012a) indicated the following:

> The vegetation surrounding Donalds Castle Creek to the east of Area 5 is dominated by dry Eucalypt forest which extends to the banks of the creek;

> The stream banks are composed mostly of well vegetated sandy soil with little erosion or undercutting evident and extensive overhanging vegetation along the stream margin;

> Riparian vegetation comprises numerous native plants, including saw grass (*Gahnia* sp.), mat rush (*Lomandra* sp.), wattles (*Acacia* sp.), and tea-tree (*Leptospermum* sp.) along the creek banks;

> The main channel comprises a series of relatively small permanent pools with a maximum depth of 1.5 m, width of 6 m and length of 25 m. The pools are connected by narrow channels with a sandy substratum, small sections of gravel riffles and some sandstone rockbars with small cascades up to 1 m in height;

> The pools have a sandy substratum also, with some areas of bedrock, boulder and gravel. The connectivity between pools is not expected to persist through extended dry periods. There are numerous in-stream habitat features, including snags and tree roots;

> Aquatic vegetation is relatively sparse, and includes brown and green algae, twigrush (*Baumea* sp.) and clubrush (*Schoenoplectus* sp.). Some *Triglochin* sp. is present downstream of the Fire Road 6 crossing;

> Natural waterfalls are present on the creek which could pose a barrier to passage for some fish; and

> The Riparian Channel and Environmental Inventory (RCE) undertaken at the commencement of the baseline monitoring program indicated the aquatic habitat in Donalds Castle Creek was in very good condition, with both sites having an overall score of 49 out of a possible total of 52.

The aquatic habitat provided by drainage lines is described in **Section 3.3.3**.

3.3.3 Existing Aquatic Habitat Mapping

The July 2007 investigations (The Ecology Lab 2007) mapped four habitat types (adapted from Fairfull and Witheridge 2003) within Wongawilli Creek, Donalds Castle Creek and their drainage lines:

> Unlikely habitat: Ephemeral drainage lines that only contain flow during and immediately after significant rainfall. Permanent or semi-permanent pools that could provide refuge for aquatic biota during prolonged dry weather are absent.

> Minimal habitat: Watercourses that contain some small semi-permanent refuge pools which are unlikely to persist through prolonged drought. Flow connectivity would only occur during and following significant rainfall. These pools may provide habitat for some aquatic species including aquatic macroinvertebrates and freshwater crayfish.

> Moderate habitat: Watercourses that contain some larger permanent and semi-permanent refuge pools, which would persist through prolonged drought, although become greatly reduced in extent. These watercourses should support a relatively diverse array of aquatic biota including some fish, freshwater crayfish and aquatic macroinvertebrates. There may also be some aquatic plant species present.

> Significant habitat: Watercourses that contain numerous large, permanent pools and generally have flow connectivity except during prolonged drought. They provide extensive and diverse aquatic habitat for aquatic flora and fauna.

It was found that:

> Wongawilli Creek and Donalds Castle Creek provides provide significant habitat and moderate habitat, respectively;

> The lower reaches of drainage lines WC25, WC26, WC27 and WC31 contain “minimal” aquatic habitat. The other tributaries are “unlikely” to provide aquatic habitat. WC26, the largest of these tributaries, contains some small pools and is therefore likely to provide some aquatic habitat for aquatic macroinvertebrates, including freshwater crayfish.

> In Zone 2, drainage line WC21 contains “moderate” aquatic habitat, WC17, WC20, WC23 and WC24 contain “minimal” aquatic habitat. WC18, WC19, and WC22 are “unlikely” to contain aquatic habitat. WC21, the largest tributary within this Zone, is characterised by a permanent pool at the base of a large sandstone cascade/waterfall. This pool is approximately 15 m in diameter and has sandy substratum with large sandstone boulders and bedrock throughout. This pool would provide habitat for fish and invertebrates throughout prolonged dry periods. The cascade on WC21 consists of a series of sandstone steps up to 4 m high with a total change in elevation of approximately 20 m over a horizontal distance of approximately 70 m and would thus prevent upstream passage of Macquarie perch.

These findings were used to inform the detailed KFH mapping using the updated classifications in NSW DPI (2013a) during the current assessment (**Section 4.2.2**)

The broad scale KFH map for Wollongong available on the NSW DPI website indicates that Wongawilli Creek is KFH (NSW DPI 2017a). Donalds Castle Creek and the drainage lines that traverse the Study Area are not identified as KFH by this map.

3.4 Water Quality

The limited *in-situ* water quality measurements taken in Wongawilli Creek during the baseline aquatic ecology monitoring showed electrical conductivity (EC) levels were generally within the ANZECC/ARMCANZ (2000) guideline default trigger values (DTVs) (30 to 350 (µS/cm) for upland rivers in south-east Australia (Cardno Ecology Lab 2009 and 2011). EC measurements below the lower DTV were recorded at Sites X5, X4 and 4, but only on one occasion. The pH of the water at all sites was generally below the DTVs (pH 6.5 to 8.0). It should be noted that this is typical for watercourses that flow through Hawkesbury sandstone environments. The dissolved oxygen (DO) levels at all the sites on the creek fell below the lower DTV (90 % saturation) during some surveys, more commonly at the downstream sites (2, 3, 4, 5 and X4) than upstream sites (X6, X5 and 1). DO levels in excess of the upper DTV (110 % saturation) were recorded at Sites X6, 3 and 4 in September 2010 and at Sites 1, 2, 3 and 4 in April 2009. In spring, the turbidity measurements taken at Sites X6, X5 and 5 were frequently below the lower DTV (2 ntu), as were the measurements taken at Sites 1 and X4 in autumn. Turbidity readings in excess of the upper DTV (25 ntu) were recorded at Sites 3 and 4, but only in October/November 2011.

Previous surveys have indicated that some measures of water quality within Donalds Castle Creek have often also been outside of ANZECC/ARMCANZ (2000) guidelines. EC measurements taken during the baseline aquatic ecology monitoring for DA3B (Cardno Ecology Lab 2012b) and during recent ongoing monitoring (Cardno Ecology Lab 2015) showed levels were generally within DTVs. The exception was at one site (Site X1), where the level occasionally fell below the lower DTV. The pH of the water at monitoring sites was always below the lower DTV. DO levels at one site (Site X1) were either within DTVs or sometimes below the lower DTV. The DO measurements at Site 14 were more variable, ranging above and below the DTVs. The turbidity measurements were within, or below, the guidelines. The water quality of drainage lines is typical of that in the larger creeks, particularly with pH below the lower DTV.

While water quality measures have often been found outside DTVs, the relatively remote and undisturbed catchment area does not suggest influence by any anthropogenic disturbance. NTU values below 2 are not cause for concern, and most likely reflect the relatively low organic content of the water. Also, low pH levels have been recorded generally across the Dendrobium Mine area, and appear to occur naturally, most likely associated with local geology and its influence on water chemistry. The natural water quality of these creeks should be taken in to consideration when interpreting the results of macroinvertebrate sampling.

3.5 Macroinvertebrates

The several AUSRIVAS surveys undertaken in Wongawilli Creek and Donalds Castle Creek have indicated a relatively large among of variability in biotic indices. During relatively recent (since 2010) sampling as part of the ongoing DA3B monitoring, assemblages on Wongawilli Creek ranged from more diverse than AUSRIVAS reference condition (AUSRIVAS Band X) to severely impaired (Band C). On Donalds Castle Creek they ranged from and equivalent to reference condition (Band A) to severely impaired (Band C) on Donalds Castle Creek (**Appendix A**). AUSRIVAS Band scores are derived from the OE50 Taxa Scores, which is a biotic index of habitat and water quality. The Stream Invertebrate Grade Number Average Level (SIGNAL2) indices, a biotic index of water pollution, suggested severe to mild water pollution in both creeks. However, while the results of AUSRIVAS sampling suggest potential anthropogenic disturbance to habitat and / or water quality, there is no other evidence to support this. It is possible that the naturally low pH levels in this watercourse, and others that traverse the Dendrobium Mine area (**Section 3.4**), may be influencing the type of macroinvertebrates that are present. Other measures of water quality, such as naturally occurring levels of some heavy metals, may also influence the type of macroinvertebrates, and other organisms, present (Cardno Ecology Lab 2012a,b; Ecoengineers 2006).

3.6 Fish

Numerous fish surveys have been undertaken in Wongawilli Creek previously. In particular, in autumn 2008 and summer 2009, targeted backpack electrofishing surveys were undertaken in the reaches of Wongawilli Creek identified as containing potential habitat for Macquarie perch (*Macquaria australasica*) (Cardno

Ecology Lab 2009), including that within the Study Area. Climbing galaxias (*Galaxias brevipinnis*), Australian smelt (*Retropinna semoni*) and freshwater crayfish (*Euastacus* sp.) were caught in the reach of the creek immediately downstream of Fire Road 6, just downstream of the Study Area. The deeper pool sections immediately upstream of this road and within the Study Area contained Australian smelt and longfinned eel (*Anguilla reinhardtii*). Further upstream, large numbers of climbing galaxias and freshwater crayfish were caught. In 2001, fish occurring in pools and riffles from the upstream limit of boat passage back down to the road crossing were sampled using an electrofisher (The Ecology Lab 2001a, b). Australian Smelt, Freshwater Eels (*Anguilla* sp.), mountain galaxias and climbing galaxias were caught upstream of the major barriers. No Macquarie perch were caught during these surveys, although this species has been recorded in Wongawilli Creek in pools just upstream and downstream of Fire trail 6A (NSW DPI (Fisheries), pers. com.; The Ecology Lab, 2001a, b; MPR 2006a,b). On 31 October 2011, eight individuals of this species were observed in the pool immediately upstream of fire trail 6A (Matt Richardson, Niche pers. comm.). This species has not, however, been caught any farther upstream in Wongawilli Creek despite extensive subsequent sampling for the ongoing DA3A and DA3B investigations (Cardno 2012 and 2016) nor during targeted surveys in Donalds Castle Creek downstream of the Study Area in September 2016 (Cardno 2018b). It is possible that this species is unable to pass the natural barrier in the form of a cascade / waterfall present a few hundred m upstream of the fire road crossing, at least not in any appreciable numbers.

Some of these species were also present in Donalds Castle Creek. The bi-annual surveys undertaken for Elouera Colliery Longwalls 7-10 between 2002 and 2006 indicated that Australian smelt and mountain galaxias were present in Donalds Castle Creek (MPR 2002, 2003a and b, 2004, 2005, 2006a, b and c). Climbing galaxias and shortfinned eel (*Anguilla australis*) were also caught during the backpack electrofishing surveys in November 2011 (Cardno Ecology Lab 2012a). Climbing galaxias was caught at DA3 Site 14 (just downstream of the Fire Road 6 Crossing) and approximately 150 m further upstream. shortfinned eels were caught downstream of Site X1. Freshwater crayfish were also caught in this reach. More recently, galaxids (*Galaxias* sp.) have also been caught in Donalds Castle Creek on several occasions during the ongoing DA3A (Cardno Ecology Lab 2015) and DA3B (Cardno Ecology Lab 2016) aquatic ecology monitoring. This species was relatively scarce at Site X1, compared with Site 14 (Cardno Ecology Lab 2016), which likely reflects the disconnected nature (i.e. a series of isolated pools) of the aquatic habitat further upstream in Donalds Castle Creek. While not sampled during these surveys (except for WC21), it is possible that drainage lines within the Study Area, may also support some fish, most likely climbing galaxias. The presence and abundance of fish in drainage lines would depend on the size of drainage lines, their flow, and the presence of natural barriers to fish passage. It is likely that due to their highly disconnected nature, pools in many drainage lines would provide no, or sub-optimal at best, habitat for these fish.

In the wider catchment areas, a survey of Lake Cordeaux, undertaken in 1994 using gill nets and electro-fishing, indicated that three native fish species, longfinned eel, Australian smelt, Macquarie perch and goldfish (*Carassius auratus*), an invasive species, were present (Gehrke and Harris 1996). During subsequent surveys, Australian smelt, numbers of goldfish, longfinned eels, mountain galaxids and shortfinned eels and a single Macquarie perch were caught (Growns and Gehrke 2001). Freshwater crayfish (*Euastacus* sp.) were also caught in Lake Cordeaux (Growns and Gehrke 2001). During the third survey, undertaken when Macquarie perch are known to migrate from reservoirs to spawning habitats in creeks, four specimens were caught in Lake Cordeaux, but none were found in the creeks entering the lake. This was despite the presence of habitats suitable for spawning in Goondarrin and Kembla Creeks (Creese and Hartley 2003). It is possible that a low storage level in the dam at the time of sampling may have prevented Macquarie perch from accessing these spawning areas. In Lake Avon, Macquarie perch, longfinned eel, and Brown trout (*Salmo trutta*) have been recorded, and it is thought that a further 12 species may be present (Cardno Ecology Lab 2012a).

Aside from the listed threated Macquarie perch (**Section 3.7.2**), all species of fish identified from the Study Area are widespread and abundant, and currently have no cause for conservation concern. Aside from some invasive species identified in Cordeaux Dam (goldfish) and Lake Avon (brown trout), no invasive species of fish have been identified in the Study Area.

3.7 Listed Threatened Species, Populations and Ecological Communities

3.7.1 Desktop Searches

A search for information on records and distributions of threatened species, populations and ecological communities listed under the FM Act, EPBC Act and BC Act in the Wongawilli Creek and Donalds Castle Creek catchments was undertaken to update searches completed for previous assessments for DA3 (The Ecology Lab 2007; Cardno Ecology Lab 2011). The search used the following resources:

> The Department of the Environment and Energy (DEE) Protected Matters Search Tool (DEE 2018) was used to determine whether any Matters of National Environmental Significance (MNES) listed under schedules of the EPBC Act occurred in a 10 km radius from the centre of the Area 5 and Area 6 mine areas;

> The OEH Geographic Region Search (OEH 2018) was used to determine whether any threatened aquatic plant species or endangered ecological communities listed under the BC Act were present in the Sydney Cataract sub-region of the Hawkesbury-Nepean Catchment Management Authority Region. The OEH managed BioNet was also searched for records of BC Act listed flora and fauna within the Dendrobium Mine area held in the Atlas of NSW Wildlife; and

> Species distribution maps contained in the NSW DPI Fish Communities and Threatened Species Distributions of NSW (NSW DPI 2016a) were examined for the occurrence of threatened species listed under the FM Act in the upper catchments of Cordeaux River and Avon River.

The desktop search indicated several species that occur, or have potential to occur, in the Study Area (**Sections 3.7.2** to **3.7.5**). Amphibians, aquatic mammals, reptiles and Giant dragonfly (*Petalura gigantea*) are being considered by other specialists and were excluded from the search.

3.7.2 Macquarie Perch

Macquarie perch is listed as endangered under the EPBC Act and the FM Act. In addition to reaches of Wongawilli Creek downstream of the Study Area (**Section 3.6**) it has been recorded also in Lake Avon and Lake Cordeaux and previously recorded, or potentially present, in the upper reaches of Cordeaux and Avon Rivers (NSW DPI 2016a) in Dendrobium Area 3. Outside of these areas, Macquarie perch are found in the Murray-Darling Basin, particularly the upstream reaches of the Lachlan, Murrumbidgee and Murray rivers, and parts of south-eastern coastal NSW, including the Hawkesbury and Shoalhaven catchments.

Macquarie perch prefer clear water and deep, rocky holes with extensive cover in the form of aquatic vegetation, large boulders, debris and overhanging banks (NSW DPI 2016b). They spawn in spring or summer and lay their eggs over stones and gravel in shallow, fast-flowing upland streams or flowing parts of rivers. Macquarie perch is an active predator of macroinvertebrates. While other large-bodied percichthyids are generally higher-order ambush predators that may have limited range, the Macquarie perch tends to have a relatively larger linear (along shore) diel range (Ebner *et al*. 2010). A study in a Canberra reservoir found that Macquarie perch have a mean linear diel range of 516 m (± 89 S.E.) which suggests that discontinuous and small pools would not provide suitable habitat for this species (Ebner *et al*. 2010).

The draft National Recovery Plan for Macquarie perch has recently been released (Commonwealth of Australia 2017). This contains background information on the biology, ecology, distribution and populations, decline and threats and recovery objectives and strategies and associated actions for this species. Identified threats include:

> Habitat degradation;

> Alien (non-native) fish;

> Barriers to fish movement;

> Altered flow and thermal regimes;

> Disease;

> Illegal / incidental capture;

> Chemical water pollution; and

> Climate change.

Recovery Strategies are:

> Conserve existing Macquarie perch populations;
> Protect and restore Macquarie perch habitat;
> Investigate threats to Macquarie perch populations and habitats;
> Establish additional Macquarie perch populations;
> Improve understanding of the biology and ecology of the Macquarie perch and its distribution and abundance; and
> Increase participation by community groups in Macquarie perch conservation.

The public comment period closes 1 September 2017.

The following Priority Action Statements for Macquarie perch (NSW DPI 2017b) exist:

> Advice to consent and determining authorities;
> Collate and review existing information;
> Community and stakeholder liaison, awareness and education;
> Compliance / enforcement;
> Enhance, modify or implement Natural Resource Management planning processes to minimize adverse impacts on threatened species;
> Habitat rehabilitation;
> Pest eradication and control;
> Research / monitoring;
> Stocking / translocation; and
> Survey / mapping.

Actions directly applicable to the Project include the provision of advice on the distribution of Macquarie perch to determining authorities to ensure appropriate consideration during development assessment processes, and the undertaking of targeted surveys to determine the current distribution and abundance of Macquarie perch.

3.7.3 Australian Grayling

Australian grayling (*Prototroctes maraena*) is listed as a vulnerable species under the EPBC Act and is a protected species under the FM Act. It occurs in coastal streams and rivers on the eastern and southern flanks of the Great Dividing Range from Sydney southwards to the Otway Ranges in Victoria, and Tasmania (NSW DPI 2006). Australian grayling have been recorded in the Grose River, but there are no records of this species from the upper Nepean Catchment. They have also been recorded in estuarine areas. The life cycle of the Australian grayling is dependent upon migration to and from the sea (McDowall 1996). Spawning occurs in late summer or autumn and larvae are swept downstream to the sea (NSW DPI 2006). Juvenile fish return to freshwater when they are about six months old and remain in rivers and streams for the rest of their life. Australian Grayling has undergone a considerable decline in its distribution and abundance and, although it was historically present in the Hawkesbury-Nepean, it is now restricted to the coastal rivers of southern New South Wales (Morris *et al*. 2001; NSW DPI 2016a). The decline of this species has been attributed to dams, weirs and culverts preventing it from migrating to and from the sea and completing its life cycle. As Australian grayling is highly unlikely to occur within the Study Area, further consideration of this species is not considered necessary.

3.7.4 Sydney Hawk Dragonfly

The Sydney hawk dragonfly (*Austrocordulia leonardi*) is listed as endangered under the FM Act. It is extremely rare, having been collected in small numbers at only a few locations in a small area to the south of

Sydney, between Audley and Picton (NSW FSC 2004). The species is also known from the Hawkesbury-Nepean, Georges River and Port Hacking drainages. It was discovered in 1968 from Woronora River and Kangaroo Creek, south of Sydney, and has subsequently been found in the Nepean River at Maldon Bridge near Wilton. There are no records for this species within the Study Area or the Cordeaux and Lake Avon catchments. Extensive sampling has failed to discover further specimens in other areas suggesting that it has a highly restricted distribution within the catchment of the Nepean River (NSW DPI 2007).

Most of the lifecycle of this species is spent as an aquatic larva, with adults living for only a few weeks. The larvae appear to have specific habitat requirements, being found under rocks in deep, cool, shady pools (NSW DPI, 2007). Relative environmental stability appears to be an important habitat feature, with rapid variation in water level and flow rate likely to have a negative effect on the suitability of habitat for larvae.

No Recovery and Threat Abatement Plans exist for this species. Several conservation and recovery actions for Sydney hawk dragonfly are included in NSW DPI (2007):

> Allocate and manage environmental water through water sharing planning processes, to lessen the impacts of altered flows;

> Prevent sedimentation and poor water quality by using conservation farming and grazing practices, conserve and restore riparian (river bank) vegetation and use effective erosion and sediment control measures;

> Rehabilitate degraded habitats. Protect riparian vegetation and encourage the use of effective sediment control measures in catchments where the dragonfly may occur;

> Protect the few remaining sites with the potential to support the species, and address key threats such as habitat degradation and water quality decline;

> Conduct further research into the species' biology, ecology and distribution; and

> Implement the Protected, Threatened and Pest Species Sighting Program and report any sightings to NSW DPI.

3.7.5 <u>Adams Emerald Dragonfly</u>

Adams emerald dragonfly (*Archaeophya adamsi*) is listed as endangered under the FM Act. It is extremely rare, having been collected only in small numbers at a few locations in the greater Sydney region (NSW DPI 2013b). Specimens have been collected at five localities: Somersby Falls and Floods Creek in Brisbane Waters National Park near Gosford; Berowra Creek near Berowra and Hornsby; Bedford Creek in the Lower Blue Mountains; and Hungry Way Creek in Wollemi National Park. There are no records for this species within the Study Area or the Cordeaux and Lake Avon catchments. There are no records of Adam's emerald dragonfly occurring south of Sydney, despite active collecting in the Hawkesbury-Nepean River catchment (Fisheries Scientific Committee 2008). This species was not collected by Cardno during the baseline surveys of aquatic macroinvertebrates in Wongawilli, Donalds Castle or Native Dog Creeks as part of the Dendrobium Mine area studies, but aquatic habitat appears suitable for this species does occur within these watercourses (Cardno Ecology Lab 2011).

The larvae of Adam's Emerald Dragonfly inhabit small creeks with gravel or sandy bottoms in narrow, shaded riffle zones with moss and lush riparian vegetation (NSW Fisheries 2012). The larvae live for approximately 7 years before metamorphosing into adults that probably live for only a few months. They are thought to have a low natural rate of recruitment and limited dispersal abilities.

No Recovery and Threat Abatement Plans exist for this species. Conservation and recovery actions (NSW DPI 2007) for Adams emerald dragonfly are:

> Rehabilitate degraded habitats. Protect riparian vegetation and encourage the use of effective erosion and sediment control measures in catchments where the dragonfly may occur;

> Protect the few remaining sites that still support the species, and address key threats such as habitat degradation and water quality decline from expanding development;

> Conduct further research into the biology and distribution of the species; and

> Report any sightings to NSW DPI.

3.7.6 Likelihood of Occurrence

Table 3-1 assesses the likelihood of occurrence of Listed Threatened Species in the Study Area.

Table 3-1 Likelihood of Occurrence of Listed Threatened Species in the Study Area

Species and Listing	Likelihood of Occurrence
Macquarie perch (endangered under FM Act and EPBC Act)	Occurs in Avon River and Cordeaux River and the reach of Wongawilli Creek just upstream of Fire Road 6 and downstream of the Study Area. Suitable pool habitat exists within the Study Area and upstream but it has not been caught during numerous surveys, possibly due to the presence of natural barriers to fish movement. Very unlikely to occur in Donalds Castle Creek and drainage lines in the Study Area.
Adams emerald dragonfly (endangered under FM Act)	Unlikely to occur within the Study Area. No records within, or adjacent to the Study Area despite extensive sampling, though suitable microhabitat appears to exist in creeks and drainage lines.
Sydney hawk dragonfly (endangered under FM Act)	Unlikely to occur within the Study Area. No records within, or adjacent to the Study Area despite extensive sampling, though suitable microhabitat appears to exist in creeks and drainage lines.
Australian grayling (endangered under FM Act and vulnerable under EPBC Act)	Does not occur in the Study Area. Present in coastal rivers of southern NSW outside of the Study Area.

3.8 Critical Habitat

The Study Area does not contain any critical habitats listed under the FM Act, BC Act or EPBC Act.

4 Field Surveys

4.1 Rationale

Field surveys were undertaken in sections of Wongawilli Creek and Donalds Castle Creek within the Study Area (**Figure 3-1**). Aquatic habitat was also assessed in several drainage lines of these watercourses that traverse this area.

The surveys included the following components:

> Classification and mapping of aquatic habitat in rivers, creeks and drainage lines within, and adjacent to the Study Area using classification criteria in NSW DPI (Fisheries) (2013a); and

> Assessment of aquatic habitat, vegetation, aquatic macroinvertebrates and fish. This included consideration of Sydney hawk dragonfly and Adam's emerald dragonfly;

The primary objective of the field studies were to update the findings of the previous investigations undertaken in these areas, characterise the aquatic ecology of the Study Area and place it in context of the wider Cordeaux Catchment area. A summary of the location, timing and methods associated with each component of aquatic ecology included in the field surveys is provided in **Table 4-1** and described in detail in **Section 4.2**.

4.2 Methods

4.2.1 Timing

Field surveys of KFH and aquatic ecology were undertaken on 14, 21 and 22 June 2017. Surveys were undertaken by two ecologists.

4.2.2 Key Fish Habitat

Wongawilli Creek is KFH (**Section 3.3**). Donalds Castle Creek and the several drainage lines that traverse the Study Area are not mapped by NSW DPI as KFH, though they may still contain, or constitute, sensitive KFH as described in NSW DPI (2013a) (**Section 3.3.3**). The occurrence of sensitive fish habitat in the Study Area was assessed using the criteria in NSW DPI (2013a) relevant to freshwater habitat (**Table 4-1**).

Mapping was done initially as a desktop exercise with the aid of existing information from previous mapping (**Section 3.3.3**), with ground-truthing undertaken in during June 2016. Some drainage lines could not be accessed due to steep valley sides and waterfalls (mainly drainage line LA12 and further upstream in drainage line DC8B). Where sections of drainage lines could not be accessed, KFH type was inferred based on the findings from other drainage lines in the Study Area.

Table 4-1 Classification of KFH according to sensitivity (NSW DPI 2013a)

Classification	Habitat Type
Type 1 – highly sensitive KFH	Instream gravel beds, rocks greater than five hundred millimeters in two dimensions, snags (wood debris) greater than three hundred millimeters in diameter or three meters in length, native aquatic plants, and areas known or expected to contain threatened and protected species
Type 2 – Moderately sensitive KFH:	Freshwater habitats other than those defined in Type 1
Type 3 – Minimally sensitive KFH	Ephemeral aquatic habitat not supporting native aquatic or wetland vegetation
Not considered KFH	First and second order streams on gaining (those where streams are coming together and becoming progressively larger) streams (based on the Strahler method of stream ordering)

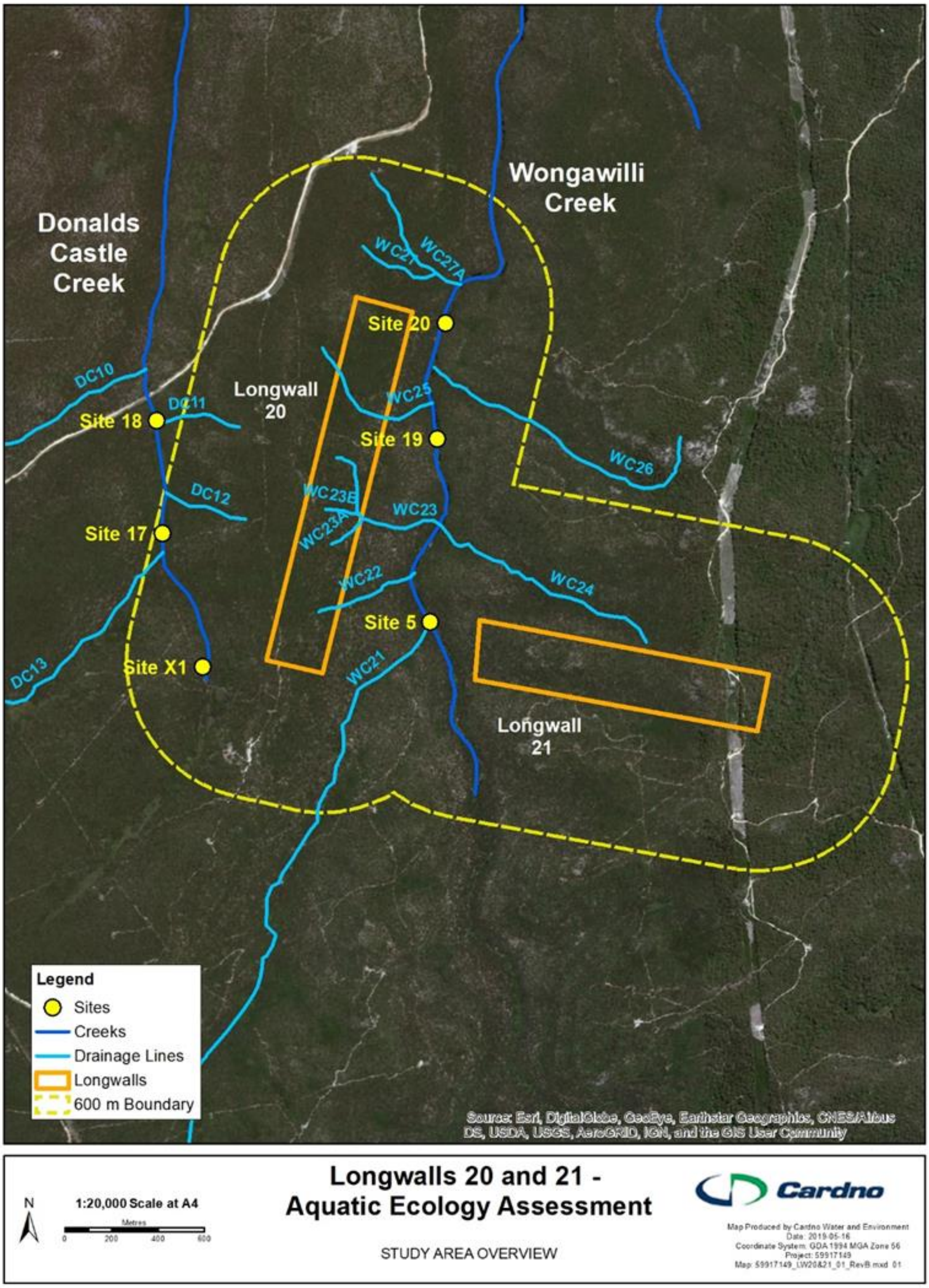

Figure 4-1 Overview of the Study Area

4.2.3 Aquatic Habitat and Biota

Six sites within the Study Area were visited and assessed for aquatic ecology (**Table 4-2**). Two of these (Sites 5 and Site X1) form part of the ongoing monitoring for DA3B and four (Sites 17 to 20) were visited to provide additional information for this assessment.

Table 4-2 Sampling Sites in the Study Area Visited 28 to 30 September 2016

Site	Watercourse	Easting	Northing
Ste 5	Wongawilli Creek	290625	6194378
Site 19	Wongawilli Creek	290645	6195106
Site 20	Wongawilli Creek	290671	6195676
Site X1	Donalds Castle Creek	289643	6194191
Site 17	Donalds Castle Creek	289493	6194818
Site 18	Donalds Castle Creek	289429	6195203

4.2.3.2 Aquatic Habitat and Vegetation

The condition of the aquatic habitat at each site was assessed using a modified version of the Riparian, Channel and Environmental Inventory method (RCE) (Chessman *et al*. 1997) (**Appendix Bi**). This assessment involves evaluation and scoring of the characteristics of the adjacent land, the condition of riverbanks, channel and bed of the watercourse, and degree of disturbance evident at each site. The occurrence of key aquatic habitat (e.g. gravel beds, pools, macrophytes, riffles, and woody debris) in these watercourses was also identified along with surrounding land uses.

Notes were also taken on the presence of the following features:

> Surrounding vegetation and riparian vegetation;

> Barriers to fish passage;

> The species and percent cover (in an approximate 100 m reach) of in-stream aquatic vegetation present at each site; and

> The presence of algae or flocculent on the surface of macrophytes was also be noted, if present.

4.2.3.3 In-situ 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 YSI multiprobe. The measurements taken would be used to assist in interpretation of the results of biotic sampling. The EC, DO, pH and turbidity measures were also compared with the ANZECC (2000) default trigger values for slightly disturbed upland rivers in south-east Australia. Specific guidelines are not available for temperature and ORP measures.

4.2.3.4 AUSRIVAS Macroinvertebrates

4.2.3.5 Field and Laboratory Methods

At each site, samples of aquatic macroinvertebrates associated with the pool edge habitat were collected by using dip nets (250 µm mesh) to agitate and scoop up material from vegetated areas of the river bank. Samples were collected over a period of 3 to 5 minutes from a 10 m length of habitat along the river, in accordance with the AUSRIVAS Rapid Assessment Method (RAM) (Turak *et al*. 2004). If the required habitat was discontinuous, patches of habitats with a total length of 10 m were sampled. Each RAM sample was rinsed from the net onto a white sorting tray from which animals were picked using forceps and pipettes. Each tray was picked for a minimum period of forty minutes, after which they were picked at ten minute intervals for either a total of one hour or until no new specimens were found. Samples were preserved in alcohol and transported to the laboratory for identification and subsequent derivation of biotic indices and assessment of habitat and water quality using the AUSRIVAS modelling software.

AUSRIVAS samples were sorted under a binocular microscope (at 40 X magnification) and identified to family level with the exception of Oligochaeta and Polychaeta (to class), Ostracoda (to subclass), Nematoda and Nemertea (to phylum), Acarina (to order) and Chironomidae (to subfamily). Up to ten animals of each family were counted, in accordance with the latest AUSRIVAS protocol (Turak *et al*. 2004). There is a possibility, albeit unlikely, that two threatened aquatic macroinvertebrate species (Adams emerald dragonfly and Sydney hawk dragonfly) occur in the Study Area. Therefore, if any individuals of the family Austrocorduliidae and Gomphomacromiidae were found these would have been identified to species level. However, no specimens from these families were found (**Section 4.3.4**).

4.2.3.5.1 AUSRIVAS Model

The AUSRIVAS protocol uses an internet-based software package to determine the environmental condition of a waterway based on predictive models of the distribution of aquatic macroinvertebrates at reference sites (Coysh *et al.* 2000). The ecological health of the creek is assessed by comparing the macroinvertebrate assemblages collected in the field (i.e. 'observed') with macroinvertebrate assemblages expected to occur in reference waterways with similar environmental characteristics. The data from this study were analysed using the NSW models for pool edge habitat sampled in spring. The AUSRIVAS predictive model generates the following indices:

> 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 scores 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 that indicate the level of impairment of the assemblage. These bands are graded as described in **Table 4-3**.

Table 4-3 AUSRIVAS Bands and corresponding OE50 Taxa Scores for AUSRIVAS edge habitat sampled in spring

Band	Description	Spring OE50 Score
X	Richer invertebrate assemblage than reference condition	>1.16
A	Equivalent to reference condition	0.84 to 1.16
B	Sites below reference condition (i.e. significantly impaired)	0.52 to 0.83
C	Sites well below reference condition (i.e. severely impaired)	0.20 to 0.51
D	Impoverished (i.e. extremely impaired)	≤0.19

The 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 between 1 and 10 to each macroinvertebrate family, based largely on their responses to chemical pollutants. The sum of all grade numbers for that site was then divided by the total number of families recorded in each site to obtain an average SIGNAL2 index. The SIGNAL2 index therefore uses the average sensitivity of macroinvertebrate families to present a snapshot of biotic integrity at a site. SIGNAL2 values are as follows:

> SIGNAL > 6 = Healthy habitat;

> SIGNAL 5 – 6 = Mild pollution;

> SIGNAL 4 – 5 = Moderate pollution; and

> SIGNAL < 4 = Severe pollution.

4.2.3.6 Fish

Fish were sampled using a backpack electrofisher (model LR-24 Smith-Root) and baited traps. At each site, four baited traps were set for approximately one hour in a variety of habitats, such as amongst aquatic plants and snags, in deep holes and over bare substratum. Bait traps were approximately 30 cm x 30 cm x 40 cm with 0.3 cm aperture mesh and a 3 cm opening and were unbaited. The backpack electrofisher was operated around the edge of pools and in riffles (if present), with four two minute shots being performed at each site. Fish stunned by the current were collected in a scoop net, identified and measured. All captured fish would be handled with care to minimise stress and be released as soon as possible.

4.3 Results

4.3.1 Key Fish Habitat

Wongawilli Creek (**Appendix C-i** to **iii**) and Donalds Castle Creek (**Appendix C-iv** to **vi**) downstream of DC13 (and within the Study Area) provide Type 1 – Highly sensitive KFH, and contain areas of aquatic plants, large rocks, large wood debris. It is noted that Donalds Castle Creek is smaller (in terms of channel width, water and pool depth) and provides less abundant and diverse fish habitat than Wongawilli Creek.

First and second order streams, such as the reach of Donalds Castle Creek upstream of DC13 Donalds Castle Creek and the 1st and 2nd order drainage lines, are not considered KFH (**Section 2.3**). Nevertheless, this section of Donalds Castle Creek and the lower reaches of drainage lines DC13 and WC21 in particular provide somewhat permanent aquatic habitat in the form of larger pools connected by flow. Further upstream of here and in the other drainage lines with aquatic habitat becomes increasingly limited as baseflow reduces due to the smaller sub-catchment areas. While these areas may contain some rocks and wood debris, they would have intermittent flow, with disconnected pools that would provide sporadic refuges for aquatic fauna such as fish and freshwater crayfish, if present. Furthermore, several substantial natural barriers to fish passage (such as waterfalls, cascades, and low flow over rock bars) were present on these drainage lines which generally have much steeper grades than the larger creeks. This would limit the number and type of fish species present to those capable of passing such barriers, such as climbing galaxiid. Donalds Castle Creek also transitions into swamp just upstream of Site X1.

4.3.2 Aquatic Habitat and Vegetation

Results of the RCE assessment are provided in **Appendix B-ii**. Total scores raged from 46 to 47 on Wongawilli Creek and were 48 for each site on Donalds Castle Creek. These are relatively high and indicative of largely undisturbed systems. All sites scored high (i.e. 4, no evidence of disturbance) in categories associated with the condition of riparian vegetation and channel morphology. While there was some evidence of sediment accumulation, this appears to be a natural occurrence given the undisturbed nature of the surrounding environment. The slightly higher scores for Donalds Castle Creek were due a greater abundance of wood debris here and less green algae.

The riparian and surrounding vegetation in the reaches of Wongawilli Creek and Donalds Castle Creek was comparable to that observed during previous investigations. It is dominated by dry Eucalypt forest which extends to the banks of the creeks. Along the banks there are numerous native grasses, shrubs and trees including saw grass (*Gahnia* sp.), mat rush (*Lomandra* sp.), wattles (*Acacia* sp.), and tea-tree (*Leptospermum* sp.). Stream banks consisted mainly of well vegetated sandy soil with little erosion or undercutting evident and extensive overhanging vegetation along the stream margin. There were numerous in-stream habitat features, including snags and tree roots. The main channel of Donalds Castle Creek consists of a series of relatively small permanent pools with sand substratum and some areas of bedrock, boulder and gravel. These pools are connected by narrow channels with a mainly sand substratum with small sections of gravel riffles and some sandstone rockbars with small cascades up to 1 metre in height. It is expected that this connectivity between pools would not persist through extended dry periods. The water within both creeks appeared very clear and there was no sign of contamination such as odour, emulsion, or discolouration.

Riparian vegetation and bank structure along drainage lines is very similar to that along Donalds Castle Creek. The primary difference in aquatic habitat between most drainage lines and Donalds Castle Creek is the relatively smaller size and reduced connectivity of pools in drainage lines. This would limit the amount of aquatic habitat available for aquatic flora and fauna. Nevertheless, the abundance of this habitat means that, cumulatively, it provides a substantial contribution to overall aquatic habitat in the Study Area. One exception was DC13 which joins Donalds Castle Creek just above Site 17. This drainage line was indistinguishable from Donalds Castle Creek at the point of confluence.

The only aquatic macrophyte observed was *Myriophyllum* sp. at Site 5 and Site 20 on Wongawilli Creek. Green filamentous algae were also abundant at Sites 19 and 20 on Wongawilli Creek. This vegetation can be indicative of nutrient enrichment.

Table 4-4 Species and percent cover of aquatic plants identified at each sampling site

Taxon	Site 5	Site 19	Site 20	Site X1	Site 17	Site 18
Myriophyllum sp.	15 %		10 %			
Green filamentous algae		60 %	15 %			40 %

4.3.3 *In-situ* Water Quality

The findings of the water quality sampling on Wongawilli Creek and Donalds Castle are presented in **Table 4-5**, the main findings were:

> Temperature ranged from 10.2 to 13.5 C and was comparable between Wongawilli Creek and Donalds Castle Creek;

> EC was within DTVs and ranged from 30 to 94 µS/cm.

> pH ranged from 5.2 to 5.4 and was slightly greater in Wongawilli Creek. It was below the lower DTV on each occasion;

> DO ranged from 53.9 % to 93.9 % saturation and was within DTVs at each site on Wongawilli Creek and below the lower DTV at each site on Donalds Castle Creek. Naturally low DO is likely associated with decomposition of organic matter in pools, and

> Turbidity ranged from 0.0 to 3.2 NTU and was below the lower DTV at each site.

Measures of water quality on Wongawilli Creek and Donalds Castle Creek were comparable with those measured previously on these creeks by Cardno. Naturally low pH. DO and turbidity is not cause for concern (**Section 3.4**)

Table 4-5 Mean in-situ water quality measures from each sampling site. Grey shading indicates value outside of DTV.

Measure	DTV	Site 5	Site 19	Site 20	Site X1	Site 17	Site 18
Temp (°C)		12.0	10.8	10.7	13.5	10.2	10.8
Cond (µS/cm)	30-350	30	77	70	30	91	94
pH	6.5-8.0	5.4	5.4	5.4	5.4	5.2	5.2
ORP (mV)		212	212	214	230	232	220
DO (%Sat)	90-110	92.3	93.8	93.9	88.0	53.9	85.1
Turbidity (NTU)	2-25	0.0	0.0	0.0	0.0	1.2	3.2

Standard errors <0.01 in each case, n = 2. Default Trigger Values (DTV) taken from ANZECC/ARMCANZ (2000) guidelines for slightly disturbed upland rivers in southeast Australia. Grey shading indicates measure outside of DTVs.

4.3.4 AUSRIVAS Macroinvertebrates

The macroinvertebrate taxa identified from each AUSRIVAS sample are provided in **Appendix D**. The number of taxa, OE50 Taxa Scores and SIGNAL2 Indices for each of the AUSRIVAS samples are provided in **Table 4-6**. The number of taxa found at each site ranged from 8 to 23 with fewer tending to be found on Donalds Castle Creek than in Wongawilli Creek. OE50 Taxa Scores ranged from 0.37 (Band C) to 1.16 (Band A) and were greater on Wongawilli Creek than on Donalds Castle Creek. SIGNAL2 Indices ranged from 3.6 (indicative of severe water pollution) to 5.3 (indicative of mild water pollution). While these scores may indicate some form of water pollution, pollution sensitive taxa were caught, including leptophlebiids (SIGNAL2 Score: 8), which were present at each site sampled. It is noted also that while several relatively pollution tolerant taxa were caught, these would also be expected to be present in un-polluted water. No. of Taxa and SIGNAL2 Indices on Donalds Castle Creek are within the range of values sampled previously in this creek as part of the DA3B aquatic ecology monitoring (**Section 3.5**). Those from the other sites sampled are also comparable to those from across from previous sampling in the Dendrobium Area 3A and 3B areas (Cardno Ecology Lab 2013; 2014; 2015; 2016). As appeared to be the case in these previous investigations, low SIGNAL2 Indices are more likely reflective of natural water quality, rather than any anthropogenic disturbance. Neither Adams emerald dragonfly, or Sydney hawk dragonfly were identified in the AUSRIVAS samples.

Table 4-6 Total number of taxa, OE50 Taxa Scores and SIGNAL2 Indices for each of the AUSRIVAS samples

		Wongawilli Creek			Donalds Castle Creek	
Indicator	Site 5	Site 19	Site 20	Site X1	Site 17	Site 18
Number of Taxa	23	15	16	11	10	8
OE50 Taxa Score	1.16	0.78	0.97	0.72	0.72	0.37
Band Score	A	B	A	B	B	C
SIGNAL2 Index	4.5	5.1	5.0	3.6	4.1	5.3

4.3.5 Fish

The total number of each species of fish and freshwater crayfish caught whilst backpack electrofishing at each site is presented in **Table 4-7**.

Table 4-7 Total numbers of each species of fish species and freshwater crayfish caught whilst electrofishing at sites within the Study Area. Obs = observed

Species	Site 5	Site 19	Site 20	Site X1	Site 17	Site 18
Galaxid (*Galaxias* sp.)	2				1	1
Australian smelt (*Retropinna semoni*)			>20			
Freshwater crayfish (*Euasticus* sp.)	Obs	Obs	Obs			Obs

No fish were caught in bait traps. Galaxids (*Galaxais* sp.) were caught at Site 5, Site 17 and Site 18. These were caught previously in the Dendrobium Mine area. Numbers of fish caught are comparable with those caught in other watercourses that traverse Dendrobium Area 3 (Cardno Ecology Lab 2013; 2014; 2015; 2016a, b).

4.4 Existing Mining Impacts to Watercourses

Cardno (2018b) undertook a review of existing mining impacts that have occurred due to previous and existing mining in the upper Avon and Cordeaux River catchments. These include the following mining in the Metropolitan Special Area:

> Longwall mines: Dendrobium Areas 1, 2, 3A, Dendrobium DA3B Longwalls 9 to 13, Elouera Mine, Cordeaux Mine, Kemira Mine; and

> Bord and pillar mines: Nebo Mine and Wongawilli Mine.

Subsidence induced impacts (fracturing, flow diversions and/or reductions in pool water levels) have been observed in watercourses overlying each of the previous mine areas. To provide an indication of the cumulative impact of these mines on aquatic ecology in these and the upper Avon and Cordeaux River catchments, the length of watercourse known or expected to experienced subsidence related impacts was calculated by the Illawarra Coal Environmental Field Team (ICEFT). As of May 2018, of the 716 km of watercourses (first order and above) mapped within the upper Avon and Cordeaux River catchments, direct mining impacts (fracturing, flow diversions and/or pool water loss) had or were highly likely to have occurred in approximately 36 km of watercourses located directly above longwall mining. This included first, second and higher order streams within the Wongawilli, Sandy and Donalds Castle Creek Catchments. The most recent impacts observed include fracturing, flow diversions, reductions in pool water levels in SC10C (a tributary of Sandy Creek) and WC17 (a tributary of Wongawilli Creek) in DA3A and in WC21 (a second order tributary of Wongawilli Creek) and in the upper Donalds Castle Creek in DA3B. In each case there was an associated loss of aquatic habitat and likely also biota. At the scale of individual watercourse, the length of complete habitat loss in WC21 was 1,710 m and 291 m in Donalds Castle Creek. These impacts in WC21 represented a relatively severe impact to aquatic ecology at the scale of the watercourse (Cardno 2018a). Approximately 77 km of watercourse is located above previous bord and pillar mining. Based on observations of impacts due to longwall mining there is potential for these to have also experienced direct subsidence related impacts similar to that experienced above longwall mining. The most severe watercourse impacts described above (fracturing and flow diversions resulting in part or complete drainage of pools and loss of surface water) tend to occur when watercourses are directly mined under. However, such impacts may also occur in watercourses that are not directly mined under. A further 18 km of watercourse located directly downstream of longwall mining is expected to have experienced indirect impacts (including reductions in pool water levels and flow). Fracturing of rockbars was observed in Donalds Castle Creek, LA4 (tributary of Lake Avon) and WC15 (a tributary of Wongawilli Creek) 100 m to 300 m from DA3B longwalls. Fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield (MSEC 2019).

Collectively, the length of watercourse that has experienced indirect and direct mining impacts is estimated to be 16 % of that present in the upper Avon and Cordeaux River catchments. The majority of this would be first and second order drainage lines. However, impacts of groundwater depressurisation have recently been observed in Wongawilli Creek. During inspections in May 2018, a reduction in flow and a series of disconnected pools were observed within an approximate 1,400 m section of Wongawilli Creek upstream of the Study Area in DA3B (representing about 10 % of its 12 km total length). This section was adjacent to Longwalls 9, 10 and 11 and included Pool 41 to Pool 44 (Pool 36 lies within this extent). Surface flow was observed just downstream of the confluence with Wongawilli Creek tributary WC21. Although fracturing in one rockbar at Pool 43a in Wongawilli Creek was observed during extraction of Longwall 9 in December 2012, this is not considered to be the cause of the reduced flow and reduction in pool water levels here. Rather, assessment of flow and water level data with rainfall and rates of pool water recession from before and after commencement of mining and the timing of fracturing suggest mining induced groundwater depression coinciding with low rainfall explain the low flow and water levels observed in Wongawilli Creek (Watershed HydroGeo 2018). Low pool water levels were not restricted to Pool 43a but were also observed in Pool 49. Pool water levels also begun to decline 2 years before the fracture was observed. The pool recession rate, calculated as the decline in pool level between consecutive observations averaged over the number of days, was not greater after the observation of the fracture. Mining is considered to be the primary cause of reductions in groundwater levels in the lower Hawksbury Sandstone and upper Bulgo Sandstone. This has contributed to a reduction in baseflow in Wongawilli Creek, which was most noticeable during periods of low rainfall and greater evapotranspiration that occurred in 2018. Extraction of each individual longwall would be expected to contribute to reductions in groundwater levels. Hydrosimulations (2018) in Watershed HydroGeo (2018) estimated baseflow capture of approximately 0.3 ML/d in Wongawilli Creek, this would be a significant fraction of flow under conditions of very low rainfall such as those that have occurred during 2018 with typical surface flow below 1 ML/day (Watershed Hydrogeo 2018). It is noted that a significant mining effect on surface flow in Wongawilli Creek was not apparent approximately 3 km downstream at gauge WWL.

Pool water levels and flow is also restored following rainfall events, thus impacts to the availability and connectivity of aquatic habitat is temporary. Nevertheless, these temporary impacts would be expected to affect aquatic biota. Changes in the abundance of several macroinvertebrate taxa in SC10C, WC21 and Donalds Castle Creek were attributed to reductions in pool water levels observed here (Cardno 2018a). These included reductions in the numbers of pollution sensitive (e.g. leptophlebiids (mayflies)) and pollution tolerant (e.g. chironomids (non-biting midges) taxa. Temporary reductions in longitudinal connectivity would also be expected to affect fish and aquatic macroinvertebrates by limiting movement in search of food and refuge. It may also result in reduction in genetic transfer, particular if it coincides with migration as part of reproduction. Species of freshwater eel (Anguilla sp.), for example, undertake long distance reproductive migration that could be hindered during times of low flow and pool water level. As well as direct habitat loss, associated reductions in water quality could also affect the type and number of macroinvertebrates and other aquatic biota (fish, large mobile invertebrates and aquatic macrophytes) in watercourses. However, the changes in water quality observed that are associated with mining (reduced dissolved oxygen and elevated electrical conductivity) have been relatively minor. Changes in macroinvertebrates appear to be localised to the areas of watercourse directly affected by physical mining impacts and habitat loss. They do not appear to persist downstream once water reappears (Cardno 2018a).

In addition to the Project, future mining is proposed in DA3B (Longwalls 14 to 18), DA3A (Longwall 19) and Area 5 and Area 6. These are located within the upper Avon River and Cordeaux River Catchments (including catchments of Wongawilli Creek, Donalds Castle Creek and tributaries of Lake Avon and Lake Cordeaux). Further, approximately 37 km (5 %) of watercourse is located above the proposed Area 5 and Area 6 longwalls and would be expected to experience direct mining induced impacts comparable to that observed above previous mine areas.

4.5 Summary

The findings of the current and previous investigations indicated that Wongawilli Creek, Donalds Castle Creek and their drainage lines within the Study Area for Longwalls 20 and 21 are largely undisturbed. Wongawilli Creek and lower reaches of Donalds Castle Creek provides the most substantial habitat for native fish, aquatic plants and macroinvertebrates. The upper reaches of Donalds Castle Creek and the lower reaches of the larger drainage lines also provide important aquatic habitat in the form of larger pools. The listed threatened Macquarie perch is likely to be present in Wongawilli Creek downstream of the Study Area, though the presence of natural barriers and its apparent absence in this and previous targeted surveys upstream of here suggests it is unlikely to occur in the section of creek within the Study Area. Based on previous surveys, natural barriers to fish movement and habitat requirements, this species is highly unlikely to occur in Donalds Castle Creek and drainage lines within the Study Area. Other threatened species (Australian grayling, Adams emerald dragonfly and Sydney hawk dragonfly) do not, or are highly unlikely to, occur in the Study Area. There is very little evidence of invasive plant species instream or within the riparian zone. The current and previous investigations indicate that the aquatic ecology in sections of these watercourses in the Study Area are comparable with that present throughout the larger catchment area. The crossing of Fire Road 6 is the only major artificial structure that would hinder fish passage along the creek. Sections of Wongawilli Creek, Donalds Castle Creek and their drainage lines have, and continue to, experience impacts associated with past and current mining-related impacts in DA3A and DA3B (**Section 4.6**).

5 Assessment of Impacts

5.1 Predicted Ground Movements

South32 have reduced the potential for mining induced impacts in watercourses by setting the proposed longwalls back from Wongawilli Creek by a minimum of 125 m and from Donalds Castle Creek by a minimum of 490 m. The mine has also been designed so that predicted valley closure (reduction in the horizontal distance between valley sides) is no greater than 210 mm. Based on monitoring data from Dendrobium Mine, this is likely to reduce the rate of rockbar fracture resulting in flow diversion and a reduction pool water levels to less than 10 % (MSEC 2019). This is an average value based on data from Dendrobium Mine (and across the Southern Coalfield) and fracture rates also depend on many factors, including other ground movements and importantly, existing natural compressive strains present in the bedrock. (e.g. a rockbar may naturally experience closure making it more susceptible to fracturing under small additional closure following mining).

The extraction of coal from the proposed longwalls will result in vertical and horizontal movements of the rock and soil mass directly above and immediately adjacent the extracted coal seam (i.e. subsidence). Subsidence that occurs under surface watercourses is likely to result in fracturing of the streambed and banks, movements of joints and bedding plates in the streambed, uplift and buckling of rock strata in the streambed. Fracturing of bedrock and diversion of surface flows in watercourses depends on the magnitude of subsidence movements, valley-related upsidence and closure movements (MSEC 2019). MSEC (2019) assess ground movements that would occur in watercourses within 600 m of the longwalls (fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield). Ground movements can also lead to tilting of streambeds that can, in turn, lead to erosion of the streambed and banks and increased instream sediment load, changes in flow rates and migration of stream channels. Subsidence may also allow the release of gas from sub-surface strata that could affect water quality and, in some cases, lead to dieback of riparian vegetation. Subsidence can potentially result in increased levels of ponding in locations where the mining induced tilts oppose and are greater than the natural drainage line gradients that exist before mining. The potential for changes to the level of ponding, flooding and scouring of banks along watercourses depends on whether the net vertical movements brought about by longwall mining alters the gradients of the watercourses. Mining can also potentially result in an increased likelihood of scouring of the banks in the locations where tilts considerably increase natural gradients. Mining induced tension and compression can also result in dilation and bed separation in the topmost bedrock.

The location of watercourses relative to Longwalls 20 and 21 and ground movements predicted to occur in each is summarised as follows:

- The maximum predicted movements of Wongawilli Creek, located at least 125 m from Longwalls 20 and 21, would include less than 20 mm vertical subsidence, 60 mm upsidence and 210 mm closure. The predicted changes in grade along the creek would be < 0.05 %, or 1 in 2000. The average natural grade of the section of Wongawilli Creek within the Study Area is approximately 0.37 % or 1 in 270. Fracturing could occur along the section of Wongawilli Creek that is located within a distance of approximately 400 m from the proposed longwalls. The rate of fracturing resulting in surface water flow diversions for the rockbars located within the Study Area would be less than 10 %.
- The maximum predicted movements of Donalds Castle Creek, located at least 490 m from Longwalls 20 and 21, would be less than 20 mm vertical subsidence, 80 mm upsidence and 170 mm closure. This includes the predicted subsidence for previous mining at DA3B. Subsidence movements due to extraction of LW20 and LW21 are less than 20 mm vertical subsidence, less than 20 mm upsidence and less than 20 mm closure. The predicted changes in grade along the creek would be < 0.05 %, or 1 in 2000. The average natural grade of the section of Donalds Castle Creek within the Study Area is approximately. 3.5 %, or 1 in 30. Based on impacts observed during previous mining, it is considered unlikely that fracturing would occur along Donalds Castle Creek due to the extraction of Longwall 20 and Longwall 21 due to the low-levels of predicted movements and its distance from the proposed longwalls.
- The drainage lines are located across the Study Area, with some directly above the longwalls, and could experience subsidence of up to 1,700 mm. The maximum predicted change in grade is 3.0 % or 1 in 33.

The natural gradients of the drainage lines vary from 10 to 20 %. It is expected that fracturing would occur along the sections of the drainage lines that are located directly above the proposed LW20 and LW21. Surface water flow diversions are also likely to occur along the sections of drainage lines that are located directly above and adjacent to the proposed longwalls.

The predicted vertical and horizontal movements at Lake Cordeaux and Lake Avon and their dam walls are very small and are unlikely to be measurable. Previous experience of mining in DA1, DA2, DA3A and DA3B has not resulted in adverse impacts on these structures. It is unlikely that the reservoirs and dam would experience adverse impacts due to the extraction of the proposed longwalls (MSEC 2019). Water quality effects on stored waters of the reservoirs are expected to be negligible and undetectable (HGeo 2019). Thus, impacts to these features are not considered further.

5.2 Impacts on Aquatic Ecology

Physical impacts such as creek bed fracturing may cause diversion of surface and sub-surface flows, drainage of pools and increases in groundwater inflows. These changes, in turn, may have adverse effects on aquatic flora and fauna via reductions in the amount of aquatic habitat, desiccation of fringing vegetation and reductions in longitudinal connectivity. The impact of changes in surface and sub-surface flows on the availability of aquatic habitats is likely to be greater if it coincides with periods of low or no flow. The duration of these impacts on aquatic habitats depends on the characteristics of the watercourses, such as substratum type, and subsequent flow events. In some cases, cracks in bedrock may be filled partially or completely by alluvial deposits during subsequent flow events. Aquatic habitat can also be adversely affected by changes in water quality resulting from mine subsidence impacts. The assessment of impacts to aquatic habitat was undertaken with consideration of amount (linear length) of watercourse that would be affected by physical mining impacts, their severity, and the amount of comparable watercourse present in the wider catchment and that would remain unaffected by the mining.

The assessment of potential impacts on aquatic ecology arising from the extraction of Longwalls 20 and 21 was based on the maximum predicted movements for the sections of Wongawilli Creek, Donalds Castle Creek and the drainage lines that flow through the Study Area and their predicted impacts on the physical (MSEC 2019) and surface water (HGeo 2019) characteristics of the waterways. **Table 5.1** summarises the predicted geophysical, water availability and quality impacts to watercourses predicted due to subsidence associated with extraction of Longwalls 20 and 21 and the associated consequences for aquatic habitat and biota in the Study Area.

Table 5-1 Predicted physical impacts and associated impacts to aquatic ecology in watercourses in the Study Area due to proposed longwalls 20 and 21

Watercourse	Attribute	Predicted Physical and Chemical Impacts	Predicted Impacts on Aquatic Habitat and Biota
Wongawilli Creek	Ponding, flooding and scouring of stream banks due to subsidence induced tilt	Localised changes in the levels of ponding or flooding are possible where the maximum changes in grade coincide with existing pools, steps or cascades along the creek. It is not anticipated that these changes would result in adverse impacts on the creek since the predicted changes in grade are less than 0.05 %. The natural grade is 0.37 % or 1 in 270. Adverse changes in the potential for ponding, flooding or scouring of the banks along the creek due to the mining-induced tilt are unlikely.	Measurable effects on the availability and connectivity of most aquatic habitats are unlikely. There is potential for minor, localised changes in the availability of aquatic habitat in some pools. Associated impacts to aquatic biota, if they occur, are therefore expected to be minor and localised.
	Fracturing of bedrock and diversion of surface flows due to subsidence induced strain	The overall likelihood of significant fracturing resulting in surface water flow diversions at the rockbars along Wongawilli Creek is 7 % (based on the rate of rockbar fractures experienced in DA3B due to extraction of Longwalls 9 to 12). Minor fracturing could occur along the creek at distances up to approximately 400 m from the proposed longwalls.	Risk to aquatic biota due to loss of habitat associated with flow diversions would depend on the number of rockbars that would be affected and the size of the associated upstream pools (where water may be lost from following any fracturing of controlling rockbars). Seventeen rockbars are located in Wongawilli Creek within 600 m of Longwalls 20 and 21. Based on the predicted fracture rate, it would be expected that on average one of these would experience fracturing associated with flow diversions. The length of aquatic habitat that would be affected due to flow diversions is expected to be approximately 22 m (the average length of the seventeen pools upstream of rockbars). However, this assumes that flow diversions are restricted to the pool immediately upstream of the affected rockbar. The potential loss of habitat could also be greater (pools range in length from 3 m to 100 m). The potential drainage of smaller pools would represent a relatively minor impact in the context of the length of pool habitat within the Study Area (365 m). The loss of the largest pool (100 m in length) does, however, represent a relatively large impact to aquatic habitat and biota in the section of creek within the Study Area. This would manifest in a reduction in population size of aquatic biota associated with pool habitat (fish and many macroinvertebrates). Though it is noted also that water may not drain from the entire pool due to the presence of unmapped subsurface rockbars or other restrictions e.g. logs/riffles. Thus, loss of habitat and biota loss may not occur throughout an entire pool. A complete drainage of a pool or section of pool would reduce longitudinal connectivity in the creek and impact the ability of aquatic biota to move in search of food and refuge. Ongoing reductions in connectivity could alter the fish assemblage in Wongawilli Creek, particularly in upstream sections that are fragmented from connected waterways downstream. Freshwater eels (*Anguilla* sp.), which undertake long distance migrations, may reduce in abundance within disconnected sections upstream following impacts to connectivity. However, based on the low rate of fracture that would result in flow diversions and the size range of associate pools, the probability of fracturing resulting in large reduction in pool habitat is expected to be low. In isolation, impacts

			associated with extraction of Longwalls 20 and 21 would also be expected to be relatively minor in the context of the Avon and Cordeaux River catchments. Minor and isolated fracturing, if it occurs, would not cause any significant diversion of surface flows although it could cause localised reductions in the availability of aquatic habitat.
	Water Quality and Availability	Baseflow to Wongawilli Creek may decline by 0.20 ML/day (approximately 1.6 % of mean annual flow) due to groundwater depressurisation following longwall extraction (HGeo 2019). The cumulative effects of DA3B and Longwalls 20 and 21 would be to further reduce flows by about 1.3 ML/d. This could result in zero flow conditions up to 44% of the time (i.e. 146 out of 365 days) compared with natural conditions (10 % of the time), although 12 % to 15 % of the time (an increase from 37 to between 44 and 54 days per year) is considered more likely based on available pre and post-mining data (HGeo 2019). The effect on overall catchment yield of the Cordeaux River catchment are expected to be negligible. Impacts to water quality due to mining are expected to be minor in stream reaches within subsidence affected areas (HGeo 2019). Effects are likely to include slight and temporary changes in water salinity, pH and iron content with local discolouration of streambeds and rock faces by iron hydroxide.	The severity of any impact on aquatic biota would depend on several factors, including the timing and duration of zero flow periods. An overall reduction in base flow and increase in the number of zero flow days would impact aquatic habitat and biota in Wongawilli Creek. Although the reduction in baseflow would be small, the predicted increase in zero flow days would reduce longitudinal connectivity in the watercourse and possibly also the amount of aquatic habitat available to biota if pool levels also decrease during these periods. If pools do not drain completely then these would provide refuge for aquatic biota until flow returns. It is expected that such impacts to aquatic habitat and biota would be restricted to sections of Wongawilli Creek adjacent to mining, as there would be negligible impact to the overall yield of the Cordeaux River catchment. Impacts to aquatic habitat and biota due to changes in water quality appear unlikely as only minor changes in water quality are expected.
Donalds Castle Creek	Ponding, flooding and scouring of stream banks due to subsidence induced tilt	The predicted changes in grade (<0.05 %) due to the extraction of LW20 and LW21 are considerably less than the average natural grade (3.5 %). Thus, there is unlikely to be adverse changes in the potential for ponding, flooding or scouring of the banks along the creek.	Measurable effects on the availability and connectivity of most aquatic habitats is unlikely. Minor, localised changes in the availability of aquatic habitat in some pools is possible.
	Fracturing of bedrock and diversion of surface flows due to subsidence induced strain	Fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield. Donalds Castle Creek is located 490 m from the maingate and finishing end of LW20, at its closest point to the proposed longwalls. It is considered unlikely, therefore, that fracturing would occur along Donalds Castle Creek due to the low-levels of predicted movements and its distance from the proposed longwalls.	Impacts to aquatic habitat in biota occurring in Donalds Castle Creek are not expected due to the low likelihood of fracturing occurring here.

	Water quality and availability	Base flow of Donalds Castle Creek may decline by 0.14 ML/day (approximately 8.5 % of mean annual flow) due to groundwater depressurisation following longwall extraction (HGeo 2019). The cumulative effects of DA3B and Longwalls 20 and 21 would be to further reduce flows by about 0.4 ML/d. This could result in increased cease-to-flow conditions compared with natural conditions (2 % to 3 % of the time) to up to 3 % to 5% based on available pre- and post-mining data (HGeo 2019). The effect on overall catchment yield of the Cordeaux River catchment are expected to be negligible. Impacts to water quality due to mining are expected to be minor in stream reaches within subsidence affected areas (HGeo 2019). Effects are likely to include slight and temporary changes in water salinity, pH and iron content with local discolouration of streambeds and rock faces by iron hydroxide.	The severity of any impact on aquatic biota would depend on several factors, including the timing and duration of zero flow periods. An overall reduction in base flow and increase in the number of zero flow days would impact aquatic habitat and biota in Donalds Castle Creek. Although the reduction in baseflow would be small, the predicted increase in zero flow days would reduce longitudinal connectivity in the watercourse and possibly also the amount of aquatic habitat available to biota as pool water levels decrease due to evaporation during these periods. This would depend on the size of pool, temperature and several other factors. If pools do not drain completely then these would provide refuge for aquatic biota until flow returns. It is expected that such impacts to aquatic habitat and biota would be restricted to sections of Donalds Castle Creek adjacent to mining, as there would be negligible impact to the overall yield of the Cordeaux River catchment is predicted. Impacts to aquatic habitat and biota due to changes in water quality appear unlikely as only minor changes in water quality are expected.
Drainage Lines	Ponding, flooding and scouring of stream banks due to subsidence induced tilt	Although predicted changes in grade (3 %) are larger as a proportion of the natural grade (10 % to 20 %), compared with that for creeks, it is unlikely that there would be large-scale adverse changes in the levels of ponding or scouring of the banks along these drainage lines due to subsidence induced tilt. It is possible that localised increased ponding could develop in some isolated locations, where the natural grades are small and where the drainage lines exit the mining area.	Localised changes in habitat availability and connectivity may occur along the drainage lines but will be difficult to detect due the large variability in grade and natural flows within these ephemeral systems. The impacts resulting from the changes in surface water flows are expected to be small in comparison with those which occur during natural flooding conditions. Consequently, impacts to aquatic habitat and biota, if any, are expected to be minor and localised.
	Fracturing of bedrock and diversion of surface flows due to subsidence induced strain	Fracturing is expected to occur along the sections of the drainage lines that are located directly above the proposed LW20 and LW21. Fracturing can also occur outside the extents the proposed longwalls, with minor and isolated fracturing occurring at distances up to approximately 400 m. Surface water flow diversions are also likely to occur along the sections of drainage lines that are located directly above the proposed longwalls. In times of heavy rainfall, the majority of the runoff would flow over the fractured bedrock and soil beds and would not be diverted into the dilated strata below. In times of low flow, however, surface water	Fracturing induced flow diversions in the highly ephemeral drainage lines directly above the longwalls would result in a reduction the amount of aquatic habitat. However, smaller drainage lines such as these are limited in habitat value for aquatic biota. Flow diversions would reduce the volume and duration of flow in these ephemeral drainage lines. Approximately 1,600 m of drainage lines occur directly above the longwalls.

	flows can be diverted into the dilated strata below the beds.	
Water quality	Impacts to water quality due to mining are expected to be minor in stream reaches within subsidence affected areas (HGeo 2019). Effects are likely to include slight and temporary changes in water salinity, pH and iron content with local discolouration of streambeds and rock faces by iron hydroxide.	Minor impacts to water quality are unlikely to represent substantial risks to aquatic habitat and biota in drainage lines.

5.2.2 Aquatic Habitat

5.2.2.1 Ponding, Flooding and Scouring of Stream Banks

Predictions indicate there will be very small (< 0.05%) changes in the gradients of the reaches of Wongawilli Creek and Donalds Castle Creek within the Study Area. Changes of this magnitude are unlikely to cause significant increases in the levels of ponding, flooding or scouring of banks along these creeks. There is a possibility of localised changes in ponding or flooding in areas where maximum predicted changes in slope of the ground coincide with existing pools, steps or cascades along these watercourses. These could result in changes in the availability of aquatic habitat, but these are likely to be localised. Predicted changes in grade in drainage lines are a greater proportion of their natural grade, though any changes in availability of aquatic habitat resulting from mining induced tilt will likely be negligible due the large variability in grade and natural flows within these ephemeral systems.

5.2.2.2 Fracturing and Flow Diversions

While there is a degree of uncertainty around the predicted rate of rockbar fracturing when applied to individual circumstances (i.e. discrete sections of particular watercourse) (**Section 5.1**), it is possible to make an assessment of the associated impact to aquatic ecology based on predicted fracture rate. Although the likelihood of significant fracturing resulting in flow diversions in Wongawilli Creek is low (≤ 7 %) (MSEC 2018), it is expected at least one of the flow controlling rockbars in Wongawilli Creek would experience fracturing associated with flow diversions (**Table 5-1**). The severity of the associated impacts to aquatic habitat and biota would depend on the magnitude of associated upstream pool water level reductions and the size of the affected pools. Although many of the pools that may be affected are small, some are tens of m long and the largest 100 m long. While the probability of the largest pool being effected is also low (1 in 17), and although the presence of sub-surface rockbars would potentially limit the extent of pool drainage, the loss of a 100 m pool, or part of it, if it were to occur, represents a relatively large impact to the indicial pool and to overall pool habitat (total of 365 m in length) and associated biota in the section of Wongawilli Creek in the Study Area. However, at the scale of the entire watercourse and the upper Avon and Cordeaux River catchments, this loss of habitat would be relatively minor. Fracturing may occur along the creek at distances up to approximately 400 m from the proposed longwalls. Though this would be minor and isolated and not expected to cause any significant diversion of surface flows, it could cause localised reductions in the availability of aquatic habitat. Approximately 2.5 km of Wongawilli Creek is within 400 m of the longwalls and thus may be affected by such impacts.

Drainage lines directly above the longwalls would be most at risk of flow diversions and reductions in aquatic habitat due to a greater potential for subsidence and fracturing to occur here. Smaller drainage lines such as these typically support limited aquatic ecology (i.e. consist of few disconnected pools, if any) and experience flow during and soon after rainfall only. Flow diversions would reduce the volume and duration of ephemeral flows, however, there would not be any fundamental change in habitat type (i.e. it would still be ephemeral watercourse). Approximately 1 km of drainage lines occur directly above the longwalls and would be at high risk of such impacts. Minor and isolated fracturing may also occur in drainage lines up to approximately 400 m from these longwalls. Due to the limited aquatic habitat supported by these drainage lines described above, the limited nature of associated flow diversions that would occur here and the abundance of ephemeral drainage line habitat in the wider catchment, potential consequences to aquatic ecology would be minor. Localised changes in habitat availability and connectivity would also be difficult to detect due to the large variability in grade and natural flows within these ephemeral systems.

Donalds Castle Creek is located at least 490 m from the longwalls and fracturing is not expected to occur here. There is unlikely to be adverse changes in the potential for ponding, flooding or scouring of the banks along the creek. Thus, there is a low risk of impacts to aquatic habitat in biota occurring in Donalds Castle Creek.

5.2.2.3 Water Availability

Where stream flow is partly sustained by the discharge of groundwater from adjacent aquifers (baseflow), groundwater drawdown or depressurisation due to mining can lead to a reduction in baseflow and additional cease to flow/pool dry days (HGeo 2019). It is predicted that extraction of Longwalls 20 and 21 would result in an increase in zero flows on Wongawilli Creek from 10 % of the time (natural conditions) to between 12 %

and 15 % of the time (HGeo 2019). On average, this represents an additional 7 to 17 days of zero flow. On Donalds Castle Creek it would increase from 2 % to 3 % of the time (natural conditions) to up to 5 % of the time, on average, representing an additional 7 to 11 days of zero flow. These predicted changes (assessed at downstream gauging stations) represent relatively minimal changes to natural conditions and are not expected to result in severe reductions in availability and connectivity of aquatic habitat at the scale of watercourses, though changes further upstream may be more significant (HGeo 2019). Some associated reduction in longitudinal connectivity is expected, though disconnected pools would provide refuge for aquatic biota until flow returned to the creeks (**Table 5-1**).

5.2.3 Aquatic Biota

5.2.3.1 Ponding, Flooding and Scouring of Stream Banks

Localised changes in availability of aquatic habitat due to ponding, flooding and scouring of stream banks as a result of subsidence induced tilt are expected to have no more than minor and localised impacts on aquatic habitat (**Section 5.2.2.1**), and thus biota.

5.2.3.2 Fracturing and Flow Diversions

Drainage of pools and loss of aquatic habitat following fracturing leading to flow diversion is likely to have localised, significant impact on aquatic biota, particularly on aquatic plants and sessile animals. The survival of mobile organisms is difficult to predict, it will depend on individual taxon tolerance and response to desiccation and changing water level, their ability to migrate to nearby unaffected areas, weather conditions, the underlying substratum and duration of exposure. Simple experimental observations have indicated variable responses to exposure to air among aquatic macroinvertebrate taxa. Net-spinning caddisfly (Hydropsychidae) larvae respond by commencing crawling before substratum stones dried out, but cased caddis-fly (Conoesucidae) larvae do not move until stones are dry and then they simply drop off (Bergey 2000). This suggests that net-spinning caddis fly larvae may be able to move away from receding water levels, whereas cased caddisfly larvae are more likely to fall into crevices where they desiccate. Gastropod molluscs also differ in their responses to exposure. Physids migrate off stones, and potamopyrgids migrate onto the underside. Streams with soft-sediment substratum may retain moisture within interstices and thus prolong the survivorship of stranded animals. In streams with bedrock substratum with fewer natural refuges except larger cracks and cavities, few organisms may survive complete pool drainage. The tolerance of aquatic biota to exposure is also likely to be longer on cool and rainy days than on hot days. More mobile biota such as freshwater crayfish may be able to relocate to other areas of aquatic habitat. These species can also withstand prolonged periods of drought by retreating into their burrows (NSW DPI 2006). Species of fish, such as freshwater eels and Climbing galaxids, may be able to relocate provided sufficient damp surfaces are available (McDowall 1996). Other species of fish could become isolated and asphyxiate following reductions in water levels and exposure to air.

Based on predictions of fracture and flow diversion the likelihood of extensive reductions in Wongawilli Creek pool habitat is low (**Section 5.2.2.2**). On average, the predicted rate of fracture is expected to result in the drainage of one of the pools within the Study Area. The loss of a relatively small pool (a few m long) would represent a relatively small impact. The loss of the largest pool (100 m long) represents a relatively greater impact to Wongawilli Creek in the Study Area. While the loss of associated aquatic biota represents a severe impact to aquatic biota at the scale of individual pools, at the scale of an entire watercourse and upper Avon and Cordeaux River catchments, impacts to the population size of affected aquatic biota associated with extraction of Longwalls 20 and 21 would be relatively minor.

5.2.3.3 Water Availability

The predicted increase in number of zero flow days in Wongawilli Creek and Donalds Castle Creek is expected to result in some reduction in the amount of aquatic habitat available to aquatic biota, with potential associated reductions in population size. There would also be some reduction in longitudinal connectivity in the watercourse while aquatic biota are unable to move between disconnected pools. The predicted increase in number of zero flow days (on average up to approximately two weeks in the case of Wongawilli Creek) is not expected to result in substantial impacts to aquatic biota associated with fragmentation of habitat and hindrance of movement through the watercourse, as long as flow returned soon afterwards. It would also not be expected that all of these additional low flow days would necessarily occur consecutively, which should limit prolonged periods of low flow.

5.2.3.4 Changes in Water Quality

Fracturing of the stream substrate can result in the development of ferruginous springs (iron staining), alteration of water quality parameters and the mobilisation of trace metals which may in turn affect the health of aquatic ecosystems (HGeo 2019). The destabilisation of surrounding soils due to subsidence could also increase the potential for mobilisation and transport of sediments into watercourses during rainfall events. Impacts to water quality due to mining of Longwalls 20 and 21 are expected to be minor in stream reaches within subsidence affected areas (HGeo 2019). Effects are likely to include slight and temporary changes in water salinity, pH and iron content with local discolouration of streambeds and rock faces by iron hydroxide. Thus, associated risks to aquatic habitat and biota is expected to be low.

5.2.4 Threatened Species

Sydney hawk dragonfly and Adams emerald dragonfly were not found in the AUSRIVAS samples collected during the current study nor have any been found in the samples collected as part of several previous studies within, and adjacent to, the Study Area. While suitable microhabitat for this species occurs in the Study Area, the absence of this species in the numerous collected samples, and its known distribution outside of the Study Area, provides sufficient evidence that it does not currently occur here. Australian grayling also does not occur in the Study Area, thus, assessments of significance for these species were not considered necessary.

Macquarie perch have previously been recorded in the lower reach of Wongawilli Creek downstream of the Study Area, though while habitat (larger pools) suitable for this species does occur in Wongawilli Creek within the Study Area, none have been found during the several fish surveys here and farther upstream. Donalds Castle Creek provides limited fish habitat, unsuitable for Macquarie perch. The presence of several natural barriers to movement of this species on Donalds Castle Creek downstream of the Study Area would also prevent this species utilising the vast majority of this watercourse. Nevertheless, as a precautionary measure an assessment of significance was undertaken for this species in accordance with the Threatened Species Assessment Guidelines (DECC 2007) (**Appendix E**).

These guidelines specify the important factors that must be taken into considered when assessing potential impacts on threatened species, populations, or ecological communities. The factors requiring consideration are:

> How is the Project likely to affect the lifecycle of a threatened species and/or population?
> How is the Project likely to affect the extent and composition of a threatened ecological community?
> How is the Project likely to affect the habitat of a threatened species, population or ecological community?
> Will the Project affect any critical habitat?
> Is the Project consistent with the objectives or actions of a recovery plan or threat abatement plan?
> Is the Project part of a KTP or is it likely to exacerbate a KTP?

The potential for adverse effects on the lifecycle of threatened fish species depends on whether the works are likely to cause loss or degradation of habitat, reduction in water quality, limit their foraging activities and disrupt their reproduction and recruitment. The assessment presented in **Appendix E** indicated the risk of Macquarie perch being impacted by the Project as unlikely. Further monitoring of the Macquarie perch population has been incorporated into the monitoring plan for Longwalls 20 and 21 as a precautionary measure.

5.2.5 Cumulative Impacts

Based on predicted ground movements and associated impacts to water availability and quality (**Section 5.2** and **Table 5.1**), associated impacts to aquatic habitat and biota due to extraction of Longwalls 20 and 21 are expected to be relatively minor compared with impacts that have occurred in the wider upper Avon and Cordeaux River catchments due to historic and current mining (**Section 4.2**). Due to their proximity to Wongawilli Creek, potential impacts associated with Longwalls 20 and 21 do, however, represent a relatively greater risk to aquatic habitat and biota in this watercourse. This is most likely to result from further reductions to base flow in Wongawilli Creek due to potential additional groundwater depressurisation that would occur. Along with low rainfall, this appears to be the cause of extensive but temporary reduced flow and pool water levels further upstream on Wongawilli Creek associated with DA3B longwalls, rather than fracturing induced flow diversions (**Section 4.2**). The fewer longwalls that would be extracted compared with the number in DA3B and the relatively small predicted increase in number of zero flow days that would occur suggests that impacts associated with extraction of Longwalls 20 and 21 would be less severe than those currently experienced in DA3B.

6 Recommendations

Four approaches would be used to manage potential impacts on aquatic ecology within the Study Area for Longwalls 20 and 21:

> Impact minimisation;
> Aquatic ecology monitoring;
> Additional aquatic ecology studies that would be triggered by specific impacts on physico-chemical characteristics of the watercourses; and
> Contingent measures should impacts exceed predictions.

6.1 Impact Minimisation

The potential impacts from the extraction of Longwalls 20 and 21 on aquatic habitats and biota in the watercourses overlying the Study Area would be minimised by adopting a mine layout that does not longwall mine under Wongawilli Creek or Donalds Castle Creek and setting the nearest longwall at least 125 m back from Wongawilli Creek and 490 m back from Donalds Castle Creek. The mine has also been designed to minimise valley closure so that the predicted rate of rockbar fracturing resulting in flow diversions is low (less than 10 %). Temporary erosion and sediment control measures such as sediment fences, sandbag weirs, temporary drains, and temporary silt traps should be installed prior to any minor surface works (e.g. road construction and clearing of vegetation) in the vicinity of watercourses and swamps to prevent the input of sediment into watercourses and perched aquifer systems during rainfall events.

6.2 Monitoring

6.2.1 Background

An aquatic ecology monitoring program would be implemented to:

> Determine the nature and extent of any subsidence-induced impacts on aquatic ecology due to extraction of Longwalls 20 and 21; and
> Assess the response of aquatic ecosystems to any stream remediation and management works implemented.

A comprehensive monitoring plan designed to assess the potential impacts of mine subsidence on aquatic habitat and biota within watercourses of Dendrobium Area 3 was outlined in The Ecology Lab (2007). This monitoring plan was prepared in accordance with the Dendrobium Consent, the Director General's Requirements (DoP) to modify the Dendrobium Area 3 mine area and in support of the SMP application for Dendrobium DA3B. The monitoring plan indicated that baseline sampling would be conducted in impact and control locations four times within a 12 months period, prior to the commencement of longwall mining and that during-extraction and post-extraction monitoring would be undertaken at the same seasonal periods to determine the extent and nature of any impacts and recovery. The plan also advocated a temporally staged monitoring approach be adopted and that impact and control locations relevant to each of Areas A, B and C be monitored over a 12 month period prior to that area's development. The strategic review of the impacts of underground mining in the Southern Coalfield, recommends that baseline studies be conducted at sufficient intensity over a minimum period of 18 to 24 months to gain a better understanding of the variability and seasonality in distribution of flora and fauna, prior to any mining activity (NSW DoP 2008). The review also recommends that replicate surveys be undertaken at sites directly above the mine and at comparable control sites outside the direct impact zone, so that changes and fluctuations due to mining can be distinguished from those due to natural variability.

6.2.1 Sites and Timing

Two types of monitoring sites have been incorporated into the plan: 'impact' sites that may be subject to mine subsidence impacts during and after longwall extraction and 'control' sites that will provide a measure of the background environmental variability within the catchments as distinct from any mine subsidence impacts. Monitoring sites would be established in Wongawilli Creek and Donalds Castle Creek adjacent to

Longwalls 20 and 21 (location and number to be confirmed following consultation and assessment of suitable watercourses, baseline flow, access and timing of longwall extraction), expected to be at greatest risk of an impact due to mining. Impact sites would be located within or immediately downstream of the areas expected to be most at risk of mining related impacts. Ideally, control sites would be located on the same watercourses upstream of where any impacts associated with extraction of Longwalls 20 and 21 (or other extraction) would occur. At least two control sites would be established on each monitored watercourse to provide a measure of natural variability.

Baseline surveys at impact and control sites would be undertaken over a 24 month period prior to the commencement of longwall mining and during and post-extraction monitoring to determine the extent and nature of any impacts and recovery. This would provide a better measure of background temporal variability and provide more confidence regarding potential changes occurring several years into the future. Monitoring specific to Longwalls 20 and 21 would be incorporated into ongoing monitoring in DA3B.

6.2.2 Indicators and Methods

The following indicators of aquatic ecology would be monitored at each site:

> Aquatic habitat;

> *In situ* water quality;

> Aquatic macrophytes;

> Aquatic macroinvertebrates; and

> Fish.

6.2.2.1 Aquatic Habitat

During the first baseline survey, the condition of the aquatic habitat at each site was assessed using a modified version of the Riparian, Channel and Environmental Inventory method (RCE) (Chessman et al. 1997). This assessment involved evaluation and scoring of the characteristics of the adjacent land, the condition of riverbanks, channel and bed of the watercourse, and degree of disturbance evident at each site. Any changes in the condition of the aquatic habitat would be recorded during the subsequent surveys.

During each survey, a comprehensive photo record of each site would be taken to gain an understanding of environmental variation within the watercourses. This would be done by taking standardised photos, using a 2 m tall x 1 m wide T-bar, from the top of the site looking downstream, the middle of the site looking upstream, the middle of the site looking downstream, and the bottom of the site looking upstream.

6.2.2.2 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 would be taken from just below the surface of the water. The measurements taken would be used to help interpret differences in biotic assemblages. The EC, DO, pH and turbidity measures would also be compared with the ANZECC (2000) default trigger values for slightly disturbed upland rivers in south-east Australia. Specific guidelines are not available for temperature and ORP measures.

A more comprehensive assessment of changes in surface water quality at selected sites would be undertaken by ICEFT and other specialist consultants.

6.2.2.3 Aquatic Macrophytes

At each site where instream aquatic macrophytes are present, their species composition and total area of coverage would be recorded. Features such as the presence of algae or flocculant on the surface of macrophytes would also be noted

6.2.2.4 Aquatic Macroinvertebrates

Two methods would be used to sample aquatic macroinvertebrates: the AUSRIVAS protocol for NSW streams (Turak *et al.* 2004) and artificial aquatic macroinvertebrate collectors, a quantitative method developed by Cardno for freshwater environmental impact assessment.

6.2.2.4.1 AUSRIVAS

At each site, samples of aquatic macroinvertebrates associated with the pool edge habitat would be collected by using dip nets (250 µm mesh) to agitate and scoop up material from vegetated areas of the river bank. Samples would be collected over a period of 3 to 5 mins from a 10 m length of habitat along the river, in accordance with the AUSRIVAS Rapid Assessment Method (RAM) (Turak *et al.* 2004). If the required habitat was discontinuous, patches of habitats with a total length of 10 m would be sampled. Each RAM sample would be rinsed from the net onto a white sorting tray from which animals are picked using forceps and pipettes. Each tray would be picked for a minimum period of forty minutes, after which they would be picked at 10 minute intervals for either a total of one hour or until no new specimens are found. These samples would be preserved in alcohol and transported to the laboratory for identification.

In accordance with the AUSRIVAS protocol, RAM samples would be sorted under a binocular microscope (at 40 X magnification), macroinvertebrates identified to family level and up to ten animals of any one taxon counted (Turak *et al.* 2004). A randomly chosen 10% of the RAM sample identifications would be checked by a second experienced scientist to validate macroinvertebrate identifications.

Data would be analysed using the spring AUSRIVAS predictive models for the edge habitat (Coysh *et al.* 2000). The AUSRIVAS methodology and predictive model requires that sampling be done in autumn (15 March to 15 June) and/or spring (15 September to 15 December).

AUSRIVAS models generate the following indices:

> OE50Taxa 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 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 - These indicate the level of impairment of the assemblage and are derived from OE50Taxa scores. 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.

The revised SIGNAL2 biotic index (Stream Invertebrate Grade Number Average Level) developed by Chessman (2003) would also be 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 that habitat is then divided by the total number of families recorded in each habitat 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. SIGNAL2 values greater than 6, between 5 and 6, 4 and 5 and less than 4 indicate that the quality of the water is clean, doubtful, mildly, moderately or severely degraded, respectively.

6.2.2.4.2 Artificial Macroinvertebrate Collectors

Eight replicate artificial collector units, consisting of 24 cm long x 3 cm diameter bundles of 18 wooden chopsticks held together with plastic cable ties, would be deployed at each monitoring site. The collectors would be attached to vegetation with nylon twine and submerged at least 1 meter apart at the edge of pools in 30 to 60 cm of water. The collectors would be retrieved six weeks after being deployed. During retrieval the collectors would be carefully cut away from their anchors, placed into plastic bags, labeled and preserved in 70% ethanol for subsequent laboratory identification and analysis.

The aquatic macroinvertebrates that colonise each bundle of chopsticks would be rinsed onto a 0.5 mm mesh sieve and examined in the laboratory using a binocular microscope. The samples would be sorted and macroinvertebrates identified to family (most invertebrate taxa), sub-family (chironomids) or class (flatworms and leeches) level and counted. Mayflies, damselflies and stoneflies would be identified to genus, where possible. Genus level taxonomic resolution may be more appropriate when attempting to detect an environmental impact on aquatic ecology, as some taxa within the same family may response differently to disturbance. SIGNAL2 scores would also be calculated for the macroinvertebrate assemblages that developed on the artificial collectors.

6.2.2.5 Threatened Species

As there is a possibility, albeit unlikely, that two threatened aquatic macroinvertebrate species (Adams emerald dragonfly and Sydney hawk dragonfly) occur in watercourses within the Study Area, all the dragonfly larvae collected would be identified to family level. Any individuals of the genera Austrocorduliidae and Gomphomacromiidae found would be identified to species level, if possible. If there is any uncertainty as to their identification, specimens will be referred to a specialist taxonomist. The presence of either one or both of these threatened species would trigger further investigations into the species and its habitats in relation to potential subsidence impacts.

6.2.2.6 Fish

Fish would be sampled using a back-pack electrofisher (model LR-24 Smith-Root) and baited traps. At each site, eight baited traps would be deployed for 30 to 45 minutes in a variety of habitats, such as amongst aquatic plants and snags, in deep holes and over bare substratum. The back-pack electrofisher would be operated around the edge of pools and in riffles, with four two minute shots being performed at each site. Fish stunned by the current would be collected in a scoop net, identified and measured. Native species would be released unharmed. Exotics would not be returned to the water in accordance with Cardno's Scientific Research Permit.

6.2.2.7 Statistical Analysis

The aim of the statistical analyses would be to identify differences in the selected indicators of aquatic ecology at the Impact sites that are in a different direction, or of a different magnitude, to those at the Control. Statistically significant differences provide evidence that an impact may have occurred. Evidence is assessed by examining data from before with those collected after commencement of longwall extraction. Spatial and temporal changes in macroinvertebrate abundance data from artificial collectors would be examined using Generalised Linear Mixed Modelling (GLMM) with an appropriate distributional assumption. This technique is more appropriate than distance based methods (e.g. permutational analysis of variance - PERMANOVA) for analysis of univariate data. Spatial differences and temporal changes, and their interaction, in macroinvertebrate assemblages sampled using artificial collectors would be examined (PERMANOVA+). Multivariate patterns in the data would also be examined using the unconstrained ordination technique Principal Coordinates Analysis (PCO). This provides a graphical representation of assemblages based on their similarity within and among places or times sampled. In these plots, samples which have similar sets of organisms are grouped closer together than ones containing different sets of organisms.

6.3 Additional Aquatic Ecology Studies

The aquatic ecology monitoring program outlined in **Section 6.2** has been designed to detect and determine the extent and nature of impacts on aquatic habitat and biota resulting from mining induced subsidence impacts within watercourses. It incorporates monitoring events throughout the duration of mine working regardless of observed physical and chemical impacts within watercourses. Physical-chemical impacts detected within watercourses by routine surface monitoring by ICEFT that may require further investigation into potential impacts on the aquatic ecology include:

> Rockbar fracture resulting in water loss in a pool within Wongawilli Creek;

> Reductions in flow in Wongawilli Creek or Donalds Castle Creek that exceeded predicted increase in the number of zero flow days (HGeo 2019); and

> Significant change in water chemistry (particularly pH, dissolved oxygen, turbidity, or metal concentration) in Wongawilli Creek or Donalds Castle Creek.

Other observations made during routine surface monitoring that may require further investigation of the aquatic ecology include:

> Fish/crayfish kills; and

> Die-off of macrophyte beds (if present).

Trigger values for aquatic ecology monitoring parameters are contained in the Watercourse Impact Monitoring Management and Contingency Plan (S32 2019). These are based on the duration of reductions in aquatic habitat that may occur in watercourses due to mining impacts.

6.4 Contingent Measures

In the event that the impacts due to the extraction Longwalls 20 and 21 on aquatic habitats and biota Wongawilli Creek and Donalds Castle Creek are greater than predicted the following contingent measures could be implemented:

> Implementing watercourse remediation measures, such as backfilling or grouting, in areas where fracturing of controlling rock bars and/or the creek bed leads to diversion of creek flow and drainage of pools; and

> Implementing appropriate control measures, such as installation of sediment fences down slope of areas where subsidence has led to erosion and stabilisation of areas prone to erosion and soil slumping using rock, brush matting or vegetation, to limit the potential for deposition of eroded sediment into the watercourses.

If these management strategies prove ineffectual, appropriate offset and compensatory measures would be implemented.

7 Conclusion

The layout design for Longwalls 20 and 21 includes measures to minimise potential impacts on aquatic habitat and biota. This includes set back of longwalls from major watercourses and significant features and a mine designed to reduce the probability of physical mining impacts occurring. Nevertheless, impacts to non-threatened aquatic habitat, vegetation, macroinvertebrates or fish may occur following predicted mine subsidence and associated fracturing in watercourses in and adjacent to Longwalls 20 and 21. These impacts would be relatively severe in larger pools within Wongawilli Creek but relatively minor in the context of the wider catchment area. However, the cumulative effect with mining operations in the wider catchment should be considered, in particular, mining related reductions in flow and pool water levels upstream in Wongawilli Creek attributed to mining of DA3B. While the potential impacts associated with Longwalls 20 and 21 appear to represent a relatively minor additional impact on aquatic habitat and biota compared to those that have occurred with previous and existing mines in the upper Avon and Cordeaux River catchments, they represent a relatively greater impact to Wongawilli Creek. This is most likely to manifest as further increases in the number of zero flow days in the creek, with associated further reductions in longitudinal connectivity and associated impacts to aquatic biota.

No significant impacts to listed threatened Macquarie perch, Sydney hawk dragonfly or Adams emerald dragonfly are expected as these species are unlikely to occur in Donalds Castle Creek and drainage lines that traverse the Study Area that would be most susceptible to mining related subsidence impacts. Although Macquarie perch is expected to occur in the lower reaches of Wongawilli Creek outside of the Study Area, it does not appear to be present in sections of Wongawilli Creek that would be directly affected by extraction of Longwalls 20 and 21.

Implementation of the aquatic ecology monitoring program outlined here will help determine the magnitude and extent of impacts to aquatic ecology associated with extraction of Longwalls 20 and 21. This includes impacts to aquatic habitat and biota associated with predicted fracturing in watercourses. The location of monitoring sites and staging of monitoring will be refined following further consultation with ICEFT and confirmation of the timing of extraction of each longwall.

The detection of physical impacts, such as rockbar fractures resulting in water loss in a pool within Wongawilli Creek or significant changes in water chemistry, would trigger investigations into potential impacts on aquatic ecology. Observations of fish/crayfish kills or die-off of any macrophyte beds would also trigger further monitoring to determine the nature and extent of secondary impacts on aquatic ecology. The level of impact found would determine the type of response. The implementation of such management measures would help reduce impacts on aquatic ecology.

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APPENDIX

A

RESULTS OF PREVIOUS AUSRIVAS SAMPLING

Site / Indicator	2010				2011				2013				2015			
	Mar	May	Sep	Nov	Apr	Jun	Sep	Oct	Apr	Jun	Sep	Nov	May	Jun	Sep	Nov
Wongawilli Creek																
Site 1																
No. of Taxa	18	16	19	16	16	12	11	19	18	13	12	15	12	9	14	19
OE50 Taxa Score	1.15	0.92	0.83	0.72	0.63	0.65	0.35	0.9	0.97	0.8	0.41	0.67	0.58	0.62	0.66	0.65
SIGNAL2 Index	4.1	4.7	4.6	5.4	4.2	5.2	5.5	4.2	5.0	4.4	5.5	4.9	5.4	5.8	4.8	4.9
Site 2																
No. of Taxa	19	15	15	16	20	19	18	18	24	14	15	20	24	14	15	20
OE50 Taxa Score	1.06	0.77	0.71	0.81	1.16	0.97	0.52	0.89	0.77	0.82	0.7	0.82	0.77	0.82	0.7	0.82
SIGNAL2 Index	3.9	4.1	4.8	4.2	4.4	4.4	4.5	4.5	4.7	5.3	5.4	5.4	4.7	5.3	5.4	5.4
Site 3																
No. of Taxa	20	16	21	23	14	20	14	23	17	14	15	20	16	17	17	18
OE50 Taxa Score	1.25	1.05	0.92	0.68	0.82	0.95	0.59	0.91	0.7	0.77	0.7	0.86	0.69	0.85	0.66	0.7
SIGNAL2 Index	4.4	4.1	4.6	4.8	4.1	4.6	4.8	5.0	4.4	4.3	4.4	4.7	5.2	4.9	4.7	4.8
Site 4																
No. of Taxa	18	13	19	25	23	17	14	22	21	18	16	18	14	14	16	24
OE50 Taxa Score	1.03	0.82	0.73	1.06	0.98	0.77	0.6	0.8	1.09	0.87	0.64	0.81	0.67	0.97	0.77	0.87
SIGNAL2 Index	4.2	3.8	4.4	4.8	4.5	4.9	4.9	4.5	4.8	4.4	4.9	4.8	4.5	4.4	5.6	5.1
Site 5																
No. of Taxa	24	22	21	24	20	16	22	14	23	16	24	21	23	17	18	25
OE50 Taxa Score	1.3	1.08	0.82	0.94	0.6	0.93	0.78	0.71	1.15	0.98	0.92	0.82	0.8	0.92	0.71	0.81
SIGNAL2 Index	4.4	4.5	4.1	4.5	4.8	4.5	5.0	4.2	4.8	4.4	4.6	4.8	5.3	5.1	5.2	5.3
Site X4																
No. of Taxa	18	17	10	9	17	15	18	15	11	11	11	11	12	10	11	11
OE50 Taxa Score	1.12	1.02	0.75	0.58	0.65	0.65	0.67	0.48	0.82	0.72	0.69	0.49	0.77	0.72	0.49	0.61
SIGNAL2 Index	3.9	4.4	4.4	3.9	4.6	3.9	4.8	4.7	4.0	4.1	4.9	4.9	3.8	4.9	5.7	4.9

Site / Indicator	2010				2011				2013				2015			
	Mar	May	Sep	Nov	Apr	Jun	Sep	Oct	Apr	Jun	Sep	Nov	May	Jun	Sep	Nov
Wongawilli Creek (WC21)																
Site 6																
No. of Taxa	22	27	17	16	18	16	18	15	20	13	16	19	9	12	13	25
OE50 Taxa Score	1.11	1.01	0.96	0.86	0.83	0.64	0.77	0.70	1.01	0.83	0.73	0.92	0.64	0.64	0.64	1.01
SIGNAL2 Index	4.6	4.7	4.4	4.3	4.9	4.5	4.7	4.7	4.4	4.2	5.0	3.9	5.1	5.4	5.2	4.9
Site X2																
No. of Taxa	15	21	15	20	21	15	14	16	18	18	12	12				
OE50 Taxa Score	1.01	1.2	0.86	0.76	0.65	0.57	0.64	0.75	0.92	0.83	0.57	0.67				
SIGNAL2 Index	3.8	4.1	4.3	4.3	4.7	4.7	4.7	4.1	4.6	5.3	4.5	4.5				*No water*
Site X3																
No. of Taxa	14	21	17	24	20	18	19	19	15	19	17	17	15	17	12	20
OE50 Taxa Score	0.65	0.81	0.72	0.80	0.49	0.83	0.79	0.77	0.73	0.65	0.8	0.67	0.65	0.65	0.50	0.67
SIGNAL2 Index	3.8	3.9	4.0	4.3	4.6	4.3	4.9	4.5	4.9	4.9	4.7	4.7	4.3	5.5	4.8	4.8
Donalds Castle Creek																
Site 14																
No. of Taxa	25	29	24	19	20	15	19	19	20	20	11	20	13	19	20	18
OE50 Taxa Score	1.16	1.11	0.92	0.64	0.69	0.54	0.55	0.73	0.79	0.89	0.59	0.91	0.65	0.65	0.7	0.73
SIGNAL2 Index	4.5	4.8	4.2	4.5	4.7	4.7	4.4	4.4	4.4	4.8	4.8	4.7	5.0	5.0	4.8	4.5
Site X1																
No. of Taxa	15	21	21	20	19	18	13	22	25	20	19	19	9	15	15	16
OE50 Taxa Score	0.92	0.82	0.61	0.88	0.62	0.62	0.57	0.97	1.03	0.82	0.79	1.05	0.41	0.82	0.79	0.79
SIGNAL2 Index	3.7	4.7	4.2	4.3	3.9	4.6	4.8	3.8	4.4	4.5	4.3	4.3	3.6	3.8	4.6	4.0

APPENDIX B

RCE ASSESSMENT CRITERIA AND RESULTS

i) River, Channel and Environmental (RCE) Categories

Descriptor and category	Score
1. Land use pattern beyond the immediate riparian zone	
Undisturbed native vegetation	4
Mixed native vegetation and pasture/exotics	3
Mainly pasture, crops or pine plantation	2
Urban	1
2. Width of riparian strip of woody vegetation	
More than 30 m	4
Between 5 and 30 m	3
Less than 5 m	2
No woody vegetation	1
3. Completeness of riparian strip of woody vegetation	
Riparian strip without breaks in vegetation	4
Breaks at intervals of more than 50 m	3
Breaks at intervals of 10 - 50 m	2
Breaks at intervals of less than 10 m	1
4. Vegetation of riparian zone within 10 m of channel	
Native tree and shrub species	4
Mixed native and exotic trees and shrubs	3
Exotic trees and shrubs	2
Exotic grasses / weeds only	1
5. Stream bank structure	
Banks fully stabilised by trees, shrubs etc.	4
Banks firm but held mainly by grass and herbs	3
Banks loose, partly held by sparse grass etc.	2
Banks unstable, mainly loose sand or soil	1
6. Bank undercutting	
None, or restricted by tree roots	4
Only on curves and at constrictions	3
Frequent along all parts of stream	2
Severe, bank collapses common	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

Descriptor and category	Score
8. Riffle / pool sequence	
Frequent alternation of riffles and pools	4
Long pools with infrequent short riffles	3
Natural channel without riffle / pool sequence	2
Artificial channel; no riffle / pool sequence	1
9. Retention devices in stream	
Many large boulders and/or debris dams	4
Rocks / logs present; limited damming effect	3
Rocks / logs present, but unstable, no damming	2
Stream with few or no rocks / logs	1
10. Channel sediment accumulations	
Little or no accumulation of loose sediments	4
Some gravel bars but little sand or silt	3
Bars of sand and silt common	2
Braiding by loose sediment	1
11. Stream bottom	
Mainly clean stones with obvious interstices	4
Mainly stones with some cover of algae / silt	3
Bottom heavily silted but stable	2
Bottom mainly loose and mobile sediment	1
12. Stream detritus	
Mainly un-silted wood, bark, leaves	4
Some wood, leaves etc. with much fine detritus	3
Mainly fine detritus mixed with sediment	2
Little or no organic detritus	1
13. Aquatic vegetation	
Little or no macrophyte or algal growth	4
Substantial algal growth; few macrophytes	3
Substantial macrophyte growth; little algae	2
Substantial macrophyte and algal growth	1

ii) Results of the RCE assessment

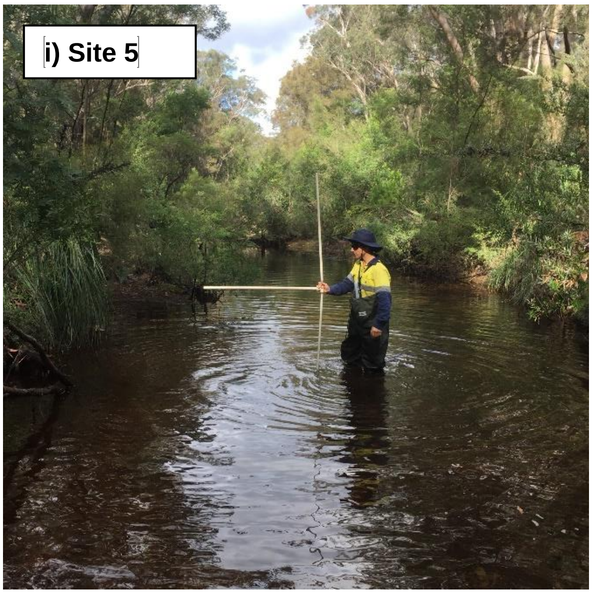
RCE Category	Site 5	Site 19	Site 20	Site X1	Site 17	Site 18
Land use pattern beyond the immediate riparian zone	4	4	4	4	4	4
Width of riparian strip of woody vegetation	4	4	4	4	4	4
Completeness of riparian strip of woody vegetation	4	4	4	4	4	4
Vegetation of riparian zone within 10 m of channel	4	4	4	4	4	4
Stream bank structure	4	4	4	4	4	4
Bank undercutting	4	4	4	4	4	4
Channel form	3	3	3	3	3	3
Riffle/pool sequence	3	3	3	2	2	2
Retention devices in stream	3	3	3	4	4	4
Channel sediment accumulations	3	3	3	3	3	3
Stream bottom	4	4	4	4	4	4
Stream detritus	4	4	4	4	4	4
Aquatic vegetation	2	3	3	4	4	4
Total	46	47	47	48	48	48

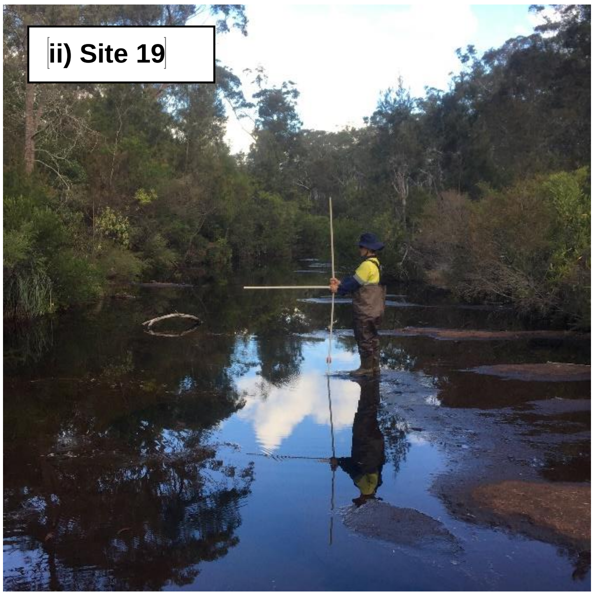
APPENDIX

C

PHOTOGRAPHS OF WATECOURSES

Cardno
Shaping the Future


i) Site 5


ii) Site 19


iii) Site 20


iv) Site X1


v) Site 17


vi) Site 18

APPENDIX

D

AUSRIVAS RESULTS

Taxon	Site 5	Site 17	Site 18	Site 19	Site 20	Site X1	SIGNAL2 Score (where available)
Aeshnidae	1	4		1	1		4
Araneae		1					
Atyidae	5			3	2		3
Baetidae	9			10	6		5
Ceratopogonidae			2				4
Chironomidae/Chironominae	5	1	2		6	10	3
Chironomidae/Tanypodinae	3	8	8	4	2	4	4
Coenagrionidae	2						2
Conoesucidae	1						7
Copepoda	6	1	10	1		7	
Cordulephyidae					1		
Culicidae						2	1
Dytiscidae	5	3		2	2	10	2
Ecnomidae	1						4
Gomphidae					1		5
Gripopterygiidae	10		9	10	5		8
Gyrinidae	2	1					4
Haliplidae						6	2
Hemicorduliidae (=Corduliidae)	5						5
Hydracarina	3			4	4		6
Hydrometridae	2						3
Hydrophilidae	1	1				1	2
Hydropsychidae				1			6
Hydroptilidae				1			4
Leptoceridae	10	1	1	10	10	9	6
Leptophlebiidae	10	10	10	5	10	3	8
Lestidae	1						1
Libellulidae				1			4
Limnichidae			1				4
Megapodagrionidae	1						5
Odontoceridae					1		7
Oligochaeta						1	2
Oniscigastridae				2			8
Philorheithridae	1						8
Scirtidae	2				2	5	6
Tipulidae					1		5
Veliidae	1			1	1		3

Note: only up to 10 individuals of each taxon were

APPENDIX

E

ASSESSMENT OF SIGNIFICANCE – MACQUARIE PERCH

Assessment of Significance (FM Act) – Macquarie perch

a) In the case of a threatened species, whether the action proposed 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

Macquarie perch has been recorded in the Dendrobium Mine area in the mid to lower reaches of Wongawilli Creek, including pools just upstream and downstream of Fire trail 6A (NSW DPI (Fisheries), pers. com.; The Ecology Lab, 2001 and pers. obs. 2005; MPR 2006b; Matt Richardson, Niche, pers. obs. 2011). However, this species was not caught further upstream in Wongawilli Creek despite extensive sampling (Cardno 2012 and 2016). It has been recorded also in Lake Avon and Lake Cordeaux and previously recorded, or potentially present, in the upper reaches of Cordeaux and Avon Rivers (NSW DPI 2016a). The steep bedrock cascade features directly upstream of the crossing at Fire Road No. 6 would pose a significant barrier to the upstream passage of the Macquarie perch populations within the lower to mid reaches of Wongawilli Creek. The presence of several natural barriers to movement of this species on Donalds Castle Creek would also prevent or severely hinder this species utilising the vast majority of this watercourse.

Life history studies of Macquarie perch have been largely carried out on western drainage populations. These populations are known to spawn just above riffles in shallow upland streams in October to January when water temperatures rise to around 16 C. Eastern populations, however, inhabit rivers with very different hydrological conditions to the inland populations and very little is known of their life cycle. The eggs are adhesive and stick to gravel. Hatching commences 13 days after fertilisation and is completed by 18 days after fertilisation at water temperatures of 11 to 18°C Newly-hatched larvae shelter amongst pebbles. In impounded waters, hatched fish move back downstream to the lake habitat from their upstream spawning sites.

The lifecycle of Macquarie perch could be adversely affected if mining results in changes in levels of ponding, flooding or scouring of river banks, fracturing of rock bars and diversion of surface flows and these, in turn, lead to drainage of pools, loss of habitat, and reductions in habitat connectivity and/or water quality. The subsidence predictions indicate that extraction of the proposed longwalls is likely to result in the fracturing of at least one flow controlling rockbar in Wongawilli Creek that would result in flow diversions and drainage of the associated upstream pool. Suitable Macquarie perch habitat (woody debris, rocks and boulders) is present within the section of Wongawilli Creek within the Study Area that could be affected. However, given that Macquarie perch do not appear to be able to access this habitat due to the presence downstream natural barriers to fish passage associate impacts to this species are unlikely. In any case, given the extensive amount of potential habitat available for this species further downstream and in Avon and Cordeaux rivers, it is highly unlikely that mining would have any adverse effects on the life cycle of Macquarie perch in the Avon / Cordeaux River Catchment or place a viable local population at risk of extinction. Macquarie perch are considered very unlikely to occur in Donalds Castle Creek and drainage lines, and, thus, would not be affected by any mining induced impacts here. Likewise, any impacts to water quality in these creeks and rivers due to the project are expected to be minor and localised not affect Macquarie perch.

b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

No endangered populations of Macquarie perch have been listed on the Schedules of the FM Act.

c) In the case of an endangered ecological community or critically endangered ecological community, whether the proposed action is likely to:

i) Have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

ii) Substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to placed at risk of extinction.

Macquarie perch is not part of a listed endangered ecological community.

d) In relation to the habitat of a threatened species, population or ecological community:

i) The extent to which habitat is likely to be removed or modified as a result of the action proposed;

ii) Whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action;

iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.

Subsidence predictions indicate a low probability of occurrence of significant fracturing resulting in flow diversions in Wongawilli Creek. The section of creek within the Study Area also does not appear to be accessible to Macquarie perch. Thus there are unlikely to be any reduction in Macquarie perch habitat availability, quality or connectivity here. Although fracturing and flow diversions are likely to result in more severe impacts to habitat in Donalds Castle Creek and drainage lines, these are very unlikely to provide habitat for Macquarie perch. Thus, it is highly unlikely that mining would lead to removal, fragmentation or isolation of a Macquarie perch population.

e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no listed critical habitat for Macquarie perch listed on the NSW Register of Critical Habitat.

f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

The draft National Recovery Plan for Macquarie perch has recently been released (Commonwealth of Australia 2017). This contains background information on the biology, ecology, distribution and populations, decline and threats and recovery objectives and strategies and associated actions for this species. The objectives are:

> Conserve existing Macquarie perch populations;

> Protect and restore Macquarie perch habitat;

> Investigate threats to Macquarie perch populations and habitats;

> Establish additional Macquarie perch populations;

> Improve understanding of the biology and ecology of the Macquarie perch and its distribution and abundance; and

> Increase participation by community groups in Macquarie perch conservation.

Identified threats include:

> Habitat degradation;

> Invasive fish;

> Barriers to fish movement;

> Altered flow and thermal regimes;

> Disease;

> Illegal and incidental capture;

> Chemical water pollution;

> Climate change.

The following Priority Action Statements for Macquarie perch (NSW DPI 2017) exist:

> Advise consent and determining authorities;

> Collate and review existing information;

> Community and stakeholder liaison, awareness and education;

> Compliance / enforcement;

> Enhance, modify or implement Natural Resource Management planning processes to minimize adverse impacts on threatened species;

> Habitat rehabilitation;

> Pest eradication and control;

> Research / monitoring;

> Stocking / translocation; and

> Survey / mapping.

Potential impacts to Macquarie perch associated with the Project (primarily loss of habitat following significant fracturing leading to flow diversions and reductions in pool water levels) are unlikely. The Project is not expected to interfere with these objectives and the recovery of the species.

g) 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.

One KTP listed under the BC Act is directly applicable to the Project: *Alteration of habitat following subsidence due to longwall mining.*

While the Project is expected to exacerbate this KTP, associated impacts to Macquarie perch due to subsidence are unlikely. Macquarie perch is very unlikely to be found in Donalds Castle Creek and drainage lines that have high probability of experiencing fracturing resulting in flow diversions and loss of aquatic habitat. Significant fracturing in Avon River and Cordeaux rive resulting in flow diversions is unlikely, and, if it did occur, the relatively greater volume of water in these watercourses would limit the amount of habitat loss due flow diversions.

2) Assessment of Significance Based on Significant Impact Criteria for Endangered Species (EPBC Act) – Macquarie perch

An action is likely to have a significant impact on an endangered species if there is a real chance or possibility that it will:

a) Lead to a long-term decrease in the size of a population

Macquarie perch has been recorded in the Dendrobium Mine area in the mid to lower reaches of Wongawilli Creek, including pools just upstream and downstream of Fire trail 6A (NSW DPI (Fisheries), pers. com.; The Ecology Lab, 2001 and pers. obs. 2005; MPR 2006b; Matt Richardson, Niche, pers. obs. 2011). However, this species was not caught further upstream in Wongawilli Creek despite extensive sampling (Cardno 2012 and 2016). It has been recorded also in Lake Avon and Lake Cordeaux and previously recorded, or potentially present, in the upper reaches of Cordeaux and Avon Rivers (NSW DPI 2016a). The steep bedrock cascade features directly upstream of the crossing at Fire Road No. 6 would pose a significant barrier to the upstream passage of the Macquarie perch populations within the lower to mid reaches of Wongawilli Creek. The presence of several natural barriers to movement of this species on Donalds Castle Creek, particularly the cascade downstream of Area 5, would also prevent or severely hinder this species utilising the vast majority of this watercourse.

Life history studies of Macquarie perch have been largely carried out on western drainage populations. These populations are known to spawn just above riffles in shallow upland streams in October to January when water temperatures rise to around 16 C. Eastern populations, however, inhabit rivers with very different hydrological conditions to the inland populations and very little is known of their life cycle. The eggs are adhesive and stick to gravel. Hatching commences 13 days after fertilisation and is completed by 18 days after fertilisation at water temperatures of 11 to 18°C Newly-hatched larvae shelter amongst pebbles. In impounded waters, hatched fish move back downstream to the lake habitat from their upstream spawning sites.

The subsidence predictions indicate that extraction of the proposed longwalls is likely to result in the fracturing of at least one flow controlling rockbar in Wongawilli Creek that would result in flow diversions and drainage of the associated upstream pool. Suitable Macquarie perch habitat (woody debris, rocks and boulders) is present within the section of Wongawilli Creek within the Study Area that could be affected. However, given that Macquarie perch do not appear to be able to access this habitat due to the presence downstream natural barriers to fish passage associate impacts to this species are unlikely. In any case, given the extensive amount of potential habitat available for this species further downstream and in Avon and Cordeaux rivers, it is highly unlikely that mining would have any adverse effects on the life cycle of Macquarie perch in the Avon / Cordeaux River Catchment or place a viable local population at risk of extinction. Macquarie perch are considered very unlikely to occur in Donalds Castle Creek and drainage lines, and, thus, would not be affected by any mining induced impacts here. Likewise, any impacts to water quality in these creeks and rivers due to the project are expected to be minor and localised not affect Macquarie perch.

b) Reduce the area of occupancy of the species

As described above, significant fracturing resulting in flow diversions are unlikely in Avon River and Cordeaux River. Thus, potential impacts to identified Macquarie perch habitat due to the Project are unlikely. Any habitat loss due to any flow diversions due in these rivers may also to some extent be limited due to the large volumes of water present here, compare with flow diversions occurring in smaller watercourses. The Project would also not require any crossings over Avon River and Cordeaux River that could hinder fish passage and any impacts to water quality are expected to be localised and miner. Thus, reductions in the occupancy of this species die to the Project are unlikely.

c) Fragment an existing population into two or more populations

As described in a) and b), potential impacts to Macquarie perch due to the Project are unlikely. No structures that may hinder fish passage would be installed and significant fracturing resulting in flow diversions in Avon River and Cordeaux River, where they are known to occur, have a low probability of occurrence.

d) Adversely affect habitat critical to the survival of a species

As described in a), potential impacts to Macquarie perch habitat are unlikely. Critical breeding habitat (shallow flowing sections of rivers) is likely to be present throughout Avon River and Cordeaux River and there is unlikely to be any substantial alteration to this habitat due to the Project.

e) Disrupt the breeding cycle of a population

The subsidence predictions indicate that extraction of the proposed longwalls is likely to result in minor, localised changes in the availability, quality and connectivity of aquatic habitats within Wongawilli Creek. Macquarie perch habitat (woody debris, rocks and boulders) is likely to be abundant throughout these rivers within and adjacent to the areas potentially affected by mining. Given the extensive amount of potential habitat available for this species within these rivers and nature of the impacts, if any, it is highly unlikely that mining would have any adverse effects on the life cycle of Macquarie perch in Avon River or Cordeaux River or place a viable local population at risk of extinction. Macquarie perch are considered very unlikely to occur in Donalds Castle Creek and drainage lines, and, thus, would not be affected by any mining induced impacts here. The population in Wongawilli Creek is located downstream of the proposed mining where no fracturing would occur and is not expected to be affected by the project. Likewise, any impacts to water quality in these creeks and rivers due to the project are expected to be minor and localised not affect Macquarie perch.

f) Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

As described in (a) – (d) potential impacts to Macquarie perch and their habitat due to the Project are unlikely and not expect to affect its forage, resting or spawning habitat to the extent that the species is likely to decline.

g) Result in invasive species that are harmful to an endangered species becoming established in the endangered species' habitat

Invasive species that may predate on Macquarie perch eggs or young fish and/or potentially compete with Macquarie perch for food and habitat include redfin perch (*Perca fluviatilis*), rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), wild goldfish (*Carassius auratus*), eastern gambusia (*Gambusia holbrooki*) and carp (*Cyprinus carpio*). The Project does not include any vectors that may introduce/further introduce these species to Macquarie perch habitat within the Study Area.

h) Introduce disease that may cause the species to decline

The invasive species listed in g) may carry disease or parasites that could infect Macquarie perch. However, the Project would not result in the introduction or further introduction of these species to the Study Area.

i) Interfere substantially with the recovery of the species

The draft National Recovery Plan for Macquarie perch has recently been released (Commonwealth of Australia 2017). This contains background information on the biology, ecology, distribution and populations, decline and threats and recovery objectives and strategies and associated actions for this species. The objectives are:

- Conserve existing Macquarie perch populations;
- Protect and restore Macquarie perch habitat;
- Investigate threats to Macquarie perch populations and habitats;
- Establish additional Macquarie perch populations;
- Improve understanding of the biology and ecology of the Macquarie perch and its distribution and abundance; and
- Increase participation by community groups in Macquarie perch conservation.

Identified threats include:

- Habitat degradation;
- Invasive fish;
- Barriers to fish movement;
- Altered flow and thermal regimes;
- Disease;
- Illegal and incidental capture;
- Chemical water pollution;
- Climate change.

The following Priority Action Statements for Macquarie perch (NSW DPI 2017) exist:

- Advise consent and determining authorities;
- Collate and review existing information;
- Community and stakeholder liaison, awareness and education;

> Compliance / enforcement;
> Enhance, modify or implement Natural Resource Management planning processes to minimize adverse impacts on threatened species;
> Habitat rehabilitation;
> Pest eradication and control;
> Research / monitoring;
> Stocking / translocation; and
> Survey / mapping.

Potential impacts to Macquarie perch associated with the Project (primarily loss of habitat following significant fracturing leading to flow diversions and reductions in pool water levels) are unlikely. The Project is not expected to interfere with these objectives and the recovery of the species.