Sutton Forest Quarries Pty Ltd

ABN 66 158 999 994

Aquatic Ecology Assessment

Specialist Consultant Studies Compendium

Volume 2, Part 6

Prepared by

Cardno (NSW/ACT) Pty Ltd

March 2018

This page has intentionally been left blank

Sutton Forest Quarries Pty Ltd

ABN 66 158 999 994

Aquatic Ecology Assessment

Prepared for: R.W. Corkery & Co. Pty Limited
1st Floor, 12 Dangar Road
PO Box 239
BROOKLYN NSW 2083

Tel: (02) 9985 8511
Email: brooklyn@rwcorkery.com

On behalf of: Sutton Forest Quarries Pty Ltd
PO Box 2499
BONDI JUNCTION NSW 1355

Tel: (02) 9387 5900
Fax: (02) 9386 5249
Email: finance@tulla.com.au

Prepared by: Cardno (NSW/ACT) Pty Ltd
Level 9, The Forum
203 Pacific Highway
ST LEONARDS NSW 2065

Tel: (02) 9496 7700
Fax: (02) 9499 3902
Email: daniel.pygas@cardno.com.au

Job Reference: 59914109

March 2018

Cardno
Shaping the Future

This Copyright is included for the protection of this document

COPYRIGHT

© Cardno (NSW/ACT) Pty Ltd 2018
and
© Sutton Forest Quarries Pty Ltd 2018

All intellectual property and copyright reserved.

Apart from any fair dealing for the purpose of private study, research, criticism or review, as permitted under the Copyright Act, 1968, no part of this report may be reproduced, transmitted, stored in a retrieval system or adapted in any form or by any means (electronic, mechanical, photocopying, recording or otherwise) without written permission. Enquiries should be addressed to Cardno (NSW/ACT) Pty Ltd.

Executive Summary

Cardno (NSW/ACT) Pty Ltd ("Cardno") was commissioned by R.W. Corkery & Co. Pty Limited (RWC), on behalf of Sutton Forest Quarries Pty Ltd (the "Applicant"), to undertake a site inspection of the aquatic habitat adjacent to, and downstream of, the proposed Sutton Forest Sand Quarry (the Proposal"), to describe aquatic habitats present; identify threatened species and stygofauna that could be affected by the Proposal; and to provide the aquatic assessment to accompany the Environmental Impact statement (EIS) for the Proposal. Cardno's scope of works included:

- Review existing information on aquatic ecology and threatened species legislation regarding aquatic invertebrates, aquatic plants ("macrophytes") and fish;
- Undertake a site inspection of Long Swamp Creek to provide a description of aquatic habitats and make notes on aquatic flora and fauna observed. Long Swamp Creek flows along the northern boundary of the property where the Proposal would be located;
- Sampling of stygofauna to assess the likely occurrence and extent of stygofauna in the vicinity of the Proposal; and
- Assess the potential impacts of the proposal on aquatic ecology and provide recommendations on any impact avoidance, minimisation and mitigation measures that should be implemented.

The proposal includes development of a 47 hectare extraction area and associated infrastructure, including a processing and stockpiling area, water storage dam, fines storage areas and various water management structures (sediment control dams, diversion dams etc.), totalling 94 hectares (the "Site"). The Site is located adjacent to, but not within, Long Swamp Creek, a perennial watercourse with a catchment of 30 km^2 that provides substantial aquatic, habitat including beds of aquatic marcophytes. Long Swamp is a peat swamp located just downstream of the Site, extending 5km along of the length of Long Swamp Creek. Two Endangered Ecological Communities (EEC), the Temperate Highland Peat Swamps on Sandstone, listed under the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth) and Montane Peatlands and Swamps of the South Eastern Highlands, listed under the Threatened Species Conservation Act 1995 (NSW) (now Biodiversity Conservation Act 2016), occur within Long Swamp. These areas may also provide habitat for Giant Dragonfly, listed as endangered under the NSW Threatened Species Conservation Act 1995 (now Biodiversity Conservation Act 2016). This species has been identified in other nearby swamps, several kilometres south of Long Swamp. No listed threatened aquatic species were observed during the site inspection, and it is considered unlikely that any utilise Long Swamp Creek. No stygofauna were identified in samples collected from groundwater bores on the Site. Whilst this does not preclude their presence, it does suggest that there would be minimal, if any, direct impact to stygofauna due to excavation of the extraction area.

Two primary potential impacts to aquatic ecology due to the Proposal were identified. The first is a potential reduction in water quality in Long Swamp Creek following mobilisation and release of sediments (and other potential contaminants, such as fuels and herbicides) during construction and operation of the Proposal. The second is the potential for loss of swamp habitat (and, thus, identified EECs and habitat for Giant Dragonfly) following small, predicted reductions in water availability (≤2.6% of baseflow) and lowering of the water table (≤0.1m at the eastern extent of Long Swamp adjacent to the extraction area) due to interception of groundwater flows in the extraction area (Larry Cook Consulting 2018). No direct displacement of, or physical disturbance to, Long Swamp Creek or the associated swamp habitat would occur. The Proposal would not require abstraction of water from the creek or direct discharge of water from the Site into the creek. Several ephemeral first and second order watercourses would be disturbed, including some displacement under water storage and sediment dams and road crossings and a small, long-term reduction in the size of the upper catchments of these watercourses. However, only a relatively small area of aquatic habitat of limited ecological value would be affected.

Several recommendations have been provided aimed at minimising the risk and magnitude of these and other identified potential impacts to aquatic ecology. Potential reductions in water quality could be managed by development and implementation of a Water Management Plan that includes the measures

described in the Surface Water Impact Assessment (SEEC 2018) as well as other measures described here. Following successful implementation, residual impacts to aquatic ecology due to changes in water quality would be acceptable. Although the predicted reduction in baseflow is small, Long Swamp is considered ecologically significant due to the two identified EECs and the potential presence of the Giant Dragonfly. Thus, a monitoring program for Long Swamp Creek is recommended, with the primary aim of measuring changes in swamp habitat that could be associated with the proposed quarry. Monitoring should include characterisation of baseline conditions prior to construction and ongoing monitoring during quarry operation and using other swamps in the region as a reference condition. Any subsequent changes in swamp habitat, such as reduced soil moisture, vegetation die-back and changes in communities of aquatic plants should be correlated with any observed changes in groundwater levels and appropriate management actions taken to prevent or minimise any further change.

Table of Contents

TABLES

FIGURES

1 Introduction

1.1 Background, Scope and Study Area

Cardno (NSW/ACT) Pty Ltd ("Cardno") was commissioned by R.W. Corkery & Co. Pty Limited (RWC), on behalf of Sutton Forest Quarries Pty Ltd (the "Applicant"), to undertake a site inspection of the aquatic habitat adjacent to, and downstream of, the proposed Sutton Forest Sand Quarry (the "Proposal"), to identify threatened species and stygofauna that could be affected by the Proposal and provide the Aquatic Ecology Impact Assessment to accompany the Environmental Impact Statement for the Proposal. The proposal includes development of a 47 hectare extraction area and associated infrastructure, totalling 94 hectares. For the purposes of this document, the Quarry would be developed within an area referred to as "the Site". The Site incorporates the Quarry Operations Area, i.e. the area in which all extraction, processing and related activities would be undertaken. Access between the Quarry Operations Area and the Hume Highway would be via the Quarry Interchange and a 1.4km long Quarry Access Road.

Cardno's scope of works included:

- Review existing information on aquatic ecology and threatened species legislation regarding aquatic invertebrates, aquatic plants ("macrophytes") and fish;
- Undertake an inspection (7 March 2014) of Long Swamp Creek to provide a description of aquatic habitats and make notes on aquatic flora and fauna observed. Long Swamp Creek flows along the northern boundary of the property of the Site;
- Undertake sampling of stygofauna (May 2016) to assess the likely occurrence and extent of stygofauna that may occur in groundwater on the Site; and
- Assess the potential impacts of the proposal on aquatic ecology and provide recommendations on any impact avoidance, minimisation and mitigation measures that should be implemented

The Study Area for the inspection included a section of Long Swamp Creek, approximately 4km long, and its southern watercourses within, and adjacent to, but not within the footprint of the Site. The following coordinates (chart datum WGS 84) of the Study Area were provided to Cardno by RWC:

- Upstream limit: 34.606532^{O} S; 150.205552^{O} E;
- Downstream limit: 34.612836^{O} S; 150.177538^{O} E.

These limits are adjacent to, and up- and downstream of, the Site.

It is also noted that the commencement of the Biodiversity Conservation Act 2016 on 25 August 2017, triggered the repeal of the Threatened Species Conservation Act 1995. All threatened species and endangered ecological community listings for NSW are now provided for under the Biodiversity Conservation Act 2016. However, as the Threatened Species Conservation act 1995 is specifically referenced in the Director-General's requirements for the Proposal, reference to the Threatened Species Conservation Act 1995 is retained throughout this document.

2 Review of Existing Information

Existing information was collated on the aquatic habitats and associated biota of Long Swamp Creek and the connected catchments of Paddys River and Wollondilly River. Relevant legislation on threatened species issues was reviewed and internet tools were searched for information on the occurrence of threatened species in the vicinity of the Site.

2.1 Physical Setting

The Site is located near Sutton Forest in the NSW Southern Highlands and forms part of the Wollondilly River sub-catchment of the Hawkesbury - Nepean River catchment. The site contains a network of first and second order ephemeral watercourses that would likely flow only following rain events due to the small upslope catchment. The majority of land within the Site is open eucalypt woodland. The eastern section has been cleared for grazing and there are several dams and unsealed roads. There are several small sand quarries to the south west of the Site and the southern side of the Hume Highway supports larger sand quarries and forestry activity. Land use in the greater region is characterised by agriculture.

The watercourses within the Site drain to the north into Long Swamp Creek. Long Swamp Creek is fed by a spring near its origin, which maintains year-round flows. The groundwater inputs and rainfall runoff from the catchment have facilitated the formation of a peat swamp (Long Swamp) in the valley flats downstream of the Site, where the topography has resulted in slower drainage. Long Swamp extends approximately 5km along the length of Long Swamp Creek which has a catchment of 30km^2 (DEWHA 2008). The accumulated peaty and organic-mineral sediments of Long Swamp are up to 2m deep in parts.

Long Swamp Creek flows westwards into Paddys River, downstream of the Site, which in turn flows into the Wollondilly River. The Wollondilly River enters the Lake Burragorang storage more than 100km downstream of its confluence with Paddys River. The Warragamba Dam wall represents a significant barrier to aquatic ecological processes and longitudinal connectivity with the Hawkesbury-Nepean river system and estuarine/marine habitat further downstream. NSW Department of Industry – Crown Lands and Water (CL&W) (formerly DPI-Water) have also identified several road crossings on Paddys River and Wollondilly River downstream of the Site that may create barriers to aquatic ecological processes (DPI NSW 2006a).

2.2 Water Quality

In situ and *ex situ* measures of water quality from Sites WQL1, WQL2 and WQL3 on Long Swamp Creek in August 2013 and March/April 2014, and from Farm Dam and Bridgewater Dam in March 2014 were provided by SEEC (2018) (refer **Appendix 1**). WQL2 and WQL3 were close to Cardno Sites 5 and 7, respectively, as surveyed by Cardno; WQL1 was upstream of Cardno's Site 1 (see **Figure 3.1** below). These data were compared with ANZECC (2000) Default Trigger Values for slightly disturbed upland streams in Southeast Australia and the key findings summarised as follows:

- pH was below the lower Default Trigger Value (DTV) (pH 6.5) at WQL1 and WQL2 (pH 6.3) in April 2014;
- Dissolved Oxygen ranged from 38 to 72 % saturation and was below the lower DTV (90 % saturation) on each occasion;
- Electrical conductivity (EC) ranged from 84 to 107 mS/cm in the dams and from 125 to 314 mS/cm in Long Swamp Creek and was below the lower DTV on each occasion;
- Nitrate ranged from 0.02 to 0.06 mg/L and exceeded the DTV (0.015 mg/L – for oxides of nitrogen) on each occasion except for Bridgewater Dam where it was not detected at the Limit of Reporting (LOR);

- Total nitrogen ranged from 0.26 to 1.10 mg/L and exceeded the DTV (0.250 mg/L) on each occasion; and
- Total phosphorus at Bridgwater Dam was 0.05 mg/L and exceeded the DTV (0.020 mg/L)

These findings suggest that Long Swamp Creek may experience some degree of environmental stress due to poor water quality, in particular, low dissolved oxygen, which was often well below the lower DTV. Nutrient levels, while above the DTV, were not excessively so, and EC was within DTVs. It is noted, however, that this is based on DTVs, rather than site-specific guidelines, and that these data may to some degree represent natural conditions in a creek associated with a peat wetland.

Somewhat poor water quality may be related to surrounding historic land clearing and agricultural practices. Elevated nutrient (nitrate and total nitrogen) levels could be associated with organic input into the creek and dams, for example from faecal matter from livestock and fertilizers. Entry of nutrients into the creek could occur during periods of high rainfall and if trampling of banks by livestock, and associated mobilisation of sediments, occurs. Low dissolved oxygen maybe be associated with elevated nutrient levels. The growth of oxygen respiring microorganisms would likely be encouraged by the availability of nutrients which could explain why dissolved oxygen levels were consistently below the lower DTV. Notwithstanding this, nutrient levels were not considered to substantially exceed DTVs. pH was also below the lower DTV on occasion, but only marginally, and this unlikely to be cause for concern.

Previous sampling at Paddys River, upstream of the Long Swamp Creek confluence, recorded electrical conductivity in excess of the upper limit of 350µS cm^{-1} specified in the ANZECC (2000) guidelines and dissolved oxygen levels were below the lower limit of 90% saturation (Cardno Ecology Lab 2010). Note that these data were collected on two consecutive days and therefore represent only a 'snapshot' of water quality in Paddys River.

2.3 Aquatic Plants

Previous aquatic surveys of the lower Wollondilly River and Paddys River recorded 17 aquatic plant species, all of which are common in the Hawkesbury-Nepean catchment (The Ecology Lab 2006, Cardno Ecology Lab 2010). These included the predominantly submerged macrophytes: pondweeds (*Potamogeton* spp.), watermilfoils (*Myriophyllum* spp.), water ribbons (*Triglochin microtuberosum*), ribbon weed (*Vallisneria gigantea*), emergent macrophytes: cumbungi (*Typha orientalis*), tall spike rush (*Eleocharis sphacelata*), river clubrush (*Schoenoplectus validas*) and aquatic plants more commonly found on the margins of water bodies, such as: knotweeds (*Persicaria* spp.), umbrella sedge (*Cyperus erograstus*) and rushes (*Juncus* spp.).

Long Swamp forms part of two Endangered Ecological Communities (EECs): Temperate Highland Peat Swamps on Sandstone, listed under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (Section 2.6.1.2) and Montane Peatlands and Swamps of the South Eastern Highlands listed under the Threatened Species Conservation Act 1995 (TSC Act) (now Biodiversity Conservation Act 2016) (Section 2.6.3.3).

2.4 Aquatic Macroinvertebrates

Fifty aquatic macroinvertebrate taxa were identified from samples collected in pool edge habitat from a reach of Paddys River immediately to the south of the Hume Highway in 2008 (Cardno Ecology Lab 2010). The health of the macroinvertebrate assemblages was assessed using the AusRivAS protocol (Turak *et al*. 2004) and the majority were equivalent to reference condition, indicating that this reach of Paddys River was in relatively good condition.

Brainwood *et al.* (2008) recorded three species of freshwater mussels*, Hyridella depressa, H. drapeta* and *Velesunio ambiguus* at a small causeway on Paddys River near the Hume Highway and noted that freshwater mussels were also present at Kippilaw Weir on the Upper Wollondilly River.

Four sites on the Wollondilly River (three upstream of the Paddys River junction) and two sites in the Wollondilly sub-catchment are included in Water NSW's (formerly Sydney Catchment Authority) Macroinvertebrate Monitoring Program. In spring 2004, the edge and/or riffle habitats at these sites were assessed using the AusRivAS protocol and the majority were found to be ecologically impaired (Ecowise 2005). The impaired assemblages were predominantly located in agricultural areas characterised by a degraded riparian zone and high levels of sedimentation in edge and riffle habitats.

In autumn 2006, the condition of the aquatic macroinvertebrate fauna associated with edge and riffle habitats was assessed at Archies Island and upstream of 500 Acre Flat on the Lower Wollondilly River (The Ecology Lab 2006). Both sites are located downstream of the confluence with Paddys River. The fauna associated with the edge habitat was assessed as being equivalent to the AusRivAS reference condition, whereas that associated with the riffle habitat was severely impaired at one site and significantly impaired at the other.

Overall, the results of macroinvertebrate sampling suggest that the macroinvertebrate assemblage of the Paddys River Catchment, including Long Swamp Creek, is in relatively good health.

2.5 Fish

Prior to the current survey, 14 native and 7 introduced fish species had been recorded in the Wollondilly sub-catchment, as reported by Cardno Ecology Lab (2010) (**Table 2.1**).

Table 2.1 Records of fish species occurring in waterways of the Wollondilly River sub-catchment relevant to the Proposal.

Common Name	Scientific Name	Long Swamp Creek	Paddys River	Wollondilly River	
				Upper Wollondilly	Lower Wollondilly
Native Fish					
Longfinned eel	*Anguilla reinhardtii*		✓		✓
Climbing galaxias	*Galaxias brevipinnis*				✓
Mountain galaxias	*Galaxias olidus*	✓	✓		
Australian smelt	*Retropinna semoni*		✓	✓	✓
Olive perchlet	*Ambassis agassizi*			✓	
Coxs gudgeon	*Gobiomorphus coxii*			✓	
Flathead gudgeon	*Philypnodon grandiceps*		✓	✓	✓
Dwarf flathead gudgeon	*Philypnodon macrostomus*				✓
Unidentified gudgeon	*Philypnodon* sp.			✓	✓
Empire gudgeon	*Hypseleotris compressa*				✓
Firetailed gudgeon	*Hypseleotris galii*		✓		✓
Unidentified carp gudgeon	*Hypseleotris* sp.	✓			
Macquarie perch	*Macquaria australasica*				✓
Freshwater catfish	*Tandanus*				✓
Non-native Fish					
Oriental weatherloach	*Misgurnus anguillicaudatus*				✓
Goldfish	*Carassius auratus*		✓	✓	✓
Common carp	*Cyprinus carpio*			✓	✓
Eastern gambusia	*Gambusia holbrooki*	✓	✓	✓	✓
Redfin perch	*Perca fluviatilis*		✓	✓	✓
Rainbow trout	*Oncorhynchus mykiss*		✓	✓	✓
Brown trout	*Salmo trutta*		✓	✓	

The Wollondilly River was the most diverse waterway in the region, supporting 12 native and seven introduced fish species. The diversity of native fish assemblages declined with distance upstream: ten native species have been identified in the lower reaches of the Wollondilly, whereas only five native species have been recorded in each of the upper Wollondilly River and the high elevation Paddys River. With the exception of longfinned eel and climbing galaxias, the native fish inhabiting the Wollondilly sub-catchment are all potamodromous (they can complete their lifecycle entirely in freshwater). The presence of Warragamba Dam wall and numerous other barriers to fish passage on the Nepean, Wollondilly and Paddys rivers has probably led to the disappearance of natural populations of most diadromous species (fish that migrate between freshwater and estuarine/marine habitat at some stage of their life cycle), such as Australian bass (*Macquaria novemaculeata*) and Australian grayling (*Prototroctes maraena*) from the Wollondilly sub-catchment. Other diadromous species, such as the longfinned eel are able to maintain populations in the Wollondilly sub-catchment due to their ability to climb large barrier structures.

Introduced fish species are widespread throughout the Wollondilly sub-catchment (**Table 2.1**), the most common being the eastern gambusia (*Gambusia holbrooki*) and goldfish (*Carassius auratus*). Carp (*Cyprinus carpio*) are more common in the lower Wollondilly reaches and Lake Burragorang, whereas brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykissii*) and redfin perch (*Perca fluviatilis*) tend to be restricted to the colder waterways found at higher elevations.

Macquarie perch, a species listed as threatened under both State and Federal legislation, is also known to occur in waterways of the Wollondilly sub-catchment (DPI NSW 2005a, Riches *et al.* 2016). Silver perch (*Bidyanus bidyanus*) and exotic brown trout and rainbow trout have been stocked historically in the Wollondilly sub-catchment (NSW Fisheries 2003). Silver perch are native to the Murray-Darling catchment and do not occur naturally in the Hawkesbury-Nepean system. The practice of introducing trout into the Wollondilly River below Marsden Weir (Goulburn) was ended due to the potential impact they may have on the persistence of local populations of Macquarie perch. Two other introduced species, common carp and redfin perch, recorded in the Wollondilly sub-catchment have been associated with the decline of Macquarie perch populations (Graham *et al*. 2005, DPI NSW 2009).

2.6 Threatened Species and Key Threatening Processes

This assessment includes reference to threatened species and threatening processes listed under the Commonwealth's Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), NSW Fisheries Management Act 1999 (FM Act) and NSW Threatened Species Conservation Act 1995 (TSC Act) (now Biodiversity Conservation Act 2016 (BC Act)). Threatened species, populations and ecological communities that may occur within the region of the Study Area were identified by reviewing the current listings on databases maintained by Commonwealth Department of the Environment and Energy (DEE), NSW Department of Primary Industries (DPI) (Fisheries) and NSW Office of Environment and Heritage (OEH). Database searches were done initially on 12 March 2014 and reviewed on 10 August 2016 and 19-20 February 2018. The discussion here focuses on the more recent searches and review of literature (e.g. Riches *et al.* 2016)

The DEE Protected Matters Search Tool was used to determine whether any species listed as threatened or protected under the schedules of the EPBC Act occurred in the Survey Area. The Long Swamp Creek and Paddys River catchments were used as the search area for the Environmental Reporting Tool.

The OEH Geographic Region Search was used to determine whether any threatened aquatic plant species or endangered ecological communities listed under the TSC Act (now BC Act) were present in the Survey Area. The search was performed on the Bungonia and Burragorang (Part A) sub-regions of the former Hawkesbury-Nepean Catchment Management Authority (H-NCMA) area.

The NSW DPI (Fisheries) Threatened and Protected Species Record Viewer, Riches et al. (2016) were used to search the Long Swamp Creek, Paddys River and Wollondilly River regions for records of threatened and protected species listed by Schedules 4, 4A and 5 of the FM Act.

Threatened species searches included aquatic biota listed under the EPBC Act and FM Act, specifically aquatic plants, aquatic macroinvertebrates and fish. Amphibians, aquatic reptiles, birds, aquatic mammals and terrestrial flora and fauna are addressed in the Flora and Fauna Assessment (Kevin Mills and Associates 2018).

2.6.1 Environment Protection and Biodiversity Conservation Act 1999

2.6.1.1 Threatened Species

The Protected Matters Search Tool indicated that one endangered fish species, Macquarie perch (*Macquaria australasica*) may either occur, or suitable habitat for them may occur, in the vicinity of the Site.

There are two distinct populations of Macquarie perch in NSW, a western form found naturally in the Murray-Darling Basin, and an eastern form found naturally in south east coastal NSW, including the Hawkesbury-Nepean and Shoalhaven catchments. Macquarie perch are known to occur in the Wollondilly River (DPI NSW 2005a). Macquarie perch have also been translocated into a number of river systems. They occur in lake and river habitats, particularly in the upper reaches of rivers and their watercourses. They spawn in spring or summer in shallow upland streams or flowing parts of rivers. The eggs settle among stones and gravel of the stream or riverbed.

The Protected Matters Search Tool also identified the potential presence of grayling in the region. This species, however, was not identified in the region using NSW DPI searches (see below).

2.6.1.2 Endangered Ecological Community

The EEC Temperate Highland Peat Swamps on Sandstone occurs within Long Swamp. This EEC comprises temporary or permanent swamps with a substratum of peat over sandstone and generally occurs at elevations of 600 - 1200m AHD. Sphagnum bogs and fens occupy the wetter parts while sedge and shrub association occur in drier parts of the swamps. A variety of native plants and animals are associated with these swamps, included the nationally endangered Giant Burrowing Frog and Wingecarribee Leek Orchid (DEH 2005). The EEC was listed due to its restricted distribution (only 3,000 hectares remains) and vulnerability to ongoing threats, including damage from feral animals, increased fertiliser run off, residential development, clearing, weeds, fire and changes to water flow and quality.

2.6.2 Fisheries Management Act

2.6.2.1 Threatened Species

The NSW DPI (Fisheries) Threatened and Protected Species Record Viewer included records for five fish species (Macquarie perch (Section 2.6.1), silver perch, Murray cod (*Maccullochella peelii peelii*), trout cod (*Maccullochella macquariensis*) and Australian grayling, or their habitat, could occur Long Swamp Creek, Paddys River and Wollondilly River regions. In addition, the critically endangered Fitzroy fall spiny crayfish (*Euastacus dharawalus*) occurs within the region, but only within a very small area near Fitzroy Falls Dam (DPI NSW 2012, Riches *et al.* 2016). Due to its limited range, it is not considered further in this assessment.

Three of the fish species reported above (silver perch, Murray cod and trout cod) have been translocated into the Hawkesbury-Nepean Catchment. The natural distribution of all three species is confined to the Murray-Darling Catchment. Any populations of these taxa in the Hawkesbury-Nepean Catchment are the result of historical translocations and as such, they are not considered further.

The Australian grayling is listed as Protected in NSW and Vulnerable under the EPBC Act. The species has a diadromous life cycle and must therefore migrate to marine/estuarine waters to reproduce. Newly hatched larvae are phototactic (move towards light) and swim to the surface where they are swept downstream to estuarine/marine waters migrating back to adult freshwater habitats at the age of 6 months. Adults suffer heavy post-spawning mortality, so it is possible after a few years without

juvenile recruitment that local extinction may occur (Morris *et al*. 2001). Populations are therefore very susceptible to barriers to passage. For example, following the construction of the Tallowa Dam on the Shoalhaven River in 1976 no Australian grayling were subsequently recorded in reaches above or below the dam. Historically, the Hawkesbury-Nepean Catchment represented the northern limit of the grayling's range and given that they can inhabit high elevation reaches up to 1000m AHD it is possible that waterways in the region of the Site represented potential habitat for this species. However, neither the DEE Protected Matters Search Tool nor Riches *et al.* (2016) identified Australian grayling as a threatened species that may occur within the defined search area (Long Swamp Creek and Paddys River catchments) and Australian grayling have not been recorded from the Hawkesbury – Nepean River system since the 1950s (Morris *et al*. 2001). Warragamba Dam represents an impassable barrier to juvenile grayling attempting upstream migration into the Wollondilly sub catchment. The construction of Warragamba Dam was completed in 1960 so it is very unlikely there are any grayling populations persisting in freshwater reaches upstream of Lake Burragorang. As such, Australian grayling will not be considered further in this assessment.

The Record Viewer also included records of the listed endangered Sydney Hawk Dragonfly in the Hawkesbury-Nepean drainage system. This species 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, with some specimens recently identified to the north of Sydney. 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) and to the north. There are no records for Sydney Hawk Dragonfly within the Wollondilly River sub-catchment of the Hawkesbury-Nepean system and, given its restricted distribution, it is not expected to occur within the region of the Site. Thus, the Proposal would be most unlikely to affect the Sydney Hawk Dragonfly and it is not considered further in this assessment.

2.6.2.2 Key Threatening Processes

Two of the key threatening processes (KTPs) listed under the FM Act, "Degradation of Riparian Vegetation" and "Instream Structures and Mechanisms that Alter Natural Flow" are relevant to the proposed works (DPI NSW 2005b, 2005c). The term "riparian vegetation" refers to the plants that occur on the land that adjoins, directly influences or is influenced by bodies of water, such as creeks, rivers, lakes and wetlands on river floodplains.

Degradation of riparian vegetation has been listed as a key threatening process, because of the adverse effects it can have on threatened species, populations and communities and the threat it poses to other species, populations and communities, which are not currently threatened.

2.6.3 Listings under the former Threatened Species Conservation Act 1995 (now Biodiversity Conservation Act 2016)

2.6.3.1 Threatened Species

The Geographic Region Search indicated that Giant Dragonfly (*Petalura gigantea*) was present within the Burragorang (Part A) sub-region. The Giant Dragonfly is listed as Endangered under Schedule 1 of the TSC Act (now BC Act). This species lives in permanent swamps and bogs with some free water and open vegetation (DECC 2009, OEH 2017). The adults emerge in October and live for one summer. They spend most of their time settled on low vegetation on or adjacent to the swamp, except when hunting for flying insects over and along the margins of the swamp. The larvae inhabit long chambered burrows built under swamps and emerge from the burrow entrances at night and in wet weather, in search of insects and other arthropods to eat. Larvae are not known to swim and avoid open water (DECC 2008). Vegetation within 500m of breeding habitat is utilised for foraging by adults. The larvae grow slowly and may remain in this state for up to 10 to 30 years. Degradation of habitat is the major threat to this species.

This species is known to occur in the Burragorang Part A, Bungonia and Moss Vale sub-regions of the Hawkesbury-Nepean catchment and has been recorded in the nearby Hanging Rock Swamp (Wetland

Care 2008) and Stingray Swamp (NPWS 2008), two of the nearby areas within the Paddys River wetland complex approximately 2km south, and 3km southeast, respectively, of Long Swamp. The largest population of Giant Dragonfly is believed to occur in sphagnum swamp areas within the Wingecarribee Swamp (approximately 12km east of Long Swamp).

The flora and fauna assessment for the proposal did not indicate that habitat for this species occurred within the quarry area (Kevin Mills & Associates 2018). However, there is potential for this species, or its habitat, to occur in Long Swamp Creek, downstream of the Site.

2.6.3.2 Endangered Ecological Community

The EEC Montane Peatlands and Swamps of the South Eastern Highlands occurs within Long Swamp. Much of the native fauna associated with Montane Peat Swamps are terrestrial and the vegetation is characterised by an intergrading mosaic of sedges (Cyperaceae), graminoids (grass-like plants), forbs (herbaceous plants) and shrubs (e.g. tea trees, *Leptospermum* spp.) (DEWHA 2008). Threats to this EEC include land clearing, pollution and eutrophication, erosion and sedimentation and changes to water tables and surface flows caused by drainage works or altered flows in the catchment.

2.6.3.3 Key Threatening Processes

Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands is listed as a Key Threatening Process on Schedule 3 of the TSC Act (now Schedule 4 of the BC Act). Human activities that reduce or increase flows, change the seasonality of flows, change the frequency, duration, magnitude, timing, predictability and variability of flow events, alter surface and subsurface water levels and change the rate of rise or fall of water levels can all alter the natural flow regimes of watercourses.

The flow regime is a key driver of river ecology, and changes to flow can alter the geomorphological process of sediment erosion, transport and deposition that structure a variety of important channel habitat forms, change macrophyte communities, influence water properties important to biological assemblages and alter in-stream connectivity, isolating habitats and populations.

The introduction of eastern gambusia, *Gambusia holbrooki,* is also listed as a key threatening process under the TSC Act (now BC Act). This species is extremely common in many waterways of NSW. It can potentially compete with native fishes and is known to prey on a wide range of food items, including tadpoles.

2.6.4 Summary

Of the listed threatened species identified during the online searches, two; Macquarie perch, and Giant Dragonfly, or their habitat, were considered to potentially occur within, or adjacent to, the study site. For Macquarie perch, this was based primarily on inferred historic distributions and its known occurrence in Wollondilly River. It is possible, though unlikely, that Long Swamp Creek provides habitat for this species. Giant dragonfly has been recorded in the sub-catchment and in nearby swamps and it is possible that it occurs within Long Swamp.

Long Swamp (located downstream of the Site) forms part of an (EEC) listed under the EPBC Act (Temperate Highland Peat Swamps on Sandstone) and an EEC listed under the TSC Act (now BC Act) (Montane Peatlands and Swamps of the South Eastern Highlands). The flora and fauna assessment indicated that these EECs did not occur in the quarry footprint and did not predict any direct impacts due to displacement under the extraction area (Kevin Mills and Associates 2018). However, it is possible that these EECs could experience indirect impacts associated with potential groundwater drawdown outside of the extraction footprint.

Two of the KTPs listed under the FM Act, “Degradation of Riparian Vegetation” and “Instream Structures and Mechanisms that Alter Natural Flow” are relevant to the proposed works and two of the KTPs listed under the TSC Act (now BC Act), “Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands” and “The introduction of eastern gambusia, *Gambusia holbrooki*” are also relevant to the proposal.

3 Field Surveys

3.1 Site Inspection

3.1.1 Timing and Methods

The objective of the inspection was to describe aquatic habitats and biota present in Long Swamp Creek adjacent to and downstream of the Site. The Study Area (as defined by RWC) was a reach of Long Swamp Creek immediately adjacent to the northern boundary of the Site and extending approximately 4km downstream of a dirt access track (Site 1 in **Figure 3.1**). Two Cardno staff traversed from the upstream access track along Long Swamp Creek to the downstream limit of the study area and then walked back along the creek upstream to the track, a total distance of approximately 8km. The southern bank of the creek was traversed in both directions as access along the northern bank was hampered by steep cliffs. The Study Area included the creek approximately 180m upstream of the access track, but on the day of the site visit, a powerful thunderstorm prevented safe access to the upper limit of the study area.

The inspection was undertaken on 7 March 2014, between 09:30 and 15:30. Conditions were initially sunny and hot, with a thunderstorm, heavy rain and hail commencing at about 14:30. Water levels in the Study Area were moderate following 42mm of rainfall over the preceding seven days (Moss Vale weather station BoM ID: 068239). During the downstream traverse, general observations were made and photographs taken of the creek and its southern watercourses (i.e. those watercourses potentially flowing across the boundary of the Site). Sites were selected to provide a representation of aquatic habitat types observed. Two sites were established for each habitat type to capture variation within habitat and (where possible) sites were spaced regularly apart in order to capture any environmental gradients or longitudinal patterns. Site 1 was located furthest upstream (approximately 645m AHD) and Site 9 was established at the downstream boundary of the study area (620m AHD; **Figure 3.1**).

Nine sites were visited and assessed using the RCE (Riparian, Channel and Environmental) (Chessman *et al*. 1997) inventory, assessments of fish habitat, including the presence of macrophytes, and dip netting and bait trapping for fish and macroinvertebrates was undertaken. These activities are described as follow:

- RCE records a standardised description of the adjacent land and the condition of riverbanks, channel and bed was recorded using a modified version of the Riparian, Channel and Environmental Inventory (RCE) (Chessman *et al*. 1997).
- The waterway at each site was classified for fish habitat according to the Policy and Guidelines for Fish Habitat Conservation and Management (Update 2013) (NSW DPI (Fisheries) 2013).
- The presence of aquatic macrophytes was recorded at each site.
- A dip net with a mesh size of 250µm was used to collect fish and macroinvertebrates from pool edge habitat at Sites 7 & 9. Edge habitat is defined as areas along creek banks with little or no flow, including alcoves and backwaters, with abundant leaf litter, fine sediment deposits, macrophyte beds, overhanging banks and areas with trailing bank vegetation (Turak *et al.* 2004).
- At Site 1, eight bait traps were deployed to fish for approximately four hours (i.e. set at the beginning of the traverse and retrieved on return, approximately 5.25 hours). The traps used were rectangular in shape and approximately 350mm long and 200mm wide with an entrance tapering to 45mm, with 3mm mesh size throughout. Each trap was baited with a small amount (approximately one tablespoon) of a mixture of chicken pellets and wet cat food.
- A photographic record was made of the channel, adjacent riparian habitat and biota at each site (**Plates 1a–6b**).

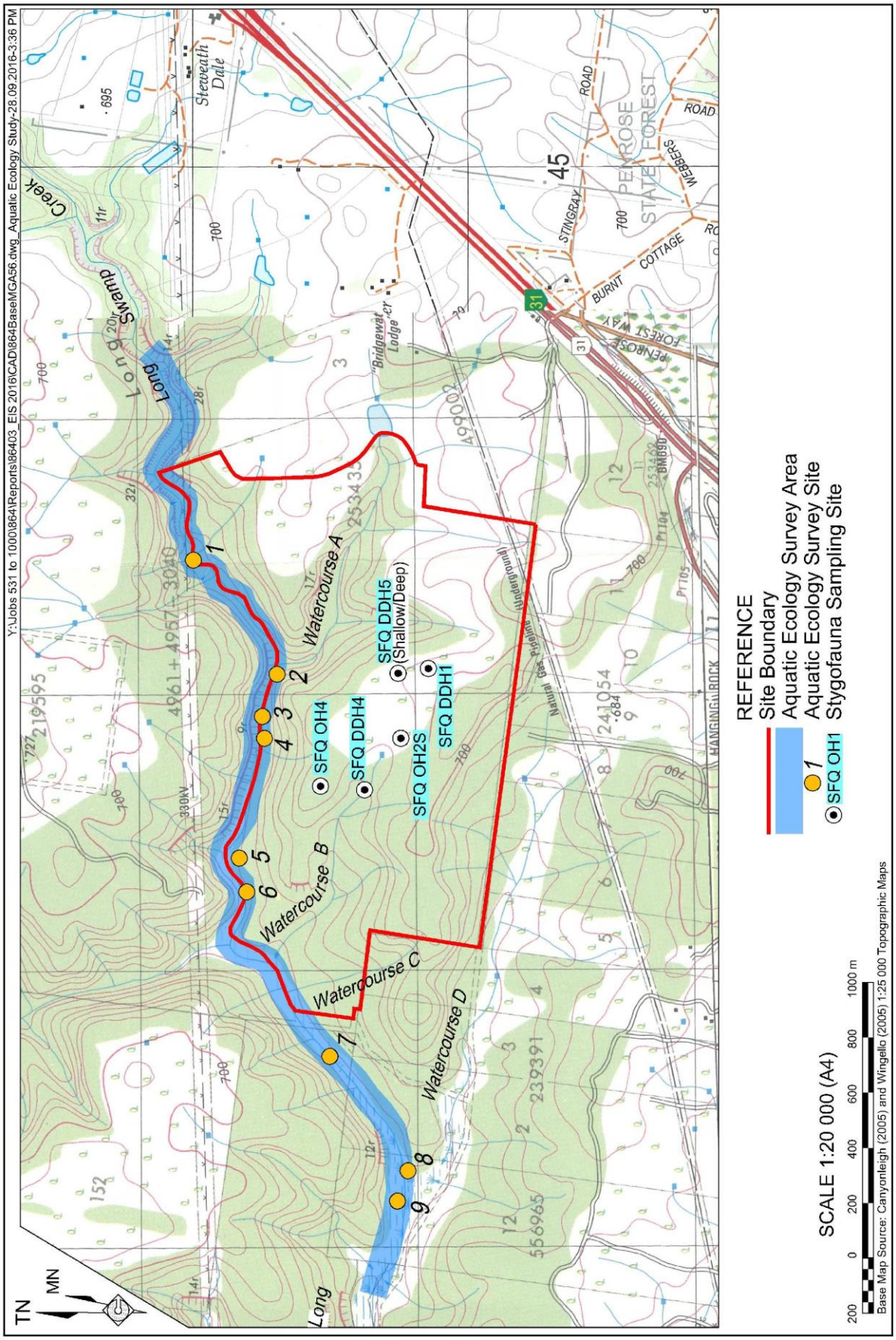

Figure 3.1 Aquatic Ecology Survey Area, Survey Sites and Stygofauna Sampling Sites

3.1.2 Description of Aquatic Habitats and Biota

Long Swamp Creek valley was narrowest at the two sites located furthest upstream (Sites 1 & 2; **Plates 1a–1c**). At Site 1, there was a long shallow pool extending at least 100m upstream of the creek crossing (i.e. a shallow ford) by the dirt track. This would have extended close to the upstream limit of the study area, which could not be accessed later due to the thunderstorm. The crossing itself had a concrete base which showed signs of erosion (**Plate 1a**).

The riparian vegetation at Sites 1 & 2 shaded the majority of the creek and the channel ranged from 1m – 3m in width. The channel alternated between shallow runs and long pools (approximately 0.4m – 0.5m deep) and the substratum was composed of cobble, pebble, gravel, sand and fine silt. Submerged and/or emergent macrophytes such as water millfoil (**Plate 5a**), blunt pondweed (**Plate 5b**) and *Lilaeopsis polyantha* (**Plate 5c**) were relatively abundant in this upper reach and the banks were stabilised by dense stands of *Lomandra longifolia* (**Plate 5d**) as well as tassel sedge (*Carex fascicularis*; **Plate 6a**) and knotweed (*Persicaria* spp.) (**Table 3.1**). Invasive weeds such as blackberry and the annual mint were relatively common on the bank flats amongst the *Lomandra*. The eight bait traps caught 30 mountain galaxias (a common species in high elevation upland creeks and rivers) and two freshwater crayfish (*Eustacus australiensis*; **Plate 6b**). Whirligig beetles (Gyrinidae) and water striders (Gerridae) were abundant at Sites 1 & 2. The ford at Site 1 may constitute a barrier to fish passage during periods of low flow.

Table 3.1 Macrophyte species present within Long Swamp Creek and associated swamp habitat

Scientific Name	Common Name	Site								
		1	2	3	4	5	6	7	8	9
Lilaeopsis polyantha	lilaeopsis			✓						
Carex fascicularis	tassel sedge		✓	✓	✓	✓	✓	✓		✓
Cyperus difformis	rice sedge				✓			✓	✓	
Eleocharis sphacelata	tall spikerush					✓	✓	✓		✓
Potamogeton ochreatus	blunt pondweed	✓								
Myriophyllum sp.	water milfoil	✓	✓	✓		✓		✓		✓
Juncus spp.	spiny rush			✓	✓	✓	✓	✓	✓	✓
Leptospermum sp.	tea tree					✓		✓	✓	✓
Phragmites australis	common reed				✓	✓	✓	✓	✓	✓
Persicaria spp.	knotweed	✓	✓	✓	✓	✓	✓	✓	✓	✓
Typha orientalis	cumbungi					✓		✓		✓
Lomandra longifolia	spiny-head mat-rush	✓	✓	✓	✓	✓	✓	✓	✓	✓

At Site 3 (**Plate 1d**) the shading from the riparian vegetation began to decline and as the valley floor widened so did the channel, averaging 4m – 5m, as slow flowing deep pools became the most dominant channel form. The bank flats were wider also but still dominated by *Lomandra* and annual weeds. Introduced eastern gambusia (*Gambusia holbrooki*; **Plate 6c**) were abundant and exotic willow (*Salix* sp.; **Plate 6d**) had colonised a few shallow sections of the channel.

Further downstream at Sites 4 and 5 (**Plates 2a & 2b**, respectively) the valley floor widened further and there was virtually no riparian shading or cover. The channel at these locations was characterised by a series of interconnected long deep pools, which were fringed by dense stands of common reed (**Plates 2b & 2c**) and sparse clumps of tall spikerush and tassel sedge, particularly against the northern bank, which ran adjacent to numerous rocky bluffs. The bank flats were more extensive on the southern side and whilst *Lomandra* was common near the channel edge, the flats were comprised of waterlogged peats that supported dense mats of sedges, graminoids, forbs and the occasional tea tree shrub

(*Leptospermum* sp.). As such, Site 4 may have represented the upstream extent of Montane Peatlands and Swamps EEC of Long Swamp (**Plate 2b**).

The Montane Peatlands and Swamps EEC was not continuous in this section of Long Swamp Creek, however, as dense stands of common reed dominated the valley floor at Site 5 and 6 (**Plate 2d**). Sparse stands of cumbungi also began to appear within the *Phragmites* stands. At Site 6 there was no obvious pool habitat or distinct channel and flow was restricted to slow moving surface waters among the dense macrophyte beds. Mature willow also became increasing more common with a large stand downstream of Site 6 on the creek bend.

As the reach of Long Swamp Creek turned to the south west, from Site 6 to Site 9 (**Figure 3.1**) the valley floor broadened further and was dominated by the extensive and contiguous peat flats of Long Swamp (**Plate 4a**) and patchy tea tree stands. Long Swamp Creek was reduced to a series of isolated pools up against the northern valley slope (e.g. Site 7; **Plate 4b**). The pools were deep and fringed by tall spike rush and cumbungi and the fish assemblage was dominated by the introduced eastern gambusia. The most waterlogged soils were found on the northern edge of the valley floor and they supported large stands of common rush. Upstream of Site 7 marked the approximate location where Long Swamp and Long Swamp Creek are no longer adjacent to the proposed Site (**Figure 3.1**).

Site 8 (**Plate 4c**) was located at the junction of Long Swamp and a second order watercourse (Watercourse D), which originated adjacent to the southern boundary of the Site (**Figure 3.1**). No obvious channel was evident for this watercourse and it probably represented a continuation of the Montane Peatlands and Swamps EEC of Long Swamp (**Plate 4d**). This watercourse could not be assessed further to establish where the swamp habitat ended due to time constraints however, assessment of the watercourse from a higher vantage point suggested that the swamp probably continued for at least a further 0.5 km upstream. Apart from Watercourse D, all other watercourses that entered Long Swamp Creek from the south (i.e. within or close to the Site) were very small and completely dry at the time of the inspection and probably flow only during high rainfall events.

Site 9 was located at the downstream extent of the Study Area in a pool that extended for hundreds of metres downstream and spaned the entire valley floor. This pool was created by historical peat mining in Long Swamp and a large earth weir forms a road crossing from one side of the valley to the other (**Plate 4a**). A narrow, deep channel under a low bridge allows water to flow past the weir. Eastern gambusia and a carp gudgeon (*Hypseleotris* sp.) were caught by dip net in this channel. The upstream extent of peat harvesting is seen looking upstream from Site 9 (**Plate 4c**). Downstream of Site 9 a large pool habitat was dominated by tall spike rush (**Plate 4d**) and fringed by *Phragmites* and remnant peat lands.

Long Swamp Creek was classified as Class 1 – Major Key Fish Habitat and Type 1 – Highly Sensitive Key Fish habitat according to the criteria in NSW DPI (Fisheries) (2013). This was based primarily on its perennial nature and the presence of native aquatic plants. Though not visited, first and second order watercourses flowing into Long Swamp Creek from within the Site would likely be classified as Class 3 – Unlikely Key Fish Habitat and Type 3 – Minimally Sensitive Key Fish Habitat. This is based on their highly ephemeral nature, and connection to Long Swamp Creek. Watercourse D would likely also be classified as Class 1 and Type 1, due to its apparent perennial nature and presence of native aquatic plants. Preferred waterway crossings for Class 3 key fish habitat are culverts or fords, with preference given to box culverts over fords and pipe culverts (NSW DPI (Fisheries) (2013).

3.1.3 Summary

Long Swamp Creek shows distinct changes over the length of the section adjacent to and near the Site. The upper reach is narrow with long, shallow runs and short riffles, with a narrow riparian strip, a small number of aquatic plants and shading from the overhanging vegetation. Freshwater crayfish and mountain galaxias, but not eastern gambusia, were observed. In the lower reaches of Long Swamp Creek, the habitat transitioned into a broad, swampy channel, with long pools of slow-flowing water and extensive riparian vegetation including rushes. Native gudgeon and large numbers of eastern gambusia were observed.

The watercourses entering Long Swamp Creek from the south were, with one exception, narrow depressions with no water present at the time of the visit. The watercourse entering Long Swamp Creek at Site 8 (**Figure 3.1**) had no observable channel but was a large extension of the swamp habitat. The Site boundary is adjacent to this watercourse with the extraction area located approximately 200m to the north. No listed threatened fish species were observed during the inspection.

3.2 Stygofauna Sampling

3.2.1 Field Methods and Bore Characteristics

The presence of stygofauna potentially inhabiting the local aquifer system was assessed by sampling existing groundwater bores in the extraction area. A total of six bores (SQF-DDH1, SQF-DDH4 (deep), SQF-DDH5 (deep), SQF-DDH5 (shallow), SQF-OH2s and SQF-OH4) were sampled in May 2016; with assistance from Larry Cook Consulting Pty. Ltd. with two samples collected per bore (**Figure 3.2**).

Details of the groundwater bores sampled are presented in **Table 3.2** and locations are shown on **Figure 3.1**.

Table 3.2 Characteristics of groundwater bores sampled for stygofauna in May 2016

Bore	Northing (m)	Easting (m)	Elevation Ground level (m AHD)	Depth of Hole (m BGL)	Screen From (m)	Screen To (m)	Column water in hole (m)
SQF-DDH1	243185	6166154	693	51.1	48	51	4.0
SQF-DDH4 (deep)	242745	6166385	671	51.1	35	41	15.7
SQF-DDH5 (deep)	243168	6166263	689	65.5	51	57	18.3
SQF-DDH5 (shallow)	243168	6166263	689	28.0	22	28	8.8
SQF-OH2S	242932	6166254	670	15.0	9	15	5.8
SQF-OH4	242758	6166545	686	40.7	35	41	3.6

AHD: Australian Height Datum, BGL: Below Ground Level, AGL: Above Ground level, TOC: Top of Collar, SWL: Standing Water Level

Bore water quality data collected by Larry Cook Consulting Pty. Ltd. prior to the field sampling in March 2016 are provided in **Table 3.3**.

Table 3.3 Bore water quality data collected by Larry Cook Consulting Pty. Ltd. March 2016

Monitoring Sites	pH	EC (us/cm)
SQF-DDH1	5.1	61
SQF-DDH4 (deep)	7.9	280
SQF-DDH5 (deep)	5.5	76
SQF-DDH5 (shallow)	5.3	53
SQF-OH2S	5.3	64
SQF-OH4	5.2	64

Samples were collected by lowering and retrieving a weighted hydra-sleeve / bore water sampler to the bottom of each bore using a tether. To minimise the potential for cross contamination \ a new bag with the hydra-sleeve was used for each bore. Once filled with water, the sleeve was retrieved, the contents rinsed through a 63um sieve to remove excess fine sediment and preserved with 70% ethanol in a sample container and labelled with site-specific codes and sampling date.

It was noted that water in bore SQFDDH4 (deep) was turbid compared with other samples.

3.2.2 Stygofauna laboratory methods

Samples were sorted under a binocular microscope (at 40 X magnification), and animals within each sample were removed from the sediment and identified to genus and species level with the exception of Copepoda (to order), Ostracoda (to subclass), and Nematoda (to phylum). The animals extracted from each sample were placed into labelled vials containing 100% ethyl alcohol. After initial sorting and identification, the samples were Quality Assurance checked by a second staff member.

3.2.3 Findings

No stygofauna taxa were identified from the samples. One non-stygofauna taxa was found in the samples from bore SQF-OH2S. This was a springtail (Order: Collembola, Family Isotomidae), a terrestrial arthropod that is often found in soils and leaf litter. It may have washed into the bore during wet weather or otherwise fallen in.

While no stygofauna were collected during the field sampling, this does not unambiguously preclude their presence at the Site. However, the absence of stygofauna does suggest that, if they are present, then they are not likely to be abundant, at least not within the extraction area. It is possible that stygofauna occur, and are more abundant, outside of the extraction area and associated with Long Swamp downstream of the Site. As the water table in these areas would be far closer to the ground surface elevations than within the extraction area, there would likely be a far greater organic input into the associated aquifer which would then be expected to support a greater abundance and diversity of groundwater-associated organisms than may be present at the sampled locations.

4 Assessment of Impacts

4.1 Description of the Proposal with Respect to Aquatic Ecology

Sections 2.2 and 3.2 describe the physical setting of the proposal with respect to aquatic ecology, and the watercourses within, and adjacent to, the site. RWC (2018) describes the Proposal in detail. Key points include the northern extent of the extraction area set back approximately 100m from Long Swamp Creek to the north, and approximately 200m from Watercourse D to the south, hence providing a buffer between quarry activities and the creek and swamp habitat. No direct displacement of, or physical disturbance to Long Swamp Creek or swamp habitat would occur. The proposal would also not require abstraction of water from the creek nor direct discharge of water from the Site into the creek. Other aspects of the proposal pertaining to aquatic ecology include:

- Development of an extraction area (47 hectares) and surface infrastructure including a processing and stockpiling area, water storage dams, fines storage areas and various water management structures in the catchment of Long Swamp Creek. Overall, the combined area of disturbance within the Site would be approximately 94 hectares. The operational life of Proposal would be greater than 30 years, plus rehabilitation activities that may extend for several more years;
- Construction of a Quarry Access Road and Quarry Interchange connecting the Site with the Hume Highway which would cross several first and second order intermittent watercourses (Watercourse A on **Figure 2.1** of the EIS) in Long Swamp Creek Catchment, but would not cross Long Swamp Creek itself;
- A diversion drain along the southern boundary of the proposed Quarry Operations Area to divert runoff away from operational areas;
- During the first 12 months following commencement, a range of site establishment activities would be undertaken. In particular, these would include vegetation clearing and soil removal;
- Surface water, sediment and erosion controls would be installed/constructed either prior to or immediately following clearing activities. These controls would help prevent any sediment-laden runoff flowing into watercourses, and directly overland into, Long Swamp Creek;
- Penetration of an aquifer during extraction. A licence from the NSW CL&W under the Water Management Act 2000 would be required to account for the in-flow of groundwater during the extraction operations, a requirement of the NSW Aquifer Interference Policy. If required, a licence from NSW CL&W for the pumping of water from groundwater for use on site under the Water Management Act 2000;
- All benches within the extraction area would be oriented such that all runoff would be contained on the active benches and directed to a pre-determined drop-down area on the floor of the extraction area. All sediment-laden water would be contained within nominated areas;
- Construction of sediment control dams designed and maintained for the life of the Proposal to ensure that no water containing unacceptable levels of suspended solids is discharged from the operational areas. The extraction area would drain internally beyond the end of extraction Stage 3. Water accumulating in the sediment control sumps would be re-used on site or transferred to the water storage dam;
- The two primary uses of water at the Quarry would be for dust suppression and sand washing. It is estimated that between 48 and 85 ML of water would be required per year, depending on production. The bulk of the water added to the wash plant would be recovered and recycled through the wash plant. Residual fines would be stored two Fines Storage Areas prior to placement directly in the extraction area to progressively rehabilitate completed sections;

- Water required for sand processing and dust suppression would be drawn principally from harvestable rights dams and supplemented by groundwater or other commercial arrangement (e.g. Goulburn – Mulwaree Pipeline);
- Fuels, lubricants and chemicals would be stored within or adjacent to the workshop within bunded areas and appropriate containers. All sewage effluent generated on site would be treated and disposed of on site. If fuel leaks or spillages occur outside these areas, the contaminated material would either be remediated on site or removed by a licenced contractor. Waste oil and filters would be collected and removed by licensed recycling operators.

4.2 Construction Impacts

4.2.1 Changes to Water Quality in Long Swamp Creek

Surface earthworks such as the clearing of soil and vegetation in the extraction area and prior to construction of the surface infrastructure, including the Quarry Access Road and watercourse crossings, and during construction of the water storage dams, have potential to impact upon the aquatic environment. Potential reductions in water quality in Long Swamp Creek could occur due to the mobilisation and release of sediments during these works, particularly via first and second order watercourses and surface run-off during rainfall.

Mobilised sediments could be transported to Long Swamp Creek, and potentially Paddys River, where it may be then deposited. If sediment transport to the creek were to occur, it may result in loss of habitat, for example, through a reduction of available deep water refuge areas (pools) for aquatic biota and smothering of habitat features such as aquatic macrophyte beds, riffles and gravel spawning grounds. Increased turbidity may result in a decline in light penetration and primary productivity, including macrophyte beds. Any resulting die back of vegetation and associated increase in nutrient concentrations following decomposition may encourage algal growth. Increased levels of suspended sediments may also clog the gills of aquatic macroinvertebrates and fish. The likelihood and magnitude of impacts on macroinvertebrates would increase closer to the construction site where turbidity and sedimentation impacts are likely to be greatest. Contaminants (if present) bound to sediments could be also be released during earthworks and transported into receiving waters via surface drainage lines where they could be detrimental to aquatic biota.

The outcome described above is considered of very low risk due to proposed emplacement of sediment and erosion controls implemented prior to, or immediately following, clearing activities as part of the Water Management Plan described in Section 4.1. In particular, the construction of the sediment control dams to manage mobilised sediments generated by disturbance with construction of the larger water storage dams would commence following the installation of downstream sediment controls. Specific recommendations on control measures that should be incorporated are provided in Section 5.1 and in SEEC (2018). Mobilised sediment and potential contaminants are unlikely to pose a significant threat to the aquatic ecology of Long Swamp Creek, provided these control measures are implemented.

4.2.2 Displacement of Aquatic Habitat

Extensive instream works would not be required as part of the Proposal and no sections of Long Swamp Creek would be displaced under the footprint of the extraction area or other infrastructure associated with the Quarry. A small amount (approximately 1km in total) of ephemeral watercourse habitat associated with small watercourses flowing from the Site into Long Swamp Creek (**Figure 3.1**) would be displaced by the extraction area and other Quarry infrastructure. Substantial instream works would be limited to the excavation of the water storage dams on two first order watercourses of Long Swamp Creek and construction of sediment control dams on other watercourses. Waterway crossings on first order watercourses associated with the Quarry Access Road and the access track to Fines Storage Area 1 would also displace a small amount of aquatic habitat.

These ephemeral habitats, which flow only after rainfall (Section 2.1), support aquatic habitat of limited ecological value and there would be minimal overall impact to the aquatic ecology of the Long Swamp Creek Catchment due to small amount of displacement proposed. Ephemeral habitat displaced under dams would be, at least partially, offset by the provision of lentic (i.e. non-flowing) aquatic habitat.

Depending on water quality within the dams, this habitat would likely be utilised by aquatic flora and fauna such as macroinvertebrates, frogs, waterbirds and some species of fish able to colonise disconnected water bodies (e.g. eels *Anguilla* sp.).

4.3 Operational Impacts

4.3.1 Changes in Ground and Surface Water Input to Aquatic Ecosystems

Baseflow to Long Swamp Creek has been modelled at 2.0ML / day (Coffey 2018). Groundwater inflows into the extraction area during operation are predicted to result in a reduction of 0.052ML / day (2.6% of estimated baseflow) to Long Swamp, Long Swamp Creek and associated waterways between year 30 and year 45 of the Proposal. By year 50, the reduction in baseflow would be less than 0.01ML / day. This reduction in baseflow is considered to be within the range of natural variation in flows for this type of system (Cook 2018). Such reductions are unlikely to result in any substantial reduction in aquatic habitat in Long Swamp Creek by causing, for example, substantial reductions in pool water levels or desiccation of aquatic macrophytes in the creek. It is also noted that the lowest level of extraction would be, at a minimum, 10m above the elevation of the channel of Long Swamp Creek.

Groundwater modelling indicates that there would be a maximum drawdown of the water table at the eastern extent of Long Swamp (nearest the extraction area) of less than 0.1 m at the end of Stage 5 (year 28) and Stage 7 (year 45) (Cook 2018). This drawdown may affect some fringing areas of swamp habitat along the eastern-most edge of Long Swamp nearest to the extraction area and no extensive loss should occur.

Potential exacerbation of the associated KTPs Instream Structures and Mechanisms that Alter Natural Flow and Alteration to Natural Flow Regimes are discussed in Section 4.5.

4.3.2 Changes to Water Quality

Product processing would not require the direct use of toxic chemicals or reagents. Hydrocarbons, aromatic hydrocarbons (lubricating oils and fuels), heavy metals (e.g. copper in brake linings, and zinc and cadmium in tyres etc.) may have a detrimental effect on aquatic biota and habitat. Water soluble components of petroleum hydrocarbons include a variety of compounds that are toxic to aquatic life (Clarke 1997). Several measures have been outlined within the Project Description to minimise, manage and clean up spillages of fuels, oils and greases and appropriate storage and refuelling areas have been identified. It is unlikely that hydrocarbons could enter surface run-off from any leakages of vehicles using the access road due to the highly permeable nature of the soils. During rainfall, it is possible that hydrocarbon residue and spillages from the roads and tracks within the Site could enter waterways via surface run-off. However, taking into account the proposed management measures and safeguards, the likely volumes of such in flows are likely to be very small.

The containment methods described in Section 5.1 (e.g. bunding and appropriate containers) would minimise the potential for the release of contaminants to the creek during operation. There are published trigger values for these toxicants designed to protect aquatic ecosystems in Australia (ANZECC 2000).

There would also be an ongoing risk of changes to water quality in Long Swamp Creek due to mobilisation and release of sediments during operation. Measures to minimise impacts associated with sediment loads during construction (Section 4.2.1) would be applicable to ongoing operations. Any Herbicides should also be stored securely in appropriate containers and in bunded areas. If any spill occurs, the input of these chemicals could cause fish kills and dieback of vegetation, including swamp and EEC vegetation

4.3.3 Disruption of the Movement of Aquatic Fauna

Even during flow following rainfall events, first and second order ephemeral watercourses would be unlikely to provide important habitat for native fish. Thus, there would be little impact to these species due to the construction of dams and crossings (e.g. fords, culverts) and associated reductions in habitat connectivity due to impediments to fish passage. Waterway crossings would likely also be passible during high flows following rainfall events. Nevertheless, all crossings should be selected and designed in accordance with (NSW DPI (Fisheries) 2013) to help ensure the type of crossings is applicable to the waterway class and ensure minimal effects on fish passage (Section 5).

4.4 Listed Threatened Aquatic Ecology

4.4.1 Macquarie Perch

No Macquarie perch were observed during the inspection of Long Swamp Creek, nor in Paddys River (Cardno 2010). It would appear that the closest records are in the lower reaches of the Wollondilly River (NSW DPI 2005a, Riches *et al*. 2016, although distribution maps presented by the latter were based on streams with > 5 ML daily flow). There was little potential spawning habitat for Macquarie perch observed in Long Swamp Creek near the Site. Given the disconnected nature of open aquatic habitat throughout Long Swamp and the existence of several road crossings on the Wollondilly and Paddys Rivers that are potential barriers to fish passage (DPI NSW 2006a), it is considered unlikely that Macquarie perch utilises the upstream reaches of Long Swamp Creek for spawning habitat. Furthermore, Macquarie perch is an active predator of macroinvertebrates, so 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 the discontinuous and small pools of Long Swamp are inadequate to support a population of Macquarie perch (Ebner *et al*. 2010). As the area of Long Swamp Creek in proximity to the Site is unlikely to support a population of adult Macquarie perch or provide accessible or viable spawning habitat, it is concluded that the Proposal is very unlikely to affect Macquarie perch. Thus, an Assessment of Significance as required by the EPBC Act and a Seven Part Test as required by the FM Act were not considered necessary.

Furthermore, given the lack of substantial changes to baseflow in Long Swamp Creek and the manageable nature of potential impacts from sedimentation and other water contamination during construction and operation, the proposed works would not be expected to lead to significant impacts to this species in the unlikely event that it does utilise Long Swamp Creek. Referral of the Proposal in relation to this species as prescribed by the EPBC Act is therefore not required. A species impact statement is also unnecessary.

4.4.2 Giant Dragonfly

The Giant Dragonfly has been recorded in the sub-catchment and in nearby swamps and it is possible that it occurs within Long Swamp. The flora and fauna assessment did not identify habitat for this species within the Site, and there would be no direct impacts due to displacement under the extraction area (Mills 2016). However, it is possible that Long Swamp provides suitable habitat for this species downstream of the Site. The apparent small predicted changes in the water table should not lead to extensive reductions in the extent of this habitat (and none on the western side of the creek), though some fringing areas on the eastern side may be reduced. Associated effects on Giant Dragonfly would depend on the importance of this habitat to this species. As the majority of swamp habitat would be unlikely to be affected by the predicted reduction of the water table elevation, associated potential effects on Giant Dragonfly through loss of habitat, if they occur, would be expected to be minimal.

4.4.3 Endangered Ecological Communities

Long Swamp (located downstream of the Site) forms part of an EEC listed under the EPBC Act (Temperate Highland Peat Swamps on Sandstone) and an EEC listed under the TSC Act (now BC Act) (Montane Peatlands and Swamps of the South Eastern Highlands). The flora and fauna assessment indicated that these EECs did not occur on the Site and did not predict any direct impacts due to displacement under the extraction area (Mills 2018).

It is unclear if the predicted reduction in water table would have an impact on swamp habitat, though it is possible that some fringing areas of swamp habitat may be lost (Section 4.3.1). Any affect would be restricted to the eastern most extent of Long Swamp nearest to the extraction area and no extensive loss would occur.

4.5 Key Threatening Processes

4.5.1 Degradation of Riparian Vegetation

Riparian vegetation along the section of Long Swamp Creek visited was relatively disturbed and consisted of mixed exotic and native species (Section 3.1). No extraction or other works would be undertaken within approximately 50m of the creek and no clearing of this vegetation would be undertaken. A small amount of vegetation adjacent to first and second order watercourses of Long Swamp Creek would be lost due to clearing for construction of Quarry infrastructures. However, examination of aerial imagery indicates that this vegetation is likely to be highly fragmented and disturbed and would provide limited function as riparian vegetation. It is unlikely that the proposed works would further degrade riparian vegetation such that there would be a significant impact on the aquatic ecology of Long Swamp Creek.

4.5.2 Instream Structures and Mechanisms that Alter Natural Flow

The construction of the water storage dams, sediment dams and waterway crossings would alter natural flow in first and second order watercourses of Long Swamp Creek and potential sections downstream. The construction of the water storage dams and water management infrastructures would isolate approximately 1km of first order watercourse from the Long Swamp Creek Catchment, which would reduce the amount of runoff to Long Swamp Creek.

The installing of waterway crossings in first order watercourses may also alter flow, with potential pooling of water upstream. However, as these watercourses would only flow primarily after rainfall events only, the effect on the natural flow regime in Long Swamp Creek due to installation of waterway crossings would be negligible.

Groundwater interception by the extraction area would reduce the baseflow and alter the natural flow regime of the Long Swamp Creek Catchment. However, the predicted reduction in baseflow as a result of groundwater interception (maximum of 2.6%) would be unlikely to result in substantial reductions in pool water levels or flow (Section 4.3.1).

4.5.3 Alteration to Natural Flow Regimes

See Section 4.5.2.

4.5.4 Introduction of eastern gambusia, *Gambusia holbrooki*

Gambusia holbrooki are extremely tolerant to degraded and disturbed conditions and can outcompete more sensitive native species. Increased turbidity and/or sedimentation potentially as a result of surface run-off from construction and operational works could therefore create conditions that favour introduced pest species such as *G. holbrooki*. The sediment and erosion controls that would be implemented to help divert sediment laden water into sediment dams is likely to minimise potential impacts to water quality and hence proliferation of this species. It is also possible that this species could become

established in the water storage and sediment dams, and that they may be released to Long Swamp Creek if the dams overflow during high rainfall. It should be noted, however, that this species is already abundant in Long Swamp Creek.

4.6 Stygofauna

The absence of stygofauna in the samples collected (Section 3.2) suggest that there would be minimal, if any, direct impact to stygofauna due to excavation of the extraction area. As with other groundwater dependant ecosystems (GDEs) identified downstream of the proposal (i.e. the two EECs associated with Long Swamp), any alteration to groundwater availability following extraction could have indirect impacts on these organisms, if present. However, as for impacts to swamp habitat described in Section 4.3.1, any impacts to associated stygofauna would be expected to be restricted to the eastern most extent of swamp habitat nearest the extraction area (and which may experience up to 0.1m reduction in depth of the water table).

5 Recommendations

Recommended control measures aimed at avoiding and minimising the potential impacts to aquatic ecology that could occur during construction and operation of the Proposal are provided in **Table 5.1**. Measures to avoid and minimise potential impacts to listed threatened aquatic ecology and exacerbation of KTPs are also provided.

Table 5.1 Recommended control measures for potential impacts occurring during construction and operation of the proposal, and potential affecting listed threatened aquatic ecology and KTPs

Construction		
Potential Impact	**Receptors**	**Control Measures**
Changes to water quality in Long Swamp Creek due to input of mobilised sediments and other potential contaminants during construction	Water quality Aquatic vegetation Macroinvertebrates Fish Threatened species	Development and implementation of a Water Management Plan including redirection of sediment-laden runoff into sediment dams and redirection of clean surface water around earthworks. Water accumulated within the extraction area, water storage dams and sediment dams should be managed appropriately. Appropriate crossing structures (causeways or culverts) are recommended where the access road traverses first and second order watercourses. Waterway crossings should be designed and constructed in accordance with NSW DPI (Fisheries) (2013). Use of silt curtains/fences/sediment basins to prevent sediments entering waterways during the construction of any surface infrastructure and roads Storage of hydrocarbons and other potential contaminants should be undertaken in accordance with the controls outlined in Section 2.9.5 of the Project Description. Access roads should be constructed in accordance with the requirements of Managing Urban Stormwater – Volume 2C Unsealed Roads (DECC 2008) to prevent surface run-off entering waterways.
Displacement of aquatic habitat under the footprint of the extraction area and surface infrastructure	Fish Threatened species	No specific control measures are recommended. The only direct loss of aquatic habitat that would occur would be the loss of approximately 1km of ephemeral first and second order stream habitat, which provides aquatic ecology of limited value.

Operation		
Potential Impact	**Receptor**	**Control Measures**
Changes in groundwater and surface water input to aquatic ecosystems due to reductions in baseflow in Long Swamp Creek following interception of ground and surface water inflow. Only a relatively small (≤ 2.6%) reduction in baseflow due to interception of groundwater by the extraction pit is predicted to occur. However, while no direct displacement of swamp (including EEC) habitat would occur, indirect downstream impacts may occur due to reductions in the depth of the water table and associated drying of soils.	Long Swamp Creek aquatic ecology Long Swamp and associated EECs and potentially the listed threatened Giant Dragonfly Any stygofauna potentially associated with swamp habitat	Monitoring of swamp habitat should occur to identify any possible dieback of vegetation and reduction in habitat quality associated with potential reductions in depth of the water table and drying of soils. The findings of the monitoring would be used to confirm predictions on the ecological effects of reductions in baseflow and potential reductions in depth of the water table and soil moisture content in swamp habitat inform management decisions. Monitoring should include: 1. Baseline survey prior to construction incorporating mapping of swamp extent, species composition, and installation of fixed photographic points. Appropriate reference sites in nearby swamps should also be established. Potential reference locations should be considered in the region, including at least two of the following: Hanging Rock, Mundego and Stingray swamps. 2. Annual monitoring during operations using methods used in the baseline survey. 3. Reporting of any identified impacts to swamp habitat and recommendations on management actions that should be undertaken to prevent any further deleterious changes due to the proposal. Monitoring should be complemented by measurement of groundwater levels and soil moisture associated with Long Swamp Creek.
Changes to water quality in Long Swamp Creek due to input of mobilised sediments and other potential contaminants during operation	Fish Threatened species	Control measures as described for potential changes to water quality occurring during construction. In addition, the quality of any water released from dams tested to conform to relevant guidelines or licence conditions.
Disruption of the Movement of Aquatic Fauna Potential for some limited blockage of passage of fish in first and second order watercourses.	Fish Threatened species	All crossings should be selected and designed in accordance with (NSW DPI (Fisheries 2013).

Listed Threatened Aquatic Ecology		
Potential Impact	**Receptor**	**Control Measures**
Changes to aquatic habitat and water quality and availability could potentially impact the listed threatened species Macquarie Perch. However, based on previous records, the presence of barriers to fish passage, and the habitat requirements of Macquarie perch, its presence in Long Swamp Creek is highly unlikely (Section 4.4.1).	Macquarie Perch	The implementation of the control measures described for construction and operational impacts to water quality and availability would be sufficient to reduce residual potential impacts to acceptable levels. No further specific control measures recommended.
Potential loss of an EEC listed under the EPBC Act (Temperate Highland Peat Swamps on Sandstone), an EEC listed under the TSC Act (now BC Act) (Montane Peatlands and Swamps of the South Eastern Highlands) and the listed threatened Giant Dragonfly due to associated habitat loss following a reduction in depth of the water table.	2 EECs Giant Dragonfly	Potential impacts to these listed threatened ecological communities could be managed by implementation of a swamp habitat monitoring program (see above).
Key Threatening Processes		
Potential Impact	**Receptor**	**Control Measures**
Degradation of Riparian Vegetation Potential for a small amount of riparian vegetation associated with first and second order watercourse to be lost under the footprint of the extraction area and infrastructure	Riparian Vegetation	Removal of riparian vegetation during construction related clearing should be avoided wherever possible. Re-planting and rehabilitation of riparian vegetation along other sections of first and second order watercourses should be conducted
Instream structures and Mechanisms that Alter Natural Flow and Alteration to Natural Flow Regimes	Long Swamp Creek aquatic ecology Long Swamp and associated EECs and potentially the listed threatened Giant Dragonfly	Monitoring of swamp habitat as described for potential changes in ground and surface water input to aquatic ecosystems due to reductions in baseflow
Introduction of eastern gambusia, *Gambusia holbrooki* Proliferation in Long Swamp Creek due to reductions in water quality. Establishment in, and subsequent release from, water storage and sediment dams.	Potential predation on native fish and frogs / tadpoles in Long Swamp Creek	Control measures associated with managing water quality. If this species is discovered to be highly abundant in dams, then measures to remove (for example, direct physical control) individuals prior to any controlled release of water should be considered

6 Conclusions

The proposal includes the disturbance of approximately 95 hectares of land, including development of a 47 hectare extraction area, adjacent to Long Swamp Creek and nearby Long Swamp. No direct displacement of Long Swamp Creek or Long Swamp, including the two identified EECs associated with this habitat, would occur. The primary potential impact to aquatic ecology associated with the proposal is related to alterations to surface and groundwater availability and associated indirect effects to these habitats and also the TSC Act (now BC Act) listed Giant Dragonfly, which occurs in nearby local swamps and potentially also Long Swamp Creek. These could arise due to interception of groundwater in the extraction area, associated with a small 2.6% reduction in baseflow to Long Swamp Creek and Long Swamp and a maximum 0.1m reduction in the depth to the water table in the eastern most section of Long Swamp. The other potential impact to aquatic ecology is associated with a reduction in water quality in Long Swamp Creek due to the mobilisation and release of sediments and other potential contaminants during construction and operation of the Proposal, which may affect aquatic habitat in receiving waters.

Several ephemeral first and second order watercourses would be disturbed, due to construction of water storage dams and road crossings. However, only a relatively small area of limited value aquatic habitat would be affected.

Potential reductions in water quality could be managed by development and implementation of a Water Management Plan that includes the measures described in SEEC (2018) and in **Section 5**. Following successful implementation, residual impacts to aquatic ecology due to changes in water quality would be negligible. Due to the potential for downstream impacts on Long Swamp, identified EECs and, the Giant Dragonfly (if present), a swamp monitoring program is recommended. The primary aim of the monitoring program would be to identify potential changes in swamp habitat that maybe associated with the Proposal and would include characterisation of baseline conditions prior to construction. Any subsequent changes in swamp habitat, such as vegetation die back and changes in plant the community, should be assessed in relation to measurable changes in groundwater levels to ensure that appropriate management actions are taken to prevent or minimise any further changes.

7 References

ANZECC (2000). *Australian guidelines for water quality monitoring and reporting.* National water quality management strategy, No. 7. Prepared for: Australian & New Zealand Governments. ANZECC//ARMCANZ, Australia.

Brainwood, M., Burgin, S. and Byrne, M. (2008). The impact of small and large impoundments on freshwater mussel distribution in the Hawkesbury-Nepean River, south-eastern Australia. *River Research and Applications*.

Cardno Ecology Lab (2010). Environmental Assessment for the Green Valley Sand Quarry Project via Paddys River. Report prepared for Rocla Pty Ltd.

Chessman, B. C., Growns, J. E. and Kotlash, A. R. (1997). Objective derivation of macroinvertebrate family sensitivity grade numbers for the SIGNAL biotic index: Application to the Hunter River system, New South Wales. *Marine & Freshwater Research* 48, pp. 159-172.

Clarke, R.B. (1997). Marine Pollution, Fourth Edition. Oxford University Press. Oxford, UK.

DECC (2005). Threats. Key threatening process. Alteration to the natural flow regimes of rivers, streams, floodplains & wetlands. http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/threat_profile.aspx?id=20002

DECC (2008). Giant dragonfly – Endangered species listing. NSW Scientific Committee – Final determination. http://www.environment.nsw.gov.au/determinations/GiantDragonflyEndSpListing.htm

DECC (2009). Threatened species. Giant dragonfly – profile. http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10600

Department of the Environment and Heritage (DEH) (2005). Nationally threatened species and ecological communities. Temperate Highland Peat Swamps on Sandstone. http://www.environment.gov.au/system/files/resources/4c456084-b8d1-4800-8e91-f98236613b1c/files/temperate-highland-peat-swamps.pdf

Department of the Environment (DOE) (2014). Biodiversity. Species Profile and Threats Database. Prototroctes maraena – Australian Grayling. http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=26179

Department of Environment, Water, Heritage and Arts (DEWHA) (2008). A Directory of Important Wetlands in Australia Long, Hanging Rock, Mundego and Stingray Swamps (Paddys River Swamps) – NSW082.

DPI NSW (2005a). Primefact 9. Threatened Species in NSW Macquarie perch *Macquaria australasica*. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/5102/Primefact_Macquarie_perch.pdf

DPI NSW (2005b). NSW DPI Primefact 10. Key Threatening Processes in NSW. Instream Structures and Other Mechanisms that Alter Natural Flows. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0016/34252/Primefact_Instream_structures.pdf

DPI NSW (2005c). NSW DPI Primefact 12. Key Threatening Processes in NSW. Degradation of Native Riparian Vegetation along NSW Water Courses. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0015/34251/Primefact_Degradation_of_Native_Riparian_Vegetation.pdf http://www.environment.gov.au/cgi-bin/wetlands/report.pl.

DPI NSW (2006a). *Reducing the impact of road crossings on aquatic habitat in coastal waterways – Hawkesbury-Nepean, NSW*. Report to the New South Wales Environmental Trust. NSW Department of Primary Industries, Flemington, NSW.

DPI NSW (2007). NSW DPI Primefact 184. Threatened species in NSW. Sydney Hawk dragonfly *Austrocordulia leonardi*. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/144127/sydney-hawk-dragonfly.pdf

DPI NSW (2008). Species Protection. What is Currently Listed? http://www.dpi.nsw.gov.au/fisheries/species-protection/species-conservation/what-current

DPI NSW (2009). Freshwater Pests. Redfin Perch (*Perca fluviatilis*). http://www.dpi.nsw.gov.au/fisheries/pests-diseases/freshwater-pests/species/redfin-perch#Where-are-they-in-NSW?

DPI NSW (2012). NSW DPI Primefact 1181. Fitzroy Falls Spiny Crayfish, *Euastacus dharawalus*. https://www.dpi.nsw.gov.au/fishing/species-protection/conservation/what-current/critically/fitzroy-falls-spiny-crayfish

Ebner, B.C., Lintermans, M., Jekabsons, M. and Dunford, M. (2010). Convoluted shorelines confound diel-range estimates of radio-tracked fish. *Marine and Freshwater Research* 61(12):1360-1365

Ecowise (2005). – SCA Macroinvertebrate Monitoring Program: 2004. Final Report prepared for Sydney Catchment Authority.

Graham, K.J., Lowry, M.B. and Walford, T.R. (2005). *Carp in NSW: Assessment of distribution, fishery and fishing methods.* NSW Department of Primary Industries - Fisheries Final Report Series No. 72.

Grant, T.R. and Temple-Smith, P.D. (1998). Field biology of the platypus (*Ornithorhynchus anatinus*): historical and current perspectives. *Philosophical Transactions of the Royal Society London B* 353: pp. 1081-1091.

Hawkesbury-Nepean Catchment Management Authority. (2008). Hawkesbury-Nepean Catchment Action Plan 2007-2016.

Kevin Mills & Associates (2018). Flora and Fauna Survey and Assessment. Sutton Forest Sand Quarry Proposal. Hume Highway. Shire of Wingecarribee. September 2016.

Larry Cook Consulting Pty. Ltd. (2018). Sutton Forest Sand Quarry. Groundwater Impact Assessment.

Morris, S. A., Pollard, D. A., Gehrke, P. and Pogonoski, J. J. (2001). *Threatened and Potentially Threatened Freshwater Fishes of Coastal New South Wales and the Murray-Darling Basin.* Prepared for: Commonwealth Government's Fisheries Action Program//World Wide Fund for Nature. NSW Fisheries Office Of Conservation, NSW.

NSW National Parks and Wildlife Service (2008). Atlas of NSW Wildlife Fauna, *Petalura gigantea* -Giant Dragonfly, CMA - Hawkesbury-Nepean. http://wildlifeatlas.nationalparks.nsw.gov.au/wildlifeatlas/watlasSpecies.jsp

NSW Department of Primary Industries (DPI) (Fisheries) (2003). *Freshwater fish stocking in NSW. Environmental impact assessment*. NSW Fisheries, Cronulla Fisheries Centre, NSW.

NSW Department of Primary Industries (DPI) (Fisheries) (2013). Policy and Guidelines for Fish Habitat Conservation and Management (2013 update).

OEH (2017). Giant Dragonfly – South Eastern Highlands: Distributions and Vegetation Associations. NSW Office of Environment and Heritage (September 2017).

Strategic Environmental and Engineering Consulting (SEEC) (2018). Surface Water Assessment. Sutton Forest Sand Quarry.

Riches, M, Gilligan, D., Danaher, K and Pursey, J. (2016). *Fish communities and threatened species distributions of NSW*. NSW Department of Primary Industries (www.dpi.nsw.gov.au)

The Ecology Lab (2006). Shoalhaven Transfer Project, Aquatic Ecology Assessment. Report prepared for NSW Department of Commerce.

Turak, E., Waddell, N. and Johnstone, G. (2004). New South Wales (NSW) Australian River Assessment System (AusRivAS) Sampling and Processing Manual. Department of Environment and Conservation (NSW).

Wetland Care Australia (2008). Paddys River Background Paper. Management of Paddys River Wetlands. Draft report prepared for Hawkesbury-Nepean Catchment Management Authority.

Plates

Plates 1a – d. Sites 1 - 3

Plates 2a – d. Sites 4 - 6

Plates 3a – d. Sites 7 – 8

Plates 4a – d. Site 9

Plates 5a – d. Macrophytes

Plates 6a – d. Macrophytes, Freshwater Crayfish and Introduced Eastern gambusia

(a)

(b)

(c)

(d)

Plate 1a – d.
(a) concrete ford water crossing at Site 1; (b) Site 1, view upstream; (c) Site 2, view downstream; (d) Site 3, view downstream.

(a)

(b)

(c)

(d)

Plate 2a – d.
(a) montane peat swamp habitat at Site 4 on the southern side of the channel; (b) pool habitat at Site 4, fringed by *Phragmites australis* on the northern bank (background) and *Lomandra longifolia* on the southern bank (foreground); (c) Site 5, view downstream; (d) Site 6 dominated by *Phragmites australis*, view upstream.

(a)

(b)

(c)

(d)

Plate 3a – d.
(a) montane peat swamp habitat at Site 7, view downstream; (b) pool habitat at Site 7 on northern edge of valley floor. Shallow boundaries of pool populated by tall spikerush (*Eleocharis sphacelata*); (c) Site 8, montane peat swamp habitat at confluence of Long Swamp Creek and Watercourse D, view upstream; (d) Site 8, upstream view of Watercourse D at confluence with Long Swamp. The unnamed watercourse lacked an obvious open water channel and was characterized by montane peat swamp habitat.

(a)

(b)

(c)

(d)

Plate 4a – d.
(a) Earth weir at Site 9 that forms a road crossing over the Long; (b) a low bridge in the weir at Site 9 permits downstream flow via a narrow channel; (c) Site 9, view upstream from the weir bridge. The pool was likely formed by historical peat harvesting and the pool edge (background) represents the upstream extent of the harvesting activity; (d) Site 9, view downstream of weir bridge.

(a)

(b)

(c)

(d)

Plate 5a – d.
(a) water millfoil (*Myriophyllum* sp.) at Site 1; (b) blunt pondweed (*Potamogeton ochreatus*) from Site 1; (c) Macrophyte *Lilaeopsis polyantha* from Site 3; (d) *Lomandra longifolia* at Site 1.

(a)

(b)

(c)

(d)

Plate 6a – d.
(a) Tassel sedge (*Carex fascicularis*) at Site 3; (b) freshwater crayfish (*Euastacus australiensis*); (c) introduced mosquitofish (*Gambusia holbrooki*); (d) introduced willow (*Salix* sp.) sapling in channel pool at Site 7.

Appendices

Appendix 1. Water Quality Data Provided by Strategic Environmental Engineering Consulting (SEEC 2018). Grey shading indicates measure outside of ANZECC (2000) trigger values.

Appendix 2. Aquatic ecology inspection survey site GPS coordinates (datum: Decimal Degrees), elevation and survey methods used.

Appendix 3. River descriptors, associated categories and values used in the modified riparian, channel and environmental inventory (RCE) From Chessman *et al.* (1997).

APPENDIX 1 – Water Quality Data Provided by Strategic Environmental Engineering Consulting (SEEC 2018). Grey shading indicates measure outside of ANZECC (2000) trigger values

Analyte	Units	LOR	ANZECC (2000) Trigger Values	Sampling Date	WQL1	WQL2	WQL3	Farm Dam	Bridgewater Dam
pH	pH units		6.5-8.0	13/08/2013	7.5	7.4	7.1		
				5/03/2014			5.5	6.3	6.74
				2/04/2014	6.3	6.3			
Electrical Conductivity	µS/cm		30-350	13/08/2013	221	211	295		
				5/03/2014			125	84	107
				2/04/2014	314	268			
Temperature	C			13/08/2013	8.6	8.2	8.2		
				5/03/2014			15.6	20	20.7
				2/04/2014	15.8	15.6			
Dissolved Oxygen	%		90-110	13/08/2013	57	53	40		
				5/03/2014			54	72	51
				2/04/2014	38	47			
Dissolved Oxygen	mg/L			13/08/2013	6.13	5.37	4.3		
Oxygen Reduction Potential	mV			13/08/2013	40				
Alkalinity CaCo3)	mg/L	5		13/08/2013	37	31	58		
				5/03/2014			24	21	19
				2/04/2014	49	32			
Nitrate	mg/kg	0.01	0.015*	13/08/2013	0.02	0.04	0.05		
				5/03/2014			0.06	0.02	ND
				2/04/2014	ND	ND			
Nitrite	mg/kg	0.01	0.015*	13/08/2013	ND	ND	ND		
				5/03/2014			ND	ND	ND
				2/04/2014	ND	ND			

Analyte	Units	LOR	ANZECC (2000) Trigger Values	Sampling Date	WQL1	WQL2	WQL3	Farm Dam	Bridgewater Dam
Total Nitrogen	mg/kg	0.1	0.250	13/08/2013	0.60	0.90	0.85		
				5/03/2014			0.26	1.00	1.10
				2/04/2014	0.3	0.3			
Total Phosphorus	mg/kg		0.020	13/08/2013	ND	ND	0.01		
				5/03/2014			0.02	ND	0.05
				2/04/2014	ND	ND			
Total Suspended Solids	mg/kg		n/a	13/08/2013	ND	ND	ND		
				5/03/2014			ND	18.0	9
				2/04/2014	7.5	ND			
Arsenic	mg/kg	0.005	0.037**						ND
Cadmium	mg/kg	0.0005	0.0002						ND
Chromium	mg/kg	0.005	0.001						ND
Copper	mg/kg	0.005	0.0014						ND
Iron	mg/kg	0.05	n/a	13/08/2013	0.76	0.78	0.54		
				5/03/2014			4.1	0.83	0.56
				2/04/2014	3.8	2.4			
Lead	mg/kg	0.005	0.0034						ND
Nickel	mg/kg	0.005	0.011						ND
Zinc	mg/kg	0.005	0.008	13/08/2013	ND	ND	ND		
				5/03/2014			ND	0.006	0.019
				2/04/2014	ND	ND			

*Total for oxides of N, **AsIII + AsV, ND = not detected at LOR

APPENDIX 2 - Aquatic ecology inspection survey site GPS coordinates (datum: Decimal Degrees), and elevation

Site	Latitude	Longitude	Elevation (m AHD)
1	-34.60678800	150.20366301	645
2	-34.60941799	150.19906201	645
3	-34.60890301	150.19741204	640
4	-34.60894802	150.19654300	640
5	-34.60801897	150.19184100	635
6	-34.60823002	150.19049001	635
7	-34.61079497	150.18389999	630
8	-34.61324299	150.17929296	625
9	-34.61287301	150.17810499	625

APPENDIX 3 - River descriptors, associated categories and values used in the modified riparian, channel and environmental inventory (RCE) From Chessman et al. (1997)

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