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Mount Pleasant Operation

A JOINT VENTURE WITH JCDA Japan Coal Development Australia

Appendix F

Aquatic Ecology Assessment

MOUNT PLEASANT OPTIMISATION PROJECT
AQUATIC ECOLOGY ASSESSMENT

PREPARED FOR
MACH Energy Australia Pty Ltd

13 November 2020

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EXECUTIVE SUMMARY

The Mount Pleasant Operation (MPO) is an open cut coal mine and associated infrastructure, located approximately 3 kilometres north-west of Muswellbrook in the Upper Hunter Valley of New South Wales (NSW).

MACH[1] is seeking approval for changes to the MPO, herein referred to as the Mount Pleasant Optimisation Project (the Project). The Project proposes extraction of additional coal reserves within MPO Mining Leases and an increase in the rate of coal extraction without significantly increasing the total disturbance footprint.

BIO-ANALYSIS Pty Ltd has been commissioned to prepare an aquatic ecology assessment for the Project, including investigations on local waterways and groundwater. The assessment includes a review of relevant databases and literature as well as field surveys. The main field survey methods included systematic assessment of the aquatic habitat, water quality measurements, sampling of macroinvertebrates, sampling of fish and sampling of groundwater for presence of stygofauna.

The Study Area is mainly used for grazing on native/natural pasture with some partly improved pasture and more intensive uses on the Hunter River floodplain along the eastern boundary. The drainage network in the vicinity of the Study Area is generally characterised by steep gullies which drain from the surrounding hills into flat alluvial plains adjacent to the Hunter River. A number of ephemeral drainage lines traverse the Study Area and drain into the Hunter River.

[1] MACH Mount Pleasant Operations Pty Ltd manages the MPO as agent for and on behalf of the unincorporated Mount Pleasant Joint Venture between MACH Energy (95 percent [%] owner) and J.C.D. Australia Pty Ltd (5% owner). Throughout this report, MACH Mount Pleasant Operations Pty Ltd and the unincorporated Mount Pleasant Joint Venture will be referred to as MACH.

Riparian and instream habitats within the Study Area have been substantially altered by historical and agricultural land use practices. Surface water in the vicinity of the Study Area has moderate to high electrical conductivity, which reflects natural high salinity in soils and groundwater, and the anthropogenic effects of numerous land use practices within the region.

No aquatic species of conservation significance listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999*, NSW *Biodiversity Conservation Act, 2016* or NSW *Fisheries Management Act, 1994* were recorded within the Study Area, or are considered likely to occur.

Three likely stygofauna (Cyclopoida, Ostracoda and Isotomidae) were identified from bore samples in the alluvial aquifer (east of the MPO, along the Hunter River), where the groundwater was relatively fresh. Each of these taxa are known from previous surveys of stygofauna within the Hunter alluvium. There is no significant drawdown predicted along the Hunter River alluvium and therefore potential impacts to these stygofauna populations are predicted to be negligible. For this reason, it is considered unlikely that the Project would have a measurable impact on subterranean groundwater dependent ecosystems.

A number of small ephemeral drainage lines would be cleared for the Project. These do not provide sufficient permanent habitat for aquatic biota as flow only occurs during heavy rainfall events.

The Project incorporates water management features designed to avoid and minimise environmental impacts to downstream environments. It is considered that the direct impacts of the Project on aquatic ecology would be minimal (clearance of ephemeral drainage lines) and the potential indirect impacts on aquatic ecology downstream of the Project would be minimised with the continuation of a number of existing mitigation measures currently implemented.

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1.0 INTRODUCTION

BIO-ANALYSIS Pty Ltd (BIO-ANALYSIS) has been engaged by MACH Energy Australia Pty Ltd (MACH Energy) to prepare an aquatic ecology assessment for the Mount Pleasant Optimisation Project (the Project).

1.1 Project Background

Overview of the Mount Pleasant Operation

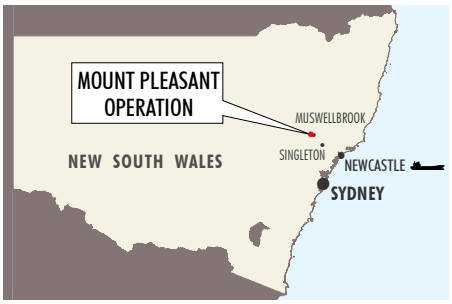
The Mount Pleasant Operation (MPO) Development Consent DA 92/97 was granted on 22 December 1999. The MPO was also approved under the *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act) in 2012 (EPBC 2011/5795).

MACH Energy acquired the MPO from Coal and Allied Operations Pty Ltd on 4 August 2016. MACH Energy commenced construction activities at the MPO in November 2016 and commenced mining operations in October 2017, in accordance with Development Consent DA 92/97 and EPBC 2011/5795.

MACH Mount Pleasant Operations Pty Ltd manages the MPO as agent for and on behalf of the unincorporated Mount Pleasant Joint Venture between MACH Energy (95 percent [%] owner) and J.C.D. Australia Pty Ltd (5% owner)[2].

The approved MPO includes the construction and operation of an open cut coal mine and associated rail spur and product coal loading infrastructure located approximately 3 kilometres (km) north-west of Muswellbrook in the Upper Hunter Valley of New South Wales (NSW) (Figures 1 and 2).

[2] Throughout this report, MACH Mount Pleasant Operations Pty Ltd and the unincorporated Mount Pleasant Joint Venture will be referred to as MACH.



LEGEND

- Mining Operation
- Proposed Mining Operation (Application Lodged)
- Railway
- Local Government Boundary
- State Forest/Reserve
- National Parks and Wildlife Estate
- Mining Lease Boundary (Mount Pleasant Operation)

Source: NSW Spatial Services (2020)

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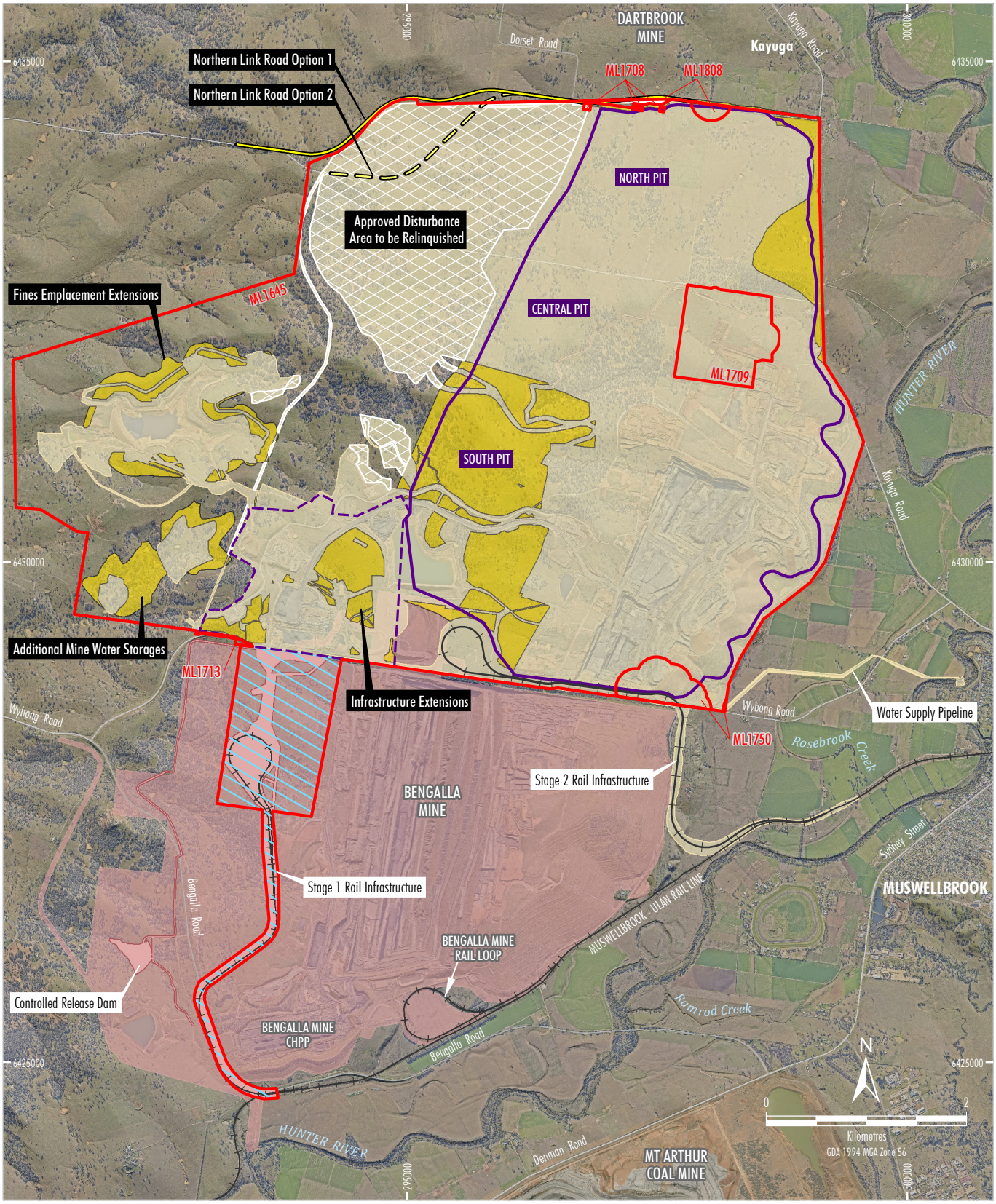
MOUNT PLEASANT OPTIMISATION PROJECT

Project Location

Figure 1

MAC-18-02 SSD_EIS_App Figure 1_Rev E



MAC-18-02 SSD_EIS_App Figure 2_Rev M

LEGEND

Existing Mine Elements

- Mining Lease Boundary (Mount Pleasant Operation)
- Approximate Extent of Existing/Approved Surface Development (DA92/97) [1]
- Infrastructure to be removed under the Terms of Condition 37, Schedule 3 (DA92/97)
- Bengalla Mine Approved Disturbance Boundary (SSD-5170)
- Existing/Approved Mount Pleasant Operation Infrastructure within Bengalla Mine Approved Disturbance Boundary (SSD-5170) [1]

Additional/Revised Project Elements

- Approved Disturbance Area to be Relinquished [2]
- Approximate Additional Disturbance of Project Extensions [1]
- Northern Link Road Option 1 Centreline [3]
- Northern Link Road Option 2 Centreline
- Approximate Extent of Project Open Cut and Waste Rock Emplacement Landforms
- Revised Infrastructure Area Envelope

NOTES

1. Excludes some incidental Project components such as water management infrastructure, access tracks, topsoil stockpiles, power supply, temporary offices, other ancillary works and construction disturbance.
2. Subject to detailed design of Northern Link Road alignment.
3. Preferred alignment subject to landholder access.

Source: MACH (2020); NSW Spatial Services (2020); Department of Planning and Environment (2016) Orthophoto: MACH (2020)

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MOUNT PLEASANT OPTIMISATION PROJECT

Project General Arrangement

Figure 2

The mine is approved to produce up to 10.5 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal. Up to approximately nine trains per day of thermal coal products from the MPO are transported by rail to the Port of Newcastle for export, or to domestic customers for use in electricity generation.

Overview of the Project

The Project would include the following development:

- increased open cut coal extraction within MPO Mining Leases by mining of additional coal reserves, including lower coal seams in North Pit;
- staged increase in extraction, handling and processing of ROM coal up to 21 Mtpa (i.e. progressive increase in ROM coal mining rate from 10.5 Mtpa over the Project life);
- staged upgrades to the existing Coal Handling and Preparation Plant and coal handling infrastructure to facilitate the handling and processing of additional coal;
- rail transport of up to approximately 17 Mtpa of product coal to domestic and export customers;
- upgrades to workshops, electricity distribution and other ancillary infrastructure;
- existing infrastructure relocations to facilitate mining extensions (e.g. local roads, powerlines and water pipelines);
- construction and operation of new water management and water storage infrastructure in support of the mine;
- additional reject dewatering facilities to allow co-disposal of fine rejects with waste rock as part of ROM waste rock operations;
- development of an integrated waste rock emplacement landform that incorporates geomorphic drainage design principles for hydrological stability, and varying topographic relief to be more natural in exterior appearance;
- construction and operation of new ancillary infrastructure in support of mining;
- extension to the time limit on mining operations to 22 December 2048;

- an average operational workforce of approximately 600 people, with a peak of approximately 830 people;
- ongoing exploration activities; and
- other associated infrastructure, plant, equipment and activities.

A referral was lodged in July 2020 for new components of the Mount Pleasant Optimisation Project (the Action) (EPBC 2020/8735), which are not already authorised by the EPBC Act Approval (EPBC 2011/5795) or the Development Consent DA 92/97. The Action includes:

- realignment of the approved Northern Link Road to a suitable design standard to compensate for the approved closure of part of Castlerock Road (the approved Western Link Road would no longer be constructed);
- increased open cut coal extraction within the approved Mount Pleasant Project (EPBC 2011/5795) development area, including accessing deeper coal reserves in North Pit;
- staged increase in the extraction, handling and processing of ROM coal up to 21 Mtpa (i.e. progressive increase in ROM coal mining rate from 10.5 Mtpa over the Project life); and
- continued use of the controlled release dam and associated infrastructure that was approved through Bengalla Mine State and Federal approvals.

A delegate of the Commonwealth Minister for the Environment determined on 26 August 2020 that the proposed action is a "controlled action" and, therefore, the Project requires approval under section 75 of the EPBC Act. The controlling provisions are "listed threatened species and communities" (sections 18 and 18A of the EPBC Act) and "a water resource, in relation to coal seam gas development and large coal mining development" (sections 24D and 24E of the EPBC Act).

The Action (EPBC 2020/8735) is to be assessed pursuant to the assessment bilateral agreement with the NSW Government.

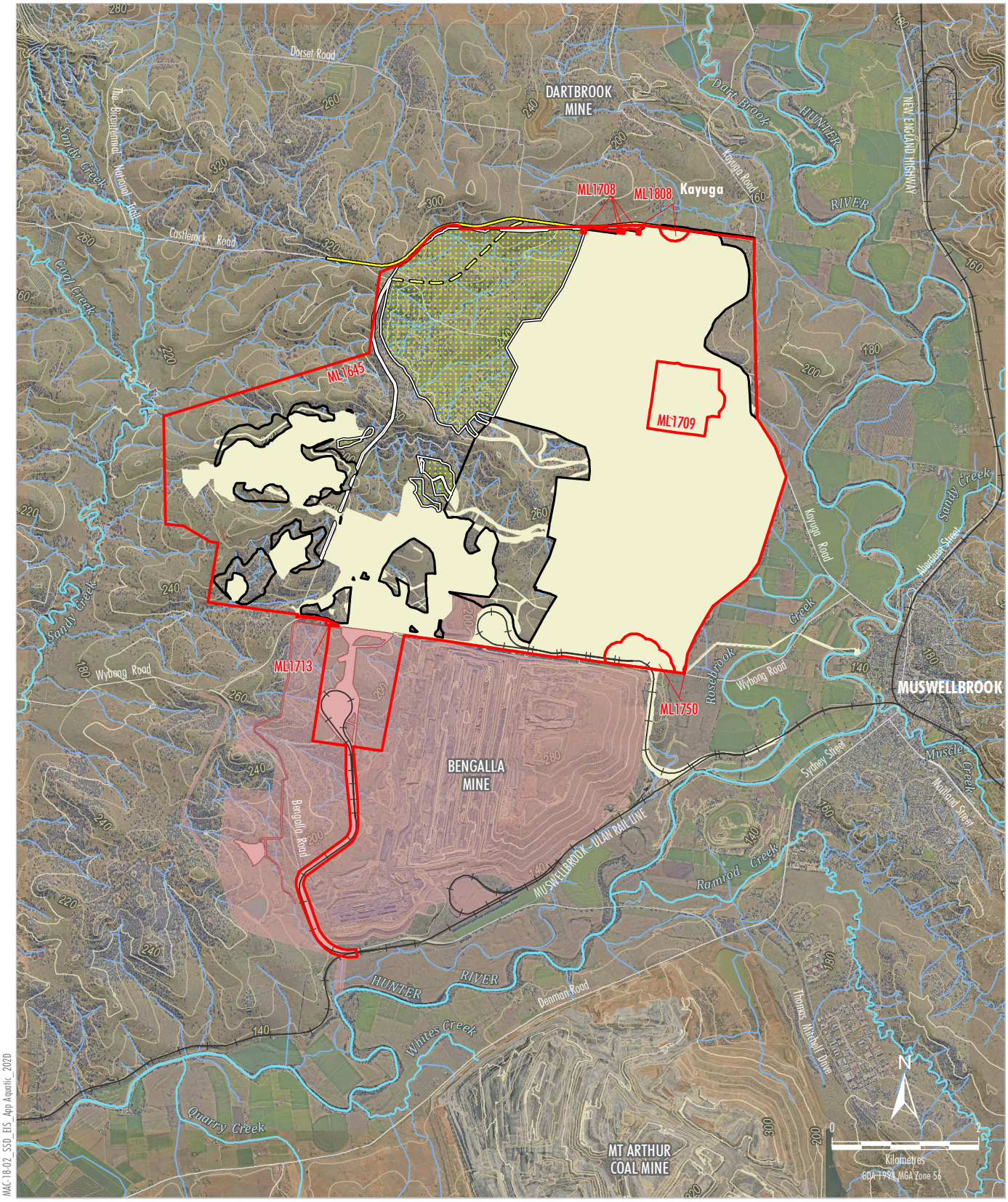
1.2 Scope of the Assessment

Figure 3 shows the topography and drainage of the area surrounding the MPO, including Rosebrook Creek, Sandy Creek and other unnamed drainage lines which make up the Study Area. The Hunter River is also included given its downstream proximity to the MPO.

The purpose of this Aquatic Ecology Assessment is to:

- review and synthesise existing information on the aquatic habitat and biota, including stygofauna, within and adjacent to the Study Area;
- conduct baseline field surveys on aquatic habitat and biota, including aquatic plants, macroinvertebrates, fish, stygofauna and threatened species within and adjacent to the Study Area;
- identify and describe the conservation significance of aquatic biota and habitat within the Study Area;
- assess the potential for the Project to impact aquatic habitat and biota; and
- provide a description of proposed impact avoidance and mitigation measures and ongoing monitoring.

This Aquatic Ecology Assessment has been prepared with reference to other technical reports prepared as part of the Project Environmental Impact Statement (EIS) and the Secretary's Environmental Assessment Requirements for the Project.



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LEGEND

- Mining Lease Boundary (Mount Pleasant Operation)
- Project Continuation of Existing/Approved Surface Development (DA92/97)
- Bengalla Mine Approved Disturbance Boundary (SSD-5170)
- Existing/Approved Mount Pleasant Operation Infrastructure within Bengalla Mine Approved Disturbance Boundary (SSD-5170)
- General Extension Areas
- Relinquishment Area
- Northern Link Road Option 1 Centreline*
- Northern Link Road Option 2 Centreline
- Major River/Creek Line
- Drainage Line
- Contour (20 m Interval)

Source: MACH (2020); NSW Spatial Services (2020)
Orthophoto: MACH (2020)

* Preferred alignment subject to landholder access.

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MOUNT PLEASANT OPTIMISATION PROJECT

Topography and Drainage

Figure 3

2.0 EXISTING INFORMATION

2.1 Physical Setting

The Study Area is wholly located within the Muswellbrook Local Government Area (LGA), approximately 3 km north-west of Muswellbrook in the Upper Hunter Valley of NSW (Figure 1).

2.2 Land Use

The Study Area has been cleared extensively and is mainly used for grazing on native/natural pasture with some partly improved pasture and more intensive uses on the floodplain of the Hunter River along the eastern boundary.

There are a number of mines in the locality. Bengalla Mine adjoins the southern boundary of the Study Area while the Mt Arthur Coal Mine is located on the southern side of the Hunter River approximately 7 km to the south of the MPO. Maxwell Infrastructure (former Drayton Mine) is located adjacent to the Mt Arthur Coal Mine approximately 12 km to the south-east of the MPO. The Dartbrook Mine is located directly to the north of the Study Area while Mangoola Coal is located approximately 13 km to the west.

2.3 Climate

The Study Area is located in the 650 millimetre (mm) average annual rainfall band (Bureau of Meteorology [BoM] 1976 – 2005 [BoM, 2020a]). Figure 4 shows the mean and highest monthly rainfall from the Spring Creek (Castle Vale) weather station (Site 61192) which is located approximately 8 km west of the MPO. Monthly minimum rainfall is not shown as it varied between 0 and 1 mm.

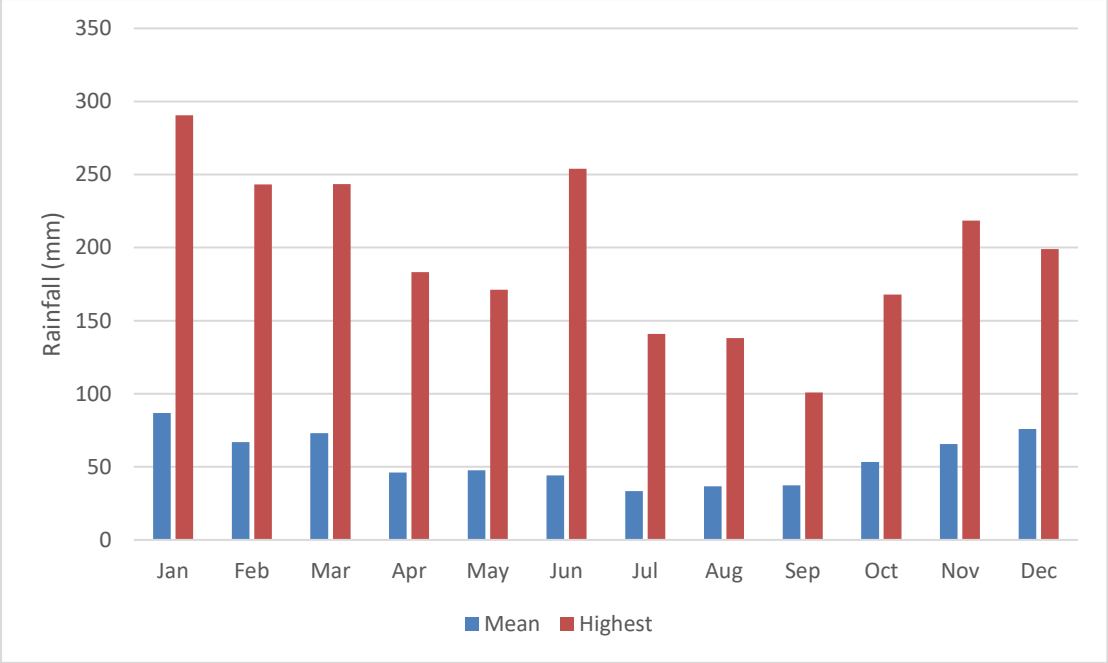


Figure 4. Long-term Average Monthly Rainfall at Spring Creek (Castle Vale).

Figure 5 shows the mean maximum and mean minimum monthly temperatures from the Scone Airport weather Station (Site 61363), the nearest station with long-term temperature records. A comparison of Figures 4 and 5 illustrates that the average coolest months of the year during winter are also the average driest months.

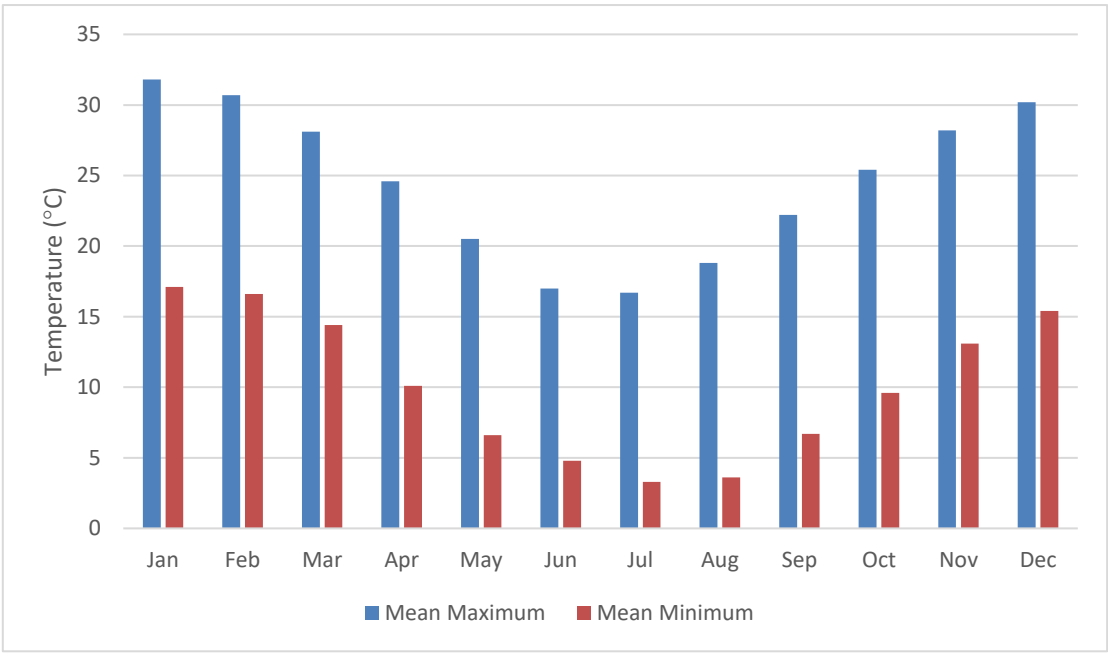


Figure 5. Long-term Monthly Average Maximum and Minimum Temperatures at Scone Airport.

2.4 Hydrology and Surface Water

The MPO is located within the Hunter Catchment. The Hunter Catchment has an overall size of 21,500 kilometres squared ($km^{2)}$ and includes the city of Newcastle and the major towns of Singleton and Muswellbrook. The Hunter River is the main drainage feature within the catchment, rising on the northern side of the Barrington Tops (Mount Royal Range) and flowing south and then east through Muswellbrook and Singleton, before draining to the Pacific Ocean at Newcastle.

The Hunter River contains a number of significant tributaries upstream of Muswellbrook, including the Pages and Isis Rivers, as well as the Middle, Dart, Stewarts, Moonan and Rouchel Brooks. The Hunter River is defined as a 'Major Regulated River', meaning that it contains a number of water storages along its length which supplement its flow (NSW Department of Primary Industries [DPI] – Water, 2016). These water storages include the Glenbawn Dam and the Glennies Creek Dam. The local drainage network in the vicinity of the MPO is shown on Figure 3. The local drainage network is generally characterised by steep gullies which drain from the surrounding hills into the flat alluvial plains adjacent the Hunter River.

The main drainage feature in the vicinity of the MPO is the Hunter River which flows in a southerly direction approximately 1 km to the east of the MPO. There are a number of ephemeral drainage lines which traverse the MPO area and drain into the Hunter River. The eastern portion of the mining area drains via Rosebrook Creek, as well as other unnamed drainages. The western portion drains via unnamed drainage lines to Sandy Creek.

2.5 Groundwater

The two main groundwater systems identified by Australasian Groundwater and Environmental Consultants (AGE) (2020) are:

- alluvium associated with the Hunter River and Sandy Creek; and
- Permian strata that host the coal measures.

The Project coal resource is located in the Permian Wittingham Coal measures of the Singleton Supergroup. Lithologies comprise mostly sandstones, siltstones and coal measures with minor conglomerates and tuffs. The coal seams are recognised as the main aquifer zones within the hard rock groundwater system (AGE, 2020).

Higher aquifer pressures within the coal measures and a regional gradient towards the alluvium result in pressure driving groundwater movement towards the Hunter River. It is likely groundwater seeps naturally from the hard (fractured and porous) rock groundwater system into the alluvial groundwater system (AGE, 2020).

Alluvial sediments associated with the Hunter River and Sandy Creek are located to the east and west of the Project, respectively. The Hunter River alluvium is the most productive aquifer in the region and comprises surficial silts and clays overlying basal sands and gravels up to approximately 20 metres (m) in depth (AGE, 2020). The basal sands and gravels are thickest along the alignment of the Hunter River, thinning out toward the edges of the extent of mapped alluvium.

Groundwater quality within and surrounding the MPO is highly variable but generally poor. The Permian groundwater is typically only suitable for livestock and irrigation of some salt tolerant crops. Groundwater in the Sandy Creek alluvium is too saline for livestock with groundwater electrical conductivity typically exceeding 14,000 microsiemens per centimetre (µS/cm). Groundwater in the Hunter River alluvium has a lower average salinity (about 1,100 µS/cm) than the underlying coal measures (3,500 µS/cm in the seams, 3000 µS/cm in the interburden) (AGE, 2020).

2.6 Aquatic Ecology and Biota

2.6.1 Aquatic Habitat and Vegetation

The Key Fish Habitat map for Muswellbrook (DPI, 2017a) indicates that first and second order drainage lines that traverse the Study Area are not Key Fish Habitat. The Hunter River, Muscle Creek, Sandy Creek (which joins the Hunter River south of Muswellbrook) and the lower reaches of Rosebrook Creek are mapped as Key Fish Habitat (DPI, 2017a).

Previous surveys (McDowall, 1996; DPI, 2006; Howell and Creese, 2010) and published distributions (DPI, 2020a) indicate up to 26 species of fish may be present within the Hunter River, including 21 native species (Table 1). The Eastern Snake-necked Turtle (*Chelodina longicollis*) has also been recorded in the river (Howell and Creese, 2010) and is likely to be found in farm dams and pools in creeks.

Table 1. Species of fish that may occur, or suitable habitat may occur, within the Hunter – Central Rivers Region.

Family	Species Name	Common Name	McDowall (1996)	DPI (2006)	Howell and Creese (2010)	DPI (2020a)
Anguillidae	*Anguilla australis*	Short-finned Eel	√	√	-	-
Anguillidae	*Anguilla reinhardtii*	Long-finned Eel	√	√	-	-
Ariidae	*Arius graeffei*	Freshwater Fork-tail Catfish	√	√	-	-
Atherinidae	*Craterocephalus amniculus*	Darling River Hardyhead	-	-	√	√
Clupeidae	*Potamalosa richmondia*	Freshwater Herring	√	√	-	-
Eleotridae	*Mogurnda adspersa*	Southern Purple-Spotted Gudgeon	-[#]	-	-	√
Galaxiidae	*Galaxias brevipinnis*	Climbing Galaxias	-	√	√	-
Galaxiidae	*Galaxias olidus*	Mountain Galaxias	√	√	√	-
Galaxiidae	*Galaxias maculatus*	Common Jollytail	-	√	-	-
Salmonidae	*Oncorhynchus mykiss*	Rainbow Trout*	√	√	√	-
Salmonidae	*Salmo trutta*	Brown Trout*	√	√	√	-
Retropinnidae	*Retropinna semoni*	Australian Smelt	√	√	√	-
Cyprinidae	*Carassius auratus*	Goldfish*	√	√	-	-
Cyprinidae	*Cyprinus carpio*	Common Carp*	√	√	-	-
Plotosidae	*Tandanus tandanus*	Freshwater Catfish	√	√	√	-
Poeciliidae	*Gambusia holbrooki*	Mosquito Fish*	-	√	√	-
Scorpaenidae	*Notesthes robusta*	Bullrout	√	√	√	-
Percichthyidae	*Macquaria novemaculeata*	Australian Bass	√	√	√	-
Terapontidae	*Leiopotherapon unicolor*	Spangled Perch	-	√	-	-
Mugilidae	*Mugil cephalus*	Sea Mullet	√	√	√	-
Mugilidae	*Myxus petardi*	Freshwater Mullet	√	√	√	-
Gobiidae	*Gobiomorphus australis*	Striped Gudgeon	√	-	-	-
Gobiidae	*Gobiomorphus coxii*	Cox's Gudgeon	√	√	-	-

Table 1 (Continued). Species of fish that may occur, or suitable habitat may occur, within the Hunter – Central Rivers Region.

Family	Species Name	Common Name	McDowall (1996)	DPI (2006)	Howell and Creese (2010)	DPI (2020a)
Gobiidae	*Hypseleotris compressa*	Empire Gudgeon	√	√	-	-
Gobiidae	*Hypseleotris galii*	Firetail Gudgeon	√	√	-	-
Gobiidae	*Philypnodon macrostomus*	Dwarf Flathead Gudgeon	√	√	√	-
Gobiidae	*Philypnodon grandiceps*	Flathead Gudgeon	√	√	√	-
Gobiidae	*Hypseleotris klunzingeri*	Western Carp Gudgeon	√	√	-	-

* Introduced species.

Found locally in coastal streams from northern NSW to northern Queensland (McDowall, 1996).

No aquatic species of conservation significance listed under the EPBC Act, NSW *Biodiversity Conservation Act, 2016* (BC Act) or NSW *Fisheries Management Act, 1994* (FM Act) have been previously recorded within the Study Area (Department of Planning, Industry and Environment [DPIE], 2020; Online Zoological Collections of Australian Museums [OZCAM], 2020).

The majority of watercourses within the Study Area have been cleared to the bank, with the most prominent strips of native vegetation along the Hunter River. River Oak (*Casuarina cunninghamiana*) and River Red Gum (*Eucalyptus camaldulensis*) commonly occur along the Hunter River, although this riparian habitat has been heavily infested by weeds including Morning Glory (*Ipomoea indica*), Privet (*Ligustrum* sp.) and Willow (*Salix* sp.) (BIO-ANALYSIS, 2017).

In September 2017, an assessment of Rosebrook Creek and unnamed tributaries (located south-east of the Project) found that trees and riparian vegetation had almost been entirely cleared and there was evidence that livestock regularly grazed and trampled the stream banks and channels (BIO-ANALYSIS, 2017). Habitat for aquatic fauna, such as rocks, snags and aquatic macrophytes was largely absent. These waterways appeared to be mostly dry for considerable periods (years) of time.

2.6.2 Aquatic Macroinvertebrates

Between 40 and 70% of sites sampled for macroinvertebrates in the Hunter River were assessed by the Healthy Rivers Commission (2002) as being in poor condition. In a later study of stream health at four sites[3] within the vicinity of the Study Area using the Australian River Assessment System (AUSRIVAS) protocol, one site (Hunt854) was rated as being similar to reference condition while three (Hunt571, Hunt585 and Hunt506) were rated 'significantly impaired' (Hose and Turak, 2004).

[3] Sites Hunt854 (Hunter River, approximately 3 km upstream of Muswellbrook [now HR3]), Hunt571 (Hunter River at Muswellbrook [now HR4]), Hunt585 (Dart Brook [now DB]) and Hunt506 (Muscle Creek at Muswellbrook [now MC]).

2.6.3 Stygofauna

The majority of stygofauna collected within the Hunter River catchment have been collected from shallow alluvial aquifers, although Eco Logical Australia (ELA) (2013) report isopods and cyclopoid copepods being collected from a deeper aquifer linked to mine workings (Hose *et al*., 2015).

Available data for the Hunter region indicate that stygofauna have been recorded in bores with standing water level between 3.8 and 14.9 metres below ground level (mbgl), electrical conductivity between 804 and 9,224 µs/cm, mostly neutral pH conditions and dissolved oxygen levels as low as 0.5 milligrams per litre (mg/L) (Hose *et al*., 2015). The Permian aquifers were considered unsuitable stygofauna habitat due to the depth of the water table, the low hydraulic conductivity and the isolation of the deeper Permian aquifers (ELA, 2013).

3.0 METHODS

3.1 Desktop Assessment

Relevant threatened species or populations and their habitats that do, or may, occur within the Study Area were identified by reviewing current listings on databases and studies conducted within the area. The primary search area was the Muswellbrook LGA.

The following database sources were reviewed:

- NSW *BioNet Atlas* (DPIE, 2020);
- Fisheries NSW *Spatial Data Portal* (DPI, 2020a);
- *OZCAM Record Search* (OZCAM, 2020); and
- Commonwealth Department of Agriculture, Water and the Environment (DAWE) *Protected Matters Search Tool* (DAWE, 2020).

The following database and literature sources were reviewed in order to characterise the aquatic ecology values of the Study Area:

- publicly available water quality data from the WaterNSW's *Water Monitoring Network* (WaterNSW, 2020);
- existing mapping of the aquatic ecological values in the vicinity of the Study Area from the Fisheries NSW *Spatial Data Portal* (DPI, 2020a);
- Key Fish Habitat map for Muswellbrook (DPI, 2017a);
- groundwater (AGE, 2020) and surface water (Hydro Engineering & Consulting Pty Ltd [HEC], 2020) assessments for the Project;
- *NSW Aquatic Pest and Disease Distribution* (DPI, 2020b);
- *NSW WeedWise* (DPI, 2020c);
- stream health monitoring surveys previously completed for the MPO (BIO-ANALYSIS 2018a, 2018b, 2019a, 2019b and 2020);

- publicly available reports from aquatic ecology assessments completed in the region; and
- aquatic ecology studies previously completed in the vicinity of the Study Area, including a baseline assessment for Bengalla Mine (ELA, 2013), for the MPO (BIO-ANALYSIS, 2017) and the Maxwell Project (ELA, 2019).

3.2 Field Surveys

BIO-ANALYSIS has undertaken stream health monitoring surveys at the MPO and surrounds since 2017. The stream health monitoring surveys occur twice a year and involve an assessment of habitat, water quality, aquatic macroinvertebrates and fish (BIO-ANALYSIS 2018a, 2018b, 2019a, 2019b and 2020).

Additional targeted field surveys were undertaken for the Project to characterise the aquatic ecology and biota, groundwater and stygofauna within the Study Area.

The additional field surveys included:

- aquatic habitat assessment including identification of channel morphology, substratum, aquatic plants (macrophytes) and riparian vegetation;
- aquatic macroinvertebrate assessment using the AUSRIVAS sampling protocol;
- fish surveys; and
- stygofauna surveys.

3.2.1 Sampling Dates

The additional aquatic ecology field surveys were conducted on 26, 27 and 28 November 2018. Stygofauna surveys were undertaken on 27 and 28 November 2018.

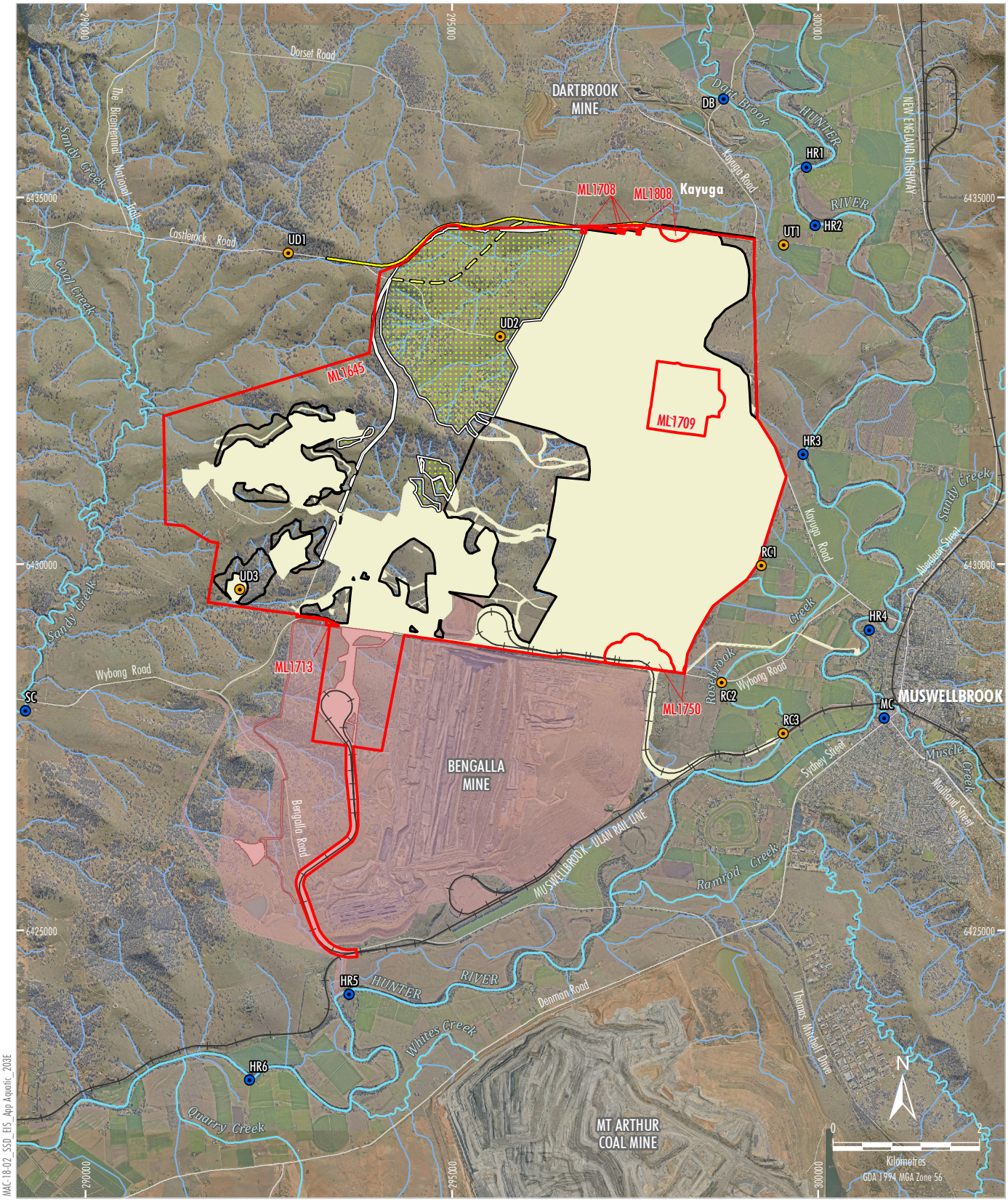
Within the two months prior to the field survey conducted in November 2018, a total of 79.4 mm of rainfall was recorded within the Muswellbrook LGA, at the Scone Automatic Weather Station (Station ID: 061363). A total of 12.8 mm of rainfall was recorded in the week prior to the survey. Mean stream water levels collected in the Hunter River at Muswellbrook Bridge (GS210002) ranged from 0.43 m (25 October 2018) to 0.75 m (5 November 2018) within the two months prior to the survey.

3.2.2 Aquatic Ecology Survey Sites

A habitat assessment was undertaken at three sites along Rosebrook Creek and four sites along unnamed tributaries and drainage lines across the Study Area (Table 2, Figure 6). Aquatic biota was sampled from nine sites (Table 2, Figure 6). Six sites were sampled along the Hunter River and one site in each of Dart Brook, Muscle Creek and Sandy Creek (Table 2, Figure 6).

In 2012, ELA (2013) undertook sampling for stygofauna at thirteen bores and wells in the vicinity of the Bengalla Mine Project Boundary (Figure 7).

Seven additional bores were sampled for stygofauna, based on the likelihood of having suitable stygofauna habitat, findings from the stygofauna assessment for the Bengalla Mine (ELA, 2013) and consideration of sites that were representative of the Study Area (Table 3, Figure 7).



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LEGEND

- Mining Lease Boundary (Mount Pleasant Operation)
- Project Continuation of Existing/Approved Surface Development (DA92/97)
- Bengalla Mine Approved Disturbance Boundary (SSD-5170)
- Existing/Approved Mount Pleasant Operation Infrastructure within Bengalla Mine Approved Disturbance Boundary (SSD-5170)
- General Extension Areas
- Relinquishment Area
- Northern Link Road Option 1 Centreline*
- Northern Link Road Option 2 Centreline
- Major River/Creek Line
- Drainage Line

Survey Sites

- Habitat Assessment Site
- Stream Health Sample Site

Source: MACH (2020); NSW Spatial Services (2020)
Orthophoto: MACH (2020)

* Preferred alignment subject to landholder access.

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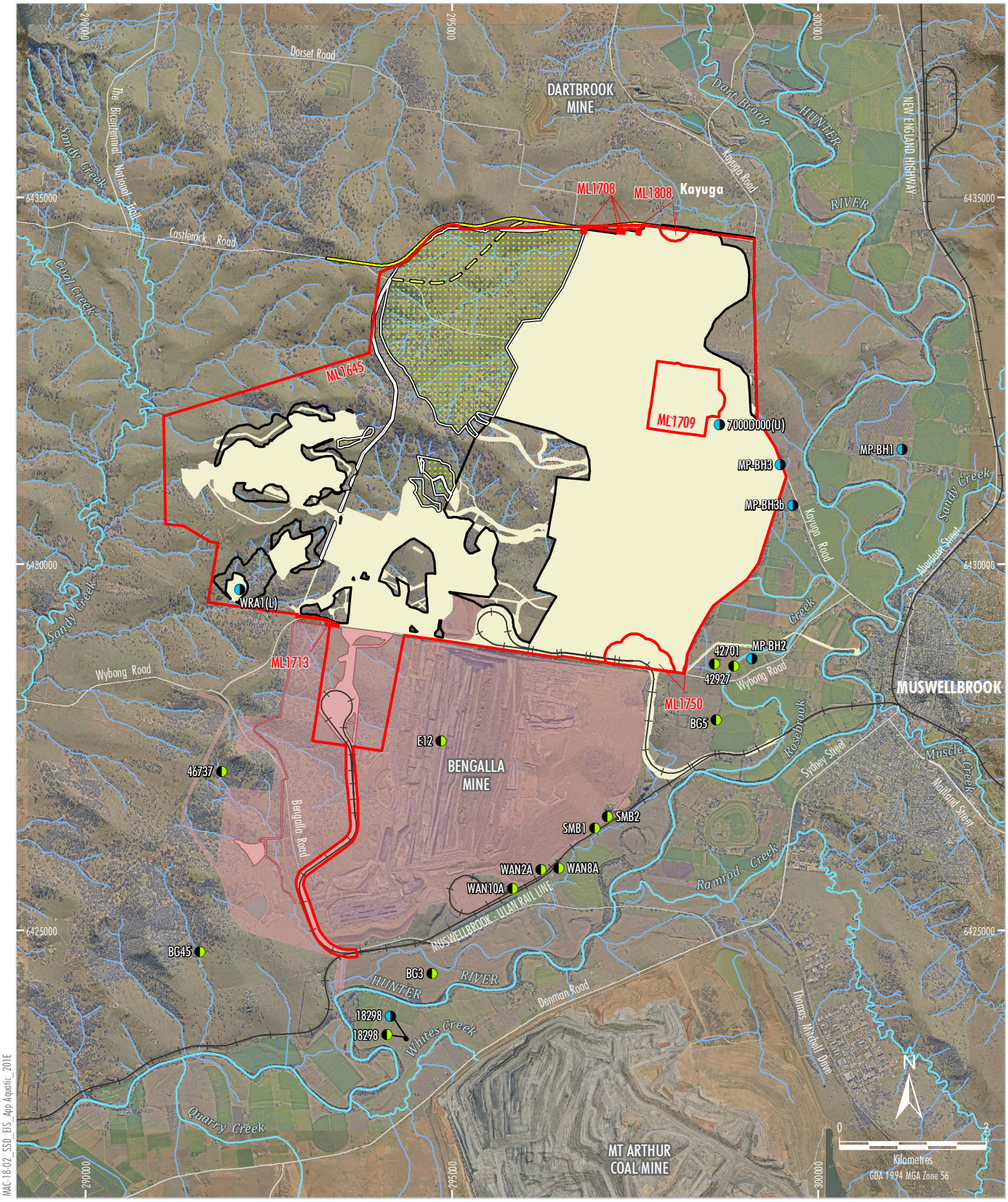
MOUNT PLEASANT OPTIMISATION PROJECT

Aquatic Ecology Survey Sites

Figure 6



MAC-18-02_SSD_EIS_App Aquatic_201E

LEGEND

- Mining Lease Boundary (Mount Pleasant Operation)
- Project Continuation of Existing/Approved Surface Development (DA92/97)
- Bengalla Mine Approved Disturbance Boundary (SSD-5170)
- Existing/Approved Mount Pleasant Operation Infrastructure within Bengalla Mine Approved Disturbance Boundary (SSD-5170)
- General Extension Areas
- Relinquishment Area
- Northern Link Road Option 1 Centreline*
- Northern Link Road Option 2 Centreline
- Major River/Creek Line
- Drainage Line

Survey Sites

- Bore Sampled for Stygofauna by Bio-Analysis (2020)
- Bore Sampled for Stygofauna by Eco Logical Australia (2013)

Source: MACH (2020); NSW Spatial Services (2020)
Orthophoto: MACH (2020)

* Preferred alignment subject to landholder access.

MACHEnergy

MOUNT PLEASANT OPTIMISATION PROJECT

Stygofauna Sample Sites

Figure 7

Table 2. Sites sampled for aquatic habitat and biota.

BIO-ANALYSIS Site Code	Site Location (Figure 6)	Easting	Northing	Survey Method
RC1*	Rosebrook Creek at Rose Road	0299226	6429979	Habitat assessment
RC2*	Rosebrook Creek at Wybong Road	0298686	6428388	
RC3*	Rosebrook Creek at Logues Lane	0299525	6427687	
UT1*	Unnamed tributary at Lawrie Lane	0299313	6434404	
UD1	Unnamed drainage line at Castlerock Road	0292768	6434243	
UD2*	Unnamed drainage line at Castlerock Road	0295666	6433103	
UD3*	Unnamed drainage line near WRA1(L)	0292108	6429649	
HR1	Hunter River upstream of Dart Brook	0299713	6436087	Habitat assessment and aquatic biota sampling
HR2	Hunter River downstream of Dart Brook	0301138	6427148	
HR3	Hunter River at Burtons Lane	0299764	6434805	
HR4	Hunter River at Muswellbrook	0300855	6429196	
HR5	Hunter River off Bengalla Road	0299710	6424208	
HR6	Hunter River near Roxburgh	0292345	6423054	
MC	Muscle Creek at Muswellbrook	0301140	6427946	
SC	Sandy Creek at Wybong Road	0301153	6428199	
DB	Dart Brook at MacIntyre Bridge	0298863	6436259	

* Site was dry at the time of survey.

Table 3. Bores sampled for stygofauna.

Bore (Figure 7)	Aquifer	Location
MP-BH1	Alluvium	East of the Hunter River
MP-BH2	Alluvium	In the vicinity of Rosebrook Creek
MP-BH3	Alluvium	West of Hunter River
MP-BH3b	Alluvium	West of the Hunter River
18298[#]	Alluvium	Downstream Hunter River
7000D000(U)	Interburden #9	Within the MPO Boundary
WRA1(L)	Permian	South-western portion of the Study Area

[#] Site also previously sampled for the stygofauna assessment for Bengalla Mine (ELA, 2013).

3.2.3 Aquatic Habitat Assessment

The condition of the aquatic habitat was assessed at each site using a modified version of the Riparian Channel and Environmental (RCE) inventory method (Chessman *et al*., 1997). This method involves evaluation and scoring of the characteristics of the adjacent land, the condition of riverbanks, channel and bed of the watercourse, and degree of disturbance evident at each site. The maximum score (52) indicates a stream with little or no obvious physical disruption and the lowest score (13) a heavily channelled stream without any riparian vegetation can be considered to be in poor condition.

Information was collected on the following features:

- characteristics of each waterway (e.g. flow and stream width);
- occurrence of key aquatic habitat (e.g. gravel beds, pools, macrophytes, riffles and woody debris);
- water clarity;
- presence of in-stream and emergent aquatic macrophytes at each site;
- barriers to fish passage;
- presence of algae, exotic plants, bank degradation, flocculent, odour, detergents, oil, rock piles or sedimentation, pipes, rubbish and point sources; and
- surrounding land uses.

Where water was present, water quality measurements were collected using a Yeo-Kal 611 probe. Three replicate measurements of pH (pH units), temperature (degrees Celsius [^{o}C]), electrical conductivity (µS/cm), dissolved oxygen (% saturation and mg/L), oxygen-reduction potential (millivolts), turbidity (Nephelometric Turbidity Unit [NTU]) and alkalinity were collected from just below the water surface at each site.

Each study site (approximately 100 m in length) was photographed and the locations recorded with a hand-held satellite-based Global Positioning System.

A general description of the aquatic habitat at sites sampled within the Hunter River, Muscle Creek, Sandy Creek and Dart Brook is also provided, based on information collected for the MPO Stream Health Monitoring Program in November 2017, May 2018, November 2018, May 2019 and November 2019 (BIO-ANALYSIS, 2018a, 2018b, 2019a, 2019b and 2020).

3.2.4 AUSRIVAS Macroinvertebrates

Field and Laboratory Methods

Aquatic macroinvertebrates were sampled using the AUSRIVAS protocol (Turak *et al*., 2004). Samples of stream edge habitats and riffle habitats (where available) were collected at a site (approximately 100 m long) within a location, over a total length of 10 m (usually in 1-2 m sections), using a 250 micrometre (µm) dip net.

The contents of each net sample were placed into a white sorting tray and animals collected for a minimum period of 30 minutes. Thereafter, removals were done in 10-minute periods, up to a total of one hour (Turak *et al*., 2004). If no new taxa were found within a 10-minute period, removals ceased (Turak *et al*., 2004).

The animals collected were placed inside a labelled container, preserved with 70% alcohol and taken to the laboratory for identification. Environmental variables required for running the AUSRIVAS predictive model, including modal river width, percentage boulder or cobble cover, latitude and longitude were recorded at each site.

In the laboratory, taxa were identified to family level with the exception of Acarina (to order), Chironomidae (to sub-family), Nematoda (to phylum), Nemertea (to phylum), Oligochaeta (to class), Ostracoda (to subclass) and Polychaeta (to class). Some families of Anisoptera (dragonfly larvae) were identified to species.

AUSRIVAS Model

Data were analysed using the appropriate AUSRIVAS predictive models developed for NSW. The ecological health of a waterway is assessed by comparing the macroinvertebrates collected at a site (i.e. Observed) to those predicted to occur (Expected) if the site is in an undisturbed or 'reference' condition. The principal outputs of the AUSRIVAS model include the Observed to Expected ratio (OE50 Taxa Score) and the BAND level for each site, which represents different levels of impairment.

The principal outputs of the AUSRIVAS model include:

- Observed to Expected ratio (OE50): the ratio of the number of macroinvertebrate families collected at a site which had a predicted probability of occurrence of greater than 50% (i.e. Observed) to the sum of the probabilities of all of the families predicted with greater than a 50% chance of occurrence (i.e. Expected) (Ransom *et al*., 2004); and
- Band: for each model, the OE50 taxa ratios are divided into bands representing different levels of impairment. Band X represents a more diverse assemblage of macroinvertebrates than control sites; Band A is considered equivalent to reference condition; Band B represents sites below reference condition (i.e. significantly impaired); Band C represents sites well below reference condition (i.e. severely impaired); and Band D represents impoverished sites (i.e. extremely impaired) (Ransom *et al*., 2004).

The Stream Invertebrate Grade Number Average Level (SIGNAL2) biotic index developed by Chessman (2003) was also calculated, to give an indication of water quality at the sites sampled. The SIGNAL2 score for a macroinvertebrate sample is calculated by averaging the pollution sensitivity grade numbers of the families present, which may range from 10 (most sensitive) to 1 (most tolerant). SIGNAL2 values are as follows:

- SIGNAL >6 = Healthy habitat;
- SIGNAL 5-6 = Mild pollution;

- SIGNAL 4-5 = Moderate pollution; and
- SIGNAL <4 = Severe pollution.

3.2.5 Fish

Fish surveys were done in accordance with section 37 of the FM Act using Scientific Collection Permit P03/0032(B) and with consideration of the *Australian Code of Electrofishing Practice* (DPI, 1997) and NSW Agriculture, Animal Research Authority Care and Ethics guidelines (including relevant legislation and the *Australian Code for the Care and Use of Animals for Scientific Purposes* [National Health and Medical Research Council, 2013]).

Fish were sampled using a Smith-Root 15C Electrofisher backpack unit. Sampling was done with consideration of the *Australian Code of Electrofishing Practice* (DPI, 1997), including the presence of an experienced electrofishing operator at all times.

The Electrofisher was used to stun the fish in open water, around the edge of pools, around snags and aquatic vegetation, overhanging banks and rocky crevices. Four replicate electrofishing 'shots' were completed at each site that held sufficient water. All stunned fish were collected using a dip net and placed into plastic trays filled with water to be counted and identified. Incidental observations, such as evidence of disease, were noted. All captured fish were handled with care to minimise stress, and native fish released as soon as possible.

Additional sampling of fish was done at two sites in the Hunter River (Site HR3 and HR5) by deploying fyke nets (panels up to 4 m long on either side of a central funnel 2.5 m long, with 5 mm mesh) and bait traps (250 mm wide with an entrance that tapered to 60 mm wide, 450 mm long and 4 mm mesh size throughout). Care was taken to ensure an air space was available for any air breathing animals, such as Platypus that may be caught inadvertently, either by tying the end of the net to a bankside tree or to a stake that was hammered into the stream substratum.

Traps were baited with a mixture of bran and bread soaked in tuna oil, chicken pellets and strips of mullet. Fyke nets were set obliquely to the stream bank, one facing downstream and one facing upstream at each site. Fyke nets and bait traps were left overnight.

3.2.6 Stygofauna

Stygofauna were collected using methods in accordance with stygofauna sampling and groundwater dependent ecosystem (GDE) assessment guidelines (Department of Environment and Science, 2018a and 2018b; Doody *et al.*, 2019). Firstly, a 40 mm diameter, weighted conical net with a 50 µm mesh was lowered to the bottom of each bore or well, bounced four times to dislodge bottom-resting fauna and slowly retrieved. Once at the surface, net contents were emptied into a 50 µm mesh sieve. The sample was then transferred to a labelled plastic container and preserved with 100% ethanol.

A Waterra groundwater pump was then used to extract water from each bore. Water was passed through a 50 µm mesh sieve, the sieve contents transferred to a labelled plastic container and preserved with 100% ethanol. Pump and net samples were later transported to the laboratory to be processed in a sorting dish under a binocular microscope and identified by Dr Sharon Cummins.

Depth of the water table for each bore or well was then measured using a dip tape. Groundwater temperature (ºC), electrical conductivity (µS/cm), dissolved oxygen (% saturation and mg/L) and pH (pH units) were measured using a Yeo-Kal 611 probe.

3.2.7 Other Aquatic Fauna

Visual searches for other aquatic fauna (Platypus [*Ornithorhynchus anatinus*] and turtles) were also undertaken.

3.2.8 Limitations

The survey data presented provided a description of the aquatic habitat and biota at the time of sampling. A general description of the aquatic habitat at sites sampled within the Hunter River, Muscle Creek, Sandy Creek and Dart Brook is also provided, based on information collected for the MPO Stream Health Monitoring Program in November 2017, May 2018, November 2018, May 2019 and November 2019 (BIO-ANALYSIS, 2018a, 2018b, 2019a, 2019b and 2020).

This study has used a range of sampling techniques to describe the aquatic habitat and biota across the Study Area and is therefore useful in providing general baseline information on aquatic ecology values for the Aquatic Ecology Assessment.

Desktop assessments were also used to inform assessment of the likelihood of occurrence of threatened species. Where potential habitats occur for threatened species the precautionary principle has been adopted and an assessment of significance was conducted for species associated with the habitat (refer Section 5.5).

4.0 RESULTS

4.1 Aquatic Habitat Characteristics

Information collected by the targeted survey done in November 2018 has been used to describe the aquatic ecology values at sites that occur within the Study Area on Rosebrook Creek, an unnamed tributary, other unnamed drainage lines and the Hunter River.

The condition of the riparian channel environment at the smaller tributary site at Dart Brook was classified as moderate, with RCE scores of between 32 and 36. Despite a relatively narrow riparian strip of woody vegetation (between 5 and 30 m), mixed native and exotic trees and shrubs were abundant within 10 m of the channel. A range of habitats available to fish and macroinvertebrates were present, including rocks, logs and emergent macrophytes (including Phragmites [*Phragmites australis*], Typha [*Typha domingensis*] and Mat Rush [*Lomandra longifolia*]). Australian Bass and Long-finned Eels were commonly caught at this site.

The overall condition of aquatic habitats at the sites sampled in Muscle Creek and Sandy Creek was classified as relatively poor, with RCE scores of between 21 and 29. The stream bank and channel at Muscle Creek has been highly modified. With the exception of isolated pools of remnant water at the Sandy Creek site, the emergent macrophyte, Bulrush (*Typha orientalis*), had colonised the stream channel.

The banks of Rosebrook Creek and the unnamed tributaries visited were almost entirely cleared of trees and riparian vegetation and there was evidence that livestock regularly grazed and trampled the stream banks and channels. Habitat for aquatic fauna, such as rocks, snags and aquatic macrophytes was largely absent. These waterways appear to be mostly dry for considerable periods (years) of time.

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

4.1.1 Unnamed Drainage Lines

Several ill-defined ephemeral drainages cross the Study Area (Figure 3, Plates 1-6). After sufficient rainfall, surface water in the unnamed drainage lines surveyed within the Study Area and from Castlerock Road (Sites UD1, UD2 and UD3) mostly drains east to west into Sandy Creek.

Plate 1: **Unnamed Drainage Line – UD1.** Near WRA1L, looking upstream (28/11/18).

Plate 2: **Unnamed Drainage Line – UD1.** Near WRA1L, looking downstream (28/11/18).

Plate 3: **Unnamed Drainage Line – UD2.** View downstream from Castlerock Road (28/11/18).

Plate 4: **Unnamed Drainage Line – UD2.** View upstream from Castlerock Road (28/11/18).

Plate 5: Unnamed Drainage Line – UD3. View west along Castlerock Road (28/11/18).

Plate 6: Unnamed Drainage Line – UD3. View west from Castlerock Road (28/11/18).

The banks of these drainage lines were largely cleared of trees and riparian vegetation and there was evidence that livestock regularly grazed and trampled the stream bank and channel (Plates 1-6). Habitat for aquatic fauna, such as rocks, snags and aquatic macrophytes was largely absent.

These first and second order drainage lines are not mapped as Key Fish Habitat under the DPI Key Fish Habitat mapping for the Muswellbrook LGA (DPI, 2017a).

4.1.2 Hunter River Tributaries

Muscle Creek at Muswellbrook (Site MC)

The site sampled in Muscle Creek is situated on the floodplain approximately 1 km upstream of the confluence with the Hunter River (Figure 6). The stream channel is highly modified with imported rock used in places to stabilise the bank (Plates 7 and 8). Average stream width was approximately 10 m, but approximately 0.5 m wide immediately downstream of a small pedestrian crossing across the middle of the study reach and up to 16 m in the larger, relatively deep (up to approximately 2 m deep) pool at the downstream end of the site. The substratum has been dominated by silt and gravel with some cobble, pebble and rock. A submerged species of macrophyte, Blunt Pondweed (*Potamogeton ochreatus*) has commonly been present.

Plate 7: Muscle Creek – MC. View downstream (26/11/18).

Plate 8: Muscle Creek – MC. View upstream (26/11/18).

The stream bank is mostly clear of vegetation with the exception of some well-established trees (River Oak and River Red Gum) and shrubs (such as Mat Rush) that appear to have been planted to stabilise the stream bank and reduce erosion (Plates 7 and 8). Emergent macrophytes, including Phragmites, Bulrush and Mat Rush, are moderately abundant in-stream. The small floating fern Azolla (*Azolla* sp.), Duckweeds (*Lemna* sp.) and aggregations of green macro-algae are often present. Conductivity levels have been as high as 1,589 µS/cm.

The RCE score has ranged between 21 and 29 between the spring 2017 and spring 2019 surveys. This site is mapped as Key Fish Habitat under the DPI Key Fish Habitat mapping for the Muswellbrook LGA.

Sandy Creek at Wybong Road (Site SC)

The site sampled in Sandy Creek is located downstream of the MPO and upstream of Mangoola Coal (Figure 6). Wybong Road crosses the stream immediately downstream of the Study Area. Stream width ranged from 1 m to greater than 7 m (Plates 9 and 10). The maximum depth of the largest pool has been up to approximately 0.5 m, the substratum of which is predominantly clay and silt with an anoxic layer. Dense stands of Typha and Phragmites have colonised the stream channel downstream of the pool.

Plate 9: Sandy Creek – SC. Aerial view (10/5/18).

Plate 10: Sandy Creek – SC. View upstream (27/11/18).

The stream banks are approximately 3 m high and heavily disturbed on either side by historical agricultural activities. Erosion and undercutting of the stream bank are apparent in areas not bound by River Oak or exotic trees and grasses (Plates 9 and 10).

Flow has not been apparent along the study reach, with the exception of flattened instream vegetation after a heavy rainfall, and water in the pool has consistently appeared stagnant. Conductivity levels have been as high as 11,200 µS/cm. The RCE score has ranged between 21 and 29 between the spring 2017 and spring 2019 surveys. This site is mapped as Key Fish Habitat under the DPI Key Fish Habitat mapping for the Muswellbrook LGA.

Dart Brook at MacIntyre Bridge (Site DB)

Sampling site Dark Brook is situated at a road crossing approximately 1 km upstream from the confluence with the Hunter River (Figure 6). The surrounding land use is mostly agriculture. This section of the stream consisted of pools up to approximately 5 m wide and 1.5 m deep (Plates 11 and 12). The substratum has been dominated by accumulations of silt, pebble and gravel and some boulders. No submerged macrophytes have been observed.

The stream banks are approximately 3 m high and heavily disturbed on either side by historical agricultural activities. Erosion and undercutting of the stream bank are apparent in areas not bound by River Oak or exotic grasses (Plates 11 and 12). Emergent macrophytes, including Phragmites, Typha and Mat Rush, are moderately abundant (Plates 11 and 12).

Plate 11: Dart Brook – DB. Aerial view (9/5/18).

Plate 12: Dart Brook – DB. View across stream (26/11/18).

There has consistently been little flow at the time of sampling and water clarity has commonly been poor. Conductivity levels have been as high as 5,905 µS/cm. The RCE score has ranged between 32 and 36 between the spring 2017 and spring 2019 surveys. This site is classified as Key Fish Habitat according to the DPI (2013) classification criteria.

Rosebrook Creek (Sites RC1, RC2 and RC3)

Rosebrook Creek is a small (approximately 7.5 km long), ephemeral creek that drains eastwards into the Hunter River approximately 1 km from the MPO boundary (Figure 6). The source of the creek is within the Study Area. Three sites were surveyed along Rosebrook Creek in November 2018, approximately 8.2 km (Site RC1), 2.7 km (Site RC2) and 1.2 km upstream from its confluence with the Hunter River (Site RC3) (Figure 6, Plates 13-18).

Plate 13: Rosebrook Creek – RC1. View upstream at Rose Lane (27/11/18).

Plate 14: Rosebrook Creek – RC1. View downstream at Rose Lane (27/11/18).

Plate 15: Rosebrook Creek – RC2. Midstream reaches at Wybong Road, looking upstream (27/11/18).

Plate 16: Rosebrook Creek – RC2. Midstream reaches at Wybong Road, looking downstream (27/11/18).

Plate 17: Rosebrook Creek – RC3. Downstream reaches at Logues Lane, looking upstream (27/11/18).

Plate 18: Rosebrook Creek – RC3. Downstream reaches at Logues Lane, looking downstream (27/11/18).

At the time of the survey, the creek was dry. The banks of the creek were almost entirely cleared of trees and riparian vegetation and there was evidence that livestock regularly grazed and trampled the stream bank and channel. The creek channel was mostly colonised by pasture grasses and habitat for aquatic fauna, such as rocks, snags and aquatic macrophytes, was absent (Plates 13-18). The creek received an RCE score of 19. The mid- to lower-reaches of Rosebrook Creek (i.e. downstream from Site RC1) are mapped as Key Fish Habitat under the DPI Key Fish Habitat mapping for the Muswellbrook LGA (DPI, 2017a).

Unnamed Tributary (Site UT1)

Several unnamed drainage paths flow from the Study Area east towards Kayuga, where they form an ephemeral unnamed tributary, approximately 3.8 km in length (Figure 6). The tributary flows through agricultural land on the Hunter River floodplain, joining the Hunter River approximately 2.8 km downstream from the MPO (Figure 3, Plates 19 and 20). The banks of the tributary have been almost entirely cleared of trees and riparian vegetation (Plates 19 and 20). The tributary was dry at the time of sampling (Plates 19 and 20).

Plate 19: Unnamed Tributary – UT1. Downstream reaches at Lawrie Lane, looking upstream (27/11/18).

Plate 20: Unnamed Tributary – UT1. Downstream reaches at Lawrie Lane, looking downstream (27/11/18).

The unnamed tributary is not mapped as Key Fish Habitat under the DPI Key Fish Habitat mapping for the Muswellbrook LGA (DPI, 2017a).

4.1.3 Hunter River

In general, the section of the Hunter River in the Study Area is characterised by a series of continuous, slow flowing pools up to approximately 30 m wide and greater than 1 m deep. The channel substratum was composed primarily of silty sand and pebble/gravel edge habitat with a considerable cover of detritus. Large woody debris and undercut banks were present at all sites.

The riparian zone along the Hunter River has been heavily degraded largely due to historical clearing of vegetation, bank erosion and invasion by introduced plant species, including Morning Glory, Privet, Balloon Vine (*Cardiospermum grandiflorum*), Wandering Jew (*Tradescantia albiflora*) and Willow. River Oak and River Red Gum were common.

Submerged, native species of macrophytes commonly found included Clasped Pondweed (*Potamogeton perfoliatus*) and Water Milfoil (*Myriophyllum* sp.). The emergent macrophyte assemblages were characterised by Typha, Umbrella Sedge (*Cyperus eragrostis*), Phragmites, Mat Rush, Common Rush (*Juncus usitatus*) and Marsh Club-rush (*Bolboschoenus fluviatilis*). The species present within the Study Area have a wide distribution and are abundant in similar aquatic habitats elsewhere in south-eastern Australia.

The section of the Hunter River within the Study Area was classified as Class 1, Type 1 fish habitat according to the DPI (2013) classification.

Site HR1 – Hunter River upstream of Dart Brook

The most upstream site (HR1) was situated within farming land, approximately 200 m upstream of the confluence with Dart Brook (Figure 6, Plate 21). The site consisted of a large (approximately 8 m to 13 m wide and up to 1 m deep) flowing pool with a heavily silted gravel bed (Plates 21 and 22). A relatively large (up to approximately 1 m wide and 3 m long) bed of the submerged, native species of macrophyte, Clasped Pondweed, has been present and woody debris scattered throughout.

Plate 21: Hunter River – HR1. Aerial view (9/5/18).

Plate 22: Hunter River – HR1. View upstream (26/11/18).

Vegetation of the riparian zone was dense, comprising mixed native and exotic trees and shrubs including River Oak, Willow and River Red Gum. Mat Rush, Common Rush, Marsh Club-rush, Wandering Jew and exotic grasses were abundant along the edge of the banks.

The RCE score has ranged between 38 and 43 between the spring 2017 and spring 2019 surveys.

Site HR2 – Hunter River downstream of Dart Brook

Site HR2 was situated approximately 900 m downstream of the confluence of the Hunter River with Dart Brook (Figure 6). Similar to Site HR1, the site consisted of a large (up to approximately 25 m wide and 1.5 m deep), and generally slow flowing pool (Plates 23 and 24). The substratum in the edge habitat is predominantly cobble, pebble and silt. Fish hotels are present within the river channel and small patches (up to approximately 1 m long) of Clasped Pondweed have been observed on occasion.

The right bank (when facing downstream) was steep and eroded where riparian vegetation was not present whilst the left bank was densely vegetated. Willow, River Oak, River Red Gum, Typha, Marsh Club-rush, Balloon Vine and exotic grasses were common.

Plate 23: Hunter River – HR2. Aerial view (10/5/18).

Plate 24: Hunter River – HR2. View across stream (26/11/18).

Despite exotic plant invasion and bank degradation, the RCE score has been as high as 45 (range = 38 to 45 between the spring 2017 and spring 2019 surveys), indicating good quality aquatic habitat.

Site HR3 – Hunter River at Burtons Lane

Site HR3 was situated approximately 6.8 km downstream of Site HR2 (Figure 6). This site consisted of a large (up to approximately 28 m wide and >1.7 m deep), continuous pool (Plates 25 and 26). The substratum in the edge habitat was predominantly pebble and gravel with a mixture of sand and silt. Bank erosion was apparent, particularly of the right bank, in several places and riparian vegetation was dominated by exotic trees, shrubs and vines. A number of fish hotels were present within the river channel.

Plate 25: Hunter River – HR3. View downstream (26/11/18).

Plate 26: Hunter River – HR3. View upstream (26/11/18).

The RCE score has ranged between 40 and 42 between the spring 2017 and spring 2019 surveys.

Site HR4 – Hunter River at Muswellbrook

Site HR4 is situated approximately 1 km downstream of the confluence of Sandy Creek with the Hunter River (Figure 6). The study reach consisted of a continuous, slow flowing pool with steep banks either side, which were fully stabilised by trees (mostly Willow and River Oak) and shrubs, including Typha and Marsh Club-rush, Wandering Jew, Balloon Vine and exotic grasses (Plates 27 and 28). Small numbers of sheep were seen grazing the right bank in spring 2019.

Plate 27: Hunter River – HR4. Aerial view upstream (10/5/18).

Plate 28: Hunter River – HR4. View upstream (26/11/18).

The substratum in the edge habitat was predominantly gravel, pebble and silt. The submerged, native species of macrophyte, Clasped Pondweed, has been noted on several occasions. Water clarity has generally been fair. The RCE score has ranged between 41 and 43 between the autumn 2018 and spring 2019 surveys.

Site HR5 – Hunter River off Bengalla Road

Site HR5 is situated immediately downstream of the approved discharge point from the MPO and the existing discharge point from Bengalla Mine (Figure 6). This site consists of a long, relatively deep pool with a short section of riffle habitat at the top of the study reach (Plates 29 and 30). Fish hotels are present. The substratum in the edge habitat is predominantly a silt, pebble, gravel matrix. Submerged macrophytes have not been recorded at this site.

Plate 29: Hunter River – HR5. Aerial view downstream (10/5/18).

Plate 30: Hunter River – HR5. View downstream (26/11/18).

The right bank (when facing downstream) is steep and eroded in some sections where riparian vegetation is not present, whilst the left bank is densely vegetated. There has been evidence of stock access to the river. Trees within the riparian habitat include Willow, River Oak and River Red Gum. Balloon Vine and exotic grasses are common.

Water clarity has generally been fair and flow moderate. The RCE score has ranged between 37 and 44 between the spring 2017 and spring 2019 surveys.

Site HR6 – Hunter River near Roxburgh

Site HR6 is situated approximately 4 km downstream of the approved discharge point from the MPO and the existing discharge point from Bengalla Mine (Figure 6). The substratum in the edge habitat is predominantly a silt, gravel matrix. The submerged, native species of macrophyte, Curly Pondweed (*Potamogeton crispus*), has been observed on occasion.

The width of the riparian strip is relatively narrow (i.e. between 5 and 30 m) and comprised of Willow, River Oak and River Red Gum trees and shrubs (Plates 31 and 32). Balloon Vine and exotic grasses are common. Water clarity is commonly fair and flow moderate. The RCE score has ranged between 38 and 40 between the spring 2017 and spring 2019 surveys.

Plate 31: Hunter River – HR6. Aerial view (9/5/18).

Plate 32: Hunter River – HR6. View upstream (26/11/18).

4.2 *In-situ* Water Quality

Surface water quality trigger values have been developed for the MPO in accordance with the Australian and New Zealand Environment Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand (ANZECC & ARMCANZ) (2000) guidelines and documented in the Water Management Plan (MACH, 2019). Default trigger values (DTV) and the mean water quality values (± standard error) recorded at each site are provided in Table 4.

Water quality samples were unable to be collected in Rosebrook Creek or the unnamed tributary and drainage lines because they were dry at the time of the Aquatic Ecology Assessment survey (spring 2018). Based on previous observations, this is commonly the case at these locations.

Mean water temperatures have ranged from 12.6 °C to 25.9°C between 2017 to 2019 and reflected seasonal trends. Measurements taken along the Hunter River varied by between 1.4°C and 3.8°C across sites, but there were no obvious trends along the river (Table 4).

Table 4. Mean (± standard error) values of water quality variables recorded at each site between spring 2017 and spring 2019.

Variable	DTV*	Spring 2017	Autumn 2018	Spring 2018	Autumn 2019	Spring 2019#
Site DB – Dart Brook at MacIntyre Bridge						
Temperature (°C)	-	25.1 (0.0)	12.6 (0.0)	22.1 (0.1)	13.5 (0.0)	20.3
pH	6.5-8.0	**8.1** (0.0)	**8.8** (0.0)	**8.2** (0.0)	8.0 (0.0)	**8.24**
Electrical Conductivity (µS/cm)	30-350	**4,257** (1.3)	**5,905** (5.0)	**4,400** (0.0)	**3,648** (0.6)	**5,210**
Dissolved Oxygen (% Sat)	90-110	**64.2** (0.8)	**60.5** (0.3)	**88.7** (0.4)	**54.9** (0.2)	**63.9**
Turbidity (NTU)	2-25	24.2 (0.5)	**52.4** (0.7)	**26.5** (0.7)	**53.2** (0.4)	**31**
Site MC – Muscle Creek at Muswellbrook						
Temperature (°C)	-	23.3 (0.0)	15.1 (0.0)	23.9 (0.0)	15.0 (0.0)	24.5
pH	6.5-8.5	7.7 (0.2)	8.3 (0.0)	7.7 (0.0)	7.5 (0.0)	7.79
Electrical Conductivity (µS/cm)	125-2,200	1,589 (2.6)	1,406 (14.5)	1,232 (1.0)	1,517 (0.3)	1,327
Dissolved Oxygen (% Sat)	85-110	86.6 (0.1)	**83.9** (0.1)	107.3 (0.2)	**52.5** (0.2)	**113.9**
Turbidity (NTU)	6-50	26.9 (0.9)	45.8 (0.1)	23.5 (0.7)	42.2 (2.1)	**2.7**
Site SC – Sandy Creek at Wybong Road						
Temperature (°C)	-	21.1 (0.0)	14.1 (0.1)	17.3 (0.0)	12.9 (0.0)	22
pH	6.5-8.0	**8.5** (0.0)	**8.6** (0.0)	8.0 (0.0)	7.9 (0.0)	7.91
Electrical Conductivity (µS/cm)	30-350	**8,000** (0.0)	**8,027** (0.3)	**9,600** (0.0)	**7,064** (13.2)	**11,200**
Dissolved Oxygen (% Sat)	90-110	**43.7** (0.0)	**49.0** (5.3)	**10.9** (0.0)	**40.8** (1.4)	**39.1**
Turbidity (NTU)	2-25	10.1 (0.1)	**77.1** (5.2)	4.8 (0.2)	**28.0** (0.2)	2.1
Site HR1 – Hunter River upstream of Dart Brook						
Temperature (°C)	-	22.4 (0.0)	17.1 (0.0)	20.2 (0.0)	15.5 (0.0)	19.6
pH	6.5-8.0	**8.3** (0.0)	**8.6** (0.0)	**8.1** (0.0)	**8.1** (0.0)	**8.3**
Electrical Conductivity (µS/cm)	30-350	264 (0.0)	256 (0.0)	276 (0.3)	321 (0.0)	**356**
Dissolved Oxygen (% Sat)	90-110	95.5 (0.4)	93.7 (0.0)	95.4 (0.1)	**87.6** (0.1)	108.2
Turbidity (NTU)	2-25	16.4 (1.4)	**44.6** (0.4)	13.8 (0.3)	**42.6** (0.9)	2.9

Table 4 (Continued). Mean (± standard error) values of water quality variables recorded at each site between spring 2017 and spring 2019.

Variable	DTV*	Spring 2017	Autumn 2018	Spring 2018	Autumn 2019	Spring 2019#
Site HR2 – Hunter River downstream of Dart Brook						
Temperature (°C)	-	22.9 (0.0)	16.2 (0.0)	19.3 (0.0)	15.7 (0.0)	22.1
pH	6.5-8.0	**8.2** (0.0)	**8.5** (0.0)	**8.2** (0.1)	7.9 (0.0)	**8.3**
Electrical Conductivity (µS/cm)	30-350	267 (1.3)	311 (0.0)	276 (0.0)	323 (2.2)	**387**
Dissolved Oxygen (% Sat)	90-110	**141.2** (3.6)	**85.8** (0.1)	92.5 (0.2)	**89.3** (0.5)	97.8
Turbidity (NTU)	2-25	**26.7** (1.2)	**43.2** (0.2)	12.8 (0.2)	**43.8** (0.7)	2.6
Site HR3 – Hunter River at Burtons Lane						
Temperature (°C)	-	24.7 (0.0)	16.1 (0.0)	18.7 (0.0)	14.5 (0.0)	21.7
pH	6.5-8.5	8.2 (0.0)	**8.6** (0.0)	7.9 (0.0)	7.7 (0.0)	8.27
Electrical Conductivity (µS/cm)	125-2,200	272 (1.3)	266 (0.0)	313 (0.0)	329 (0.0)	357
Dissolved Oxygen (% Sat)	85-110	101.7 (0.5)	85.7 (0.1)	**80.9** (0.1)	**72.3** (0.1)	**115.1**
Turbidity (NTU)	6-50	46.4 (0.3)	49.4 (0.2)	6.9 (0.2)	18.9 (0.8)	**3.3**
Site HR4 – Hunter River at Muswellbrook						
Temperature (°C)	-	24.6 (0.0)	16.6 (0.0)	21.5 (0.0)	15.2 (0.0)	22.2
pH	6.5 – 8.5	7.9 (0.0)	8.4 (0.0)	8.0 (0.0)	7.7 (0.0)	8.2
Electrical Conductivity (µS/cm)	125 – 2200	296 (1.3)	274 (20.0)	290 (0.0)	368 (1.7)	361
DO (% Sat)	85–110	93.2 (0.6)	100.0 (0.2)	101.0 (0.1)	**79.3** (0.1)	**120.8**
Turbidity (NTU)	6 – 50	26.5 (0.9)	**55.7** (0.1)	28.5 (0.4)	**51.7** (0.7)	6.7
Site HR5 – Hunter River off Bengalla Road						
Temperature (°C)	-	25.4 (0.0)	15.5 (0.0)	22.3 (0.1)	15.3 (0.0)	22.3
pH	6.5-8.5	7.9 (0.0)	8.5 (0.0)	7.7 (0.0)	7.8 (0.0)	8.1
Electrical Conductivity (µS/cm)	125-2,200	318 (1.3)	338 (2.0)	322 (0.9)	424 (0.0)	365
DO (% Sat)	85-110	**66.5** (0.8)	90.3 (0.6)	89.5 (0.2)	**79.7** (0.7)	107.9
Turbidity (NTU)	6-50	30.5 (0.5)	**57.2** (0.2)	35.3 (0.1)	45.2 (1.4)	6.8

Table 4 (Continued). Mean (± standard error) values of water quality variables recorded at each site between spring 2017 and spring 2019.

Variable	DTV*	Spring 2017	Autumn 2018	Spring 2018	Autumn 2019	Spring 2019#
Site HR6 – Hunter River near Roxburgh						
Temperature (°C)	-	25.9 (0.0)	17.0 (0.1)	22.5 (0.0)	15.9 (0.0)	22.2
pH	6.5-8.5	8.1 (0.0)	8.4 (0.0)	7.8 (0.0)	7.9 (0.0)	8.07
Electrical Conductivity (µS/cm)	125-2,200	329 (0.0)	331 (1.2)	321 (0.3)	448 (0.0)	364
Dissolved Oxygen (% Sat)	85-110	**74.7** (0.0)	**83.8** (0.6)	100.8 (0.3)	91.7 (1.5)	107
Turbidity (NTU)	6-50	35.3 (0.8)	**59.1** (0.6)	34.3 (0.2)	35.8 (0.5)	12.7

* DTVs are based on the ANZECC & ARMCANZ (2000) guidelines for the protection of slightly disturbed aquatic ecosystems in upland rivers (i.e. systems at > 150 m altitude) and lowland rivers (< 150 m altitude) in south-east Australia. Altitude at Sites HR1, HR2, DB and SC is > 150 m. Altitude at Sites HR3, HR4, HR5, HR6 and MC is > 150 m.

\# Replicate measurements of water quality were unable to be collected at the time of the spring 2019 survey, due to technical issues with BIO-ANALYSIS's water quality instrument. Temperature, pH, conductivity and dissolved oxygen measurements were collected using AECOM's water quality instrument. Water samples were collected and sent to ALS Water – Newcastle to be analysed for turbidity.

Note: Values in bold are outside of the DTV range.

Mean pH at the sites sampled ranged from 7.5 to 8.8 between 2017 to 2019 (Table 4). Mean pH at the two most upstream sites in the Hunter River (i.e. Site HR1 and HR2) commonly exceeded the upper DTV recommended by the ANZECC & ARMCANZ (2000) guidelines, but not trigger criteria developed using historical data for nearby sites[4].

[4] Using the approach recommended by ANZECC & ARMCANZ (2000), surface water quality trigger levels were developed at two sites (i.e. HR1 and W6) situated within the Hunter River (MACH, 2019). Sites HR1 and W6 (now W6A) are sampled monthly and during rain events by AECOM. The 80th percentile trigger values for pH and conductivity (EC) are: Site HR1 pH = 7.8 – 8.3, EC = 589 µS/cm; Site W6A: pH = 7.8-8.4, EC = 496 µS/cm.

Conductivity ranged from 256 to 448 µS/cm at the sites sampled along the Hunter River, exceeding the upper DTV recommended by the ANZECC & ARMCANZ (2000) guidelines at Sites HR1 and HR2 at the time of the spring 2019 survey, but not the site-specific criteria developed by MACH (2019) (Table 4). The Hunter River catchment includes a large proportion of salt-bearing sedimentary rocks and soils, and surface and underground drainage from this contributes natural salinity to the river.

Elevated salinity and occasional spikes in turbidity or low dissolved oxygen levels are also likely to reflect the condition of the Hunter River tributary catchments. Conductivity at the sites sampled in Dart Brook (range = 3,648 to 5,905 µS/cm) and Sandy Creek (range = 7,064 to 11,200 µS/cm) consistently exceeded the upper DTV recommended by the ANZECC & ARMCANZ (2000) guidelines but not Muscle Creek (range = 1,232 to 1,589 µS/cm) (Table 4).

Dissolved oxygen levels ranged from 10.9 to 141.2% saturation (Table 4). Levels recorded were consistently below the lower DTV at Dart Brook and Sandy Creek. Turbidity ranged from 2.1 to 77.1 NTU (Table 4).

4.3 Aquatic Macroinvertebrates

Macroinvertebrate samples were unable to be collected in Rosebrook Creek, the unnamed tributary or the unnamed drainage lines because there was insufficient aquatic habitat at the time of the Aquatic Ecology Assessment survey (spring 2018).

A total of 51 taxa have been recorded from edge habitat samples collected at the nine Stream Health Monitoring sites between spring 2017 and spring 2019 (Appendix 1). The number of taxa collected at each site has ranged from 3 (Site HR2 and HR6 in spring 2019) to 18 (SC in spring 2017) (Figure 8).

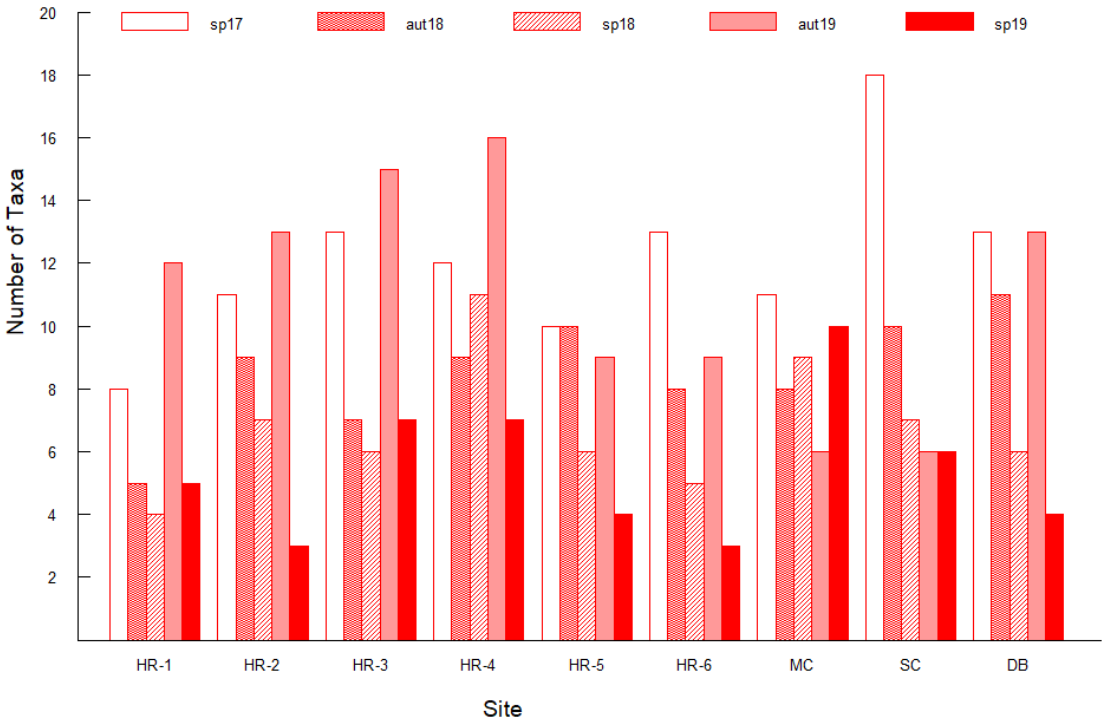


Figure 8. Number of Taxa Found in AUSRIVAS Samples Collected from Edge Habitat at Each Site Between Spring 2017 and Spring 2019.

Atyidae (freshwater shrimp) and Chironominae (non-biting midges) consistently contributed most to differences between the Hunter River and Tributary sites. Atyidae were less abundant at the tributary sites compared to the Hunter River sites but vice versa for the Chironominae. Atyidae are generally found in well-oxygenated, fast-flowing waters while chironomid larvae can be collected in a range of habitats including polluted, stagnant and saline waters. Dominance of assemblages by chironomids at the tributary sites, particularly Sandy Creek, is not surprising given that they have been relatively saline environments with little flow.

Prolonged drying from severe droughts can substantially alter macroinvertebrate assemblages, with reduced prevalence of many flow-dependent taxa and increased prevalence of taxa that are tolerant of low-flow conditions and poor water quality (Boulton and Lake, 2008). NSW is considered to have been in severe drought since mid-2017 (DPI, 2019). Rates of site failure against specified AUSRIVAS and SIGNAL2 indices for edge habitat have been shown to increase significantly during severe and prolonged drought (Rose *et al*., 2008).

The OE50 Taxa Scores have ranged from 0.14 (Site HR6 in spring 2019) to 0.78 (Site HR3 in autumn 2019) (Figure 9). All of the OE50 Taxa scores have been below 1.00 (Figure 9), indicating that the number of taxa observed was less on all occasions than would be expected relative to the AUSRIVAS reference watercourses. Locations HR6 and DB dropped from Band C to Band D between autumn and spring 2019 (Figure 9).

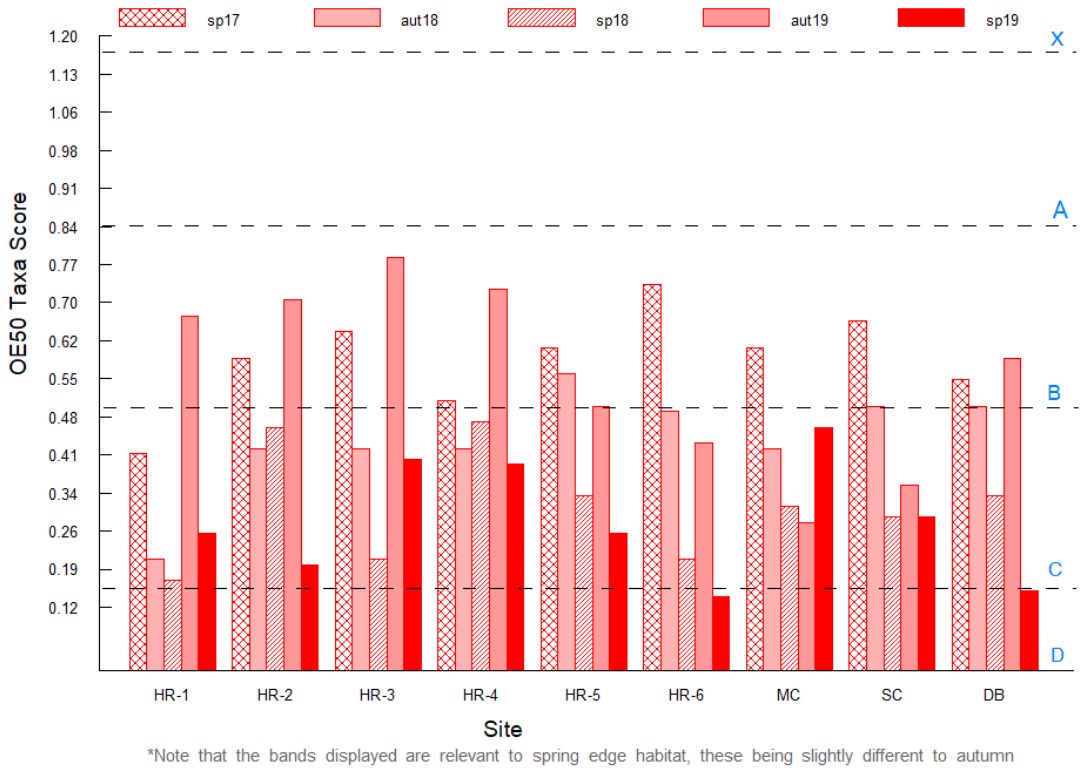


Figure 9. OE50 Taxa Scores and Their Respective Band Scores (B-D) for AUSRIVAS Samples Collected Between Spring 2017 and Spring 2019.

The SIGNAL2 Index ranged from 2.5 (Site SC in autumn 2019) to 4.31 (Site HR3 in autumn 2018) (Figure 10). Most of the SIGNAL2 values were less than 4, indicating macroinvertebrate assemblages have consistently been dominated by pollution-tolerant taxa (Figure 10).

Figure 10. Signal2 Indices for AUSRIVAS Samples Collected from Edge Habitat at Each Site Between Spring 2017 and Spring 2019.

Results from the AUSRIVAS analyses indicate that the Hunter River and its associated tributaries are in poor condition. In spring 2019, seven locations (HR1, HR2, HR3, HR4, HR5, MC and SC) were classified as severely impaired (Band C) and two locations (HR6 and DB) as impoverished (Band D). This finding is almost certainly related to the compounding effects from exposure to multiple stressors (e.g. flow alteration, sedimentation, increased salinity, nutrients and drought) that can adversely affect riverine condition.

4.4 Fish

Fish were unable to be sampled in Rosebrook Creek and the unnamed ephemeral drainage lines because they were dry at the time of sampling. However, these ephemeral systems are not likely to provide notable fish habitat.

Ten species of fish (including two introduced species) and two species of shrimp were collected across the survey sites (Table 5). Mosquito Fish (*Gambusia holbrooki*) and Long-finned Eels (*Anguilla reinhardtii*) have been the most widespread and abundant species. Australian Bass (*Macquaria novemaculeata*) were collected in autumn 2019, spring 2018 and autumn 2018 but not spring 2017 or spring 2019. Goldfish (*Carassius auratus*) and Freshwater Mullet (*Myxus petardi*) were observed by the spring 2017 survey, but not subsequently. Freshwater shrimps (Atyidae), freshwater prawns (Palaemonidae) and Mosquito Fish were caught in dip nets whilst sampling aquatic macroinvertebrates.

Table 5. Species of fish and crustaceans collected by the MPO Stream Health Monitoring Program surveys.

Scientific Name	Common Name	HR1	HR2	HR3[A]	HR4	HR5[A]	HR6	MC	SC[B]	DB[C]
Anguilla reinhardtii	Long-finned Eel	√	√	√	√	√	√	√	-	√
Cyprinus carpio	Common Carp*	-	-	√	√	-	-	-	-	√[#]
Gobiomorphus australis	Striped Gudgeon	√	√	√	-	√	√	-	-	-
Macquaria novemaculeata	Australian Bass	√	√	√	-	√	√	-	-	√
Mugil cephalus	Sea Mullet	-	-	-	√	-	√	-	-	-
Gambusia holbrooki	Mosquito Fish*	√	√	√	√	√	√	√	√	√
Philypnodon grandiceps	Flathead Gudgeon	√	√	√	-	√	-	-	-	-
Hypseleotris klunzingeri	Western Carp Gudgeon	-	-	-	√	-	-	-	-	-
Retropinna semoni	Australian Smelt	√	-	√	√	-	√	-	-	-
Tandanus tandanus	Freshwater Catfish	√	-	√	√	-	√	-	-	-

Table 5 (Continued). Species of fish and crustaceans collected by the MPO Stream Health Monitoring Program surveys.

Scientific Name	Common Name	HR1	HR2	HR3[A]	HR4	HR5[A]	HR6	MC	SC[B]	DB[C]
Atyidae sp.	Freshwater Shrimp	√	√	√	√	√	√	√	-	√
Palaemonidae sp.	Freshwater Shrimp	√	-	√	√	√	√	√	-	√

[A] Two fyke nets were set at each of HR3 and HR5 in autumn 2018, spring 2018 and autumn 2019.

[B] Sandy Creek was unable to be electrofished in autumn 2018, spring 2018 and autumn 2019 due to elevated levels of conductivity (>7,000 µS/cm).

[C] Approximately 20 m of habitat was able to be electrofished at Dart Brook in spring 2018 due to elevated levels of conductivity (>4,000 µS/cm).

* Non-native/Alien species.

Observed but not collected.

Predation by Mosquito Fish is listed as a Key Threatening Process on Schedule 3 of the *Threatened Species Conservation Act, 1995* [29 January 1999], because of known effects on frogs, freshwater fishes and other organisms such as aquatic macroinvertebrates. Alien species, particularly Mosquito Fish, commonly thrive in disturbed habitats and still waters (McDowall, 1996), especially when the pre-existing assemblages are depauperate (Ross, 1991).

All of the species caught have been recorded during previous fish surveys on the Hunter River (McDowall, 1996; DPI, 2006; Howell and Creese, 2010).

No threatened species of fish listed under the FM Act or the EPBC Act have been recorded from the Study Area during current (BIO-ANALYSIS, 2018a, 2018b, 2019a, 2019b and 2020) or previous surveys (McDowall, 1996; DPI, 2006; Howell and Creese, 2010).

4.5 Listed Threatened Species, Populations and Communities

One endangered species listed under the FM Act, the Southern Purple-Spotted Gudgeon (*Mogurnda adspersa*), and one endangered population listed under the FM Act, the Darling River Hardyhead (*Craterocephalus amniculus*) population, were identified by the desktop review as having the potential to occur downstream of the Project area (i.e. Dart Brook, Rosebrook Creek and the Hunter River) (Table 6).

Table 6. Listed threatened species and populations.

Scientific Name	Common Name	FM Act	EPBC Act
Mogurnda adspersa	Southern Purple-Spotted Gudgeon	Endangered	-
Craterocephalus amniculus	Darling River Hardyhead	Endangered Population	-

The Giant Dragonfly (*Petalura gigantea*), which is listed as Endangered under Schedule 1 of the BC Act, has suitable habitat predicted to occur within the Muswellbrook LGA, but in the Wollemi sub-region, not within the Hunter sub-region (DAWE, 2020). It is unlikely that the Giant Dragonfly occurs within the Study Area given the Study Area is outside of the species known range and the absence of suitable habitat. This species is, therefore, not considered further.

No threatened ecological communities listed under the FM Act potentially occur within the Study Area (Table 6). No threatened species or communities listed under the EPBC Act potentially occur within the Study Area (Table 6). The threatened species and population predicted in the desktop review to occur within the Study Area are not listed as Matters of National Environmental Significance.

4.5.1 Southern Purple-Spotted Gudgeon

No Southern Purple-Spotted Gudgeon have been recorded in the Hunter River (OZCAM, 2020). The population in the Hunter Valley (in Goorangoola Creek, a tributary of Glennies Creek) is outside what was previously considered the natural range of the species, so there is some uncertainty as to whether the population is endemic or recently introduced (DPI, 2017b).

Although the Southern Purple-Spotted Gudgeon has not been recorded from within the Study Area (OZCAM, 2020), DPI (2017a) consider that the Hunter River and the lower reaches of Rosebrook Creek provide suitable habitat for this species.

No Southern Purple-Spotted Gudgeon have been caught using electrofishing, fyke nets or bait traps in the sites sampled in the Hunter River, or electrofishing in Muscle Creek, Sandy Creek or Dart Brook (Section 4.4) (BIO-ANALYSIS, 2018a, 2018b, 2019a, 2019b and 2020). Potential suitable habitat including aquatic and riparian vegetation, leaf litter, rocks or snags is present at the Hunter River sites, although this species is mostly found in slow-moving waters. The sections of Muscle Creek, Sandy Creek and Dart Brook visited provide marginal habitat but are not considered suitable for this species because of high salinity levels, particularly in Dart Brook (range = 3,648 to 5,905 µS/cm) and Sandy Creek (range = 7,064 to 11,200 µS/cm) (Table 4).

While Rosebrook Creek is mapped by DPI (2017a) as potentially providing potential habitat for Southern Purple-Spotted Gudgeon in its lower reaches, this section of the creek is mostly dry for considerable periods (years) of time. The banks of the creek are almost entirely cleared of trees and riparian vegetation and there has been evidence that livestock regularly grazed and trampled the stream bank and channel. Habitat for aquatic fauna, such as rocks, snags and aquatic macrophytes was absent (Section 4.1.2).

Ephemeral drainage lines within the Study Area are not expected to provide suitable habitat for this species.

4.5.2 Darling River Hardyhead

No Darling River Hardyhead were observed during the targeted field survey done in November 2018. Although mapped as having potential habitat in the Goulburn River and the Hunter River catchment upstream of the Goulburn confluence (DPI, 2017a), they have not been mapped in the Hunter River adjacent to the Project (OZCAM, 2020).

No Darling River Hardyhead have been observed using electrofishing, fyke nets or bait traps in the sites sampled in the Hunter River, or electrofishing in Muscle Creek, Sandy Creek or Dart Brook (Section 4.4) (BIO-ANALYSIS, 2018a, 2018b, 2019a, 2019b and 2020). This species is usually found in slow-flowing, clear, shallow waters or in aquatic vegetation near the stream bank although they have also been recorded from the edge of fast-flowing habitats such as the runs at the head of pools (DPI, 2014).

It is considered that Rosebrook Creek, ephemeral tributaries and drainage lines within the Study Area do not provide suitable habitat for this species.

Although Darling River Hardyhead have been found in the headwaters of the Hunter System, no individuals have been detected from the Hunter River catchment since 2003 (DPI, 2014). It is considered unlikely that this species occurs within or adjacent to the Study Area given that no records exist despite extensive sampling.

4.6 Invasive Species and Disease

The *NSW Aquatic Pest and Disease Distribution* (DPI, 2020b) lists invasive freshwater species under the Hunter River Catchment including Common Carp and Mosquito Fish, as well as Red Spot Disease (Epizootic Ulcerative Syndrome). Common Carp and Mosquito Fish have been recorded in the Study Area (Table 5).

The following weed species are listed on *NSW WeedWise* (DPI, 2020c) as occurring within the Study Area:

- Alligator weed (*Alternanthera philoxeroides*);
- Anchored Water Hyacinth (*Eichhornia azurea*);
- Arrowhead (*Sagittaria calycina* var. *calycina*);
- Cabomba (*Cabomba caroliniana*);
- Eurasian Water Milfoil (*Myriophyllum spicatum*);
- Frogbit (*Limnobium laevigatum*);
- Hydrocotyl (*Hydrocotyle ranunculoides*);

- Hygrophila (*Hygrophila costata*);
- Lagarosiphon (*Lagarosiphon major*);
- Long-leaf Willow Primrose (*Ludwigia longifolia*);
- Ludwigia (*Ludwigia peruviana*);
- Sagittaria (*Sagittaria platyphylla*);
- Salvinia (*Salvinia molesta*);
- Water Caltrop (*Trapa* sp.);
- Water Hyacinth (*Eichhornia crassipes*);
- Water Lettuce (*Pistia stratiotes*);
- Water Soldier (*Stratiotes aloides*);
- Water Star Grass (*Heteranthera zosterifolia*); and
- Willow.

4.7 Aquatic Groundwater Dependent Ecosystems

The *Groundwater Dependent Ecosystems Atlas* (GDE Atlas) (BoM, 2020b) was developed by the BoM as a national dataset of Australian GDEs to inform groundwater planning and management. Aquatic habitat within the Hunter River is mapped as having high potential for groundwater interaction in the GDE Atlas.

4.8 Subterranean Groundwater Dependent Ecosystems

4.8.1 Groundwater Habitat

Seven accessible bores were sampled on 27 and 28 November 2018 (Table 7, Figure 7). Of these, approximately 100 litres of water was able to be pumped from four boreholes (MP-BH1, MP-BH2, 7000D000(u) and WRA1(L)) within three groundwater systems at the following depths (Table 7):

- alluvium up to approximately 22.2 mbgl;
- interburden at approximately 12.9 mbgl; and
- Permian at approximately 19.4 mbgl.

Samples were unable to be collected using the automatic pump sampler from MP-BH3, MP-BH3b or 18298 due to the dimensions of those bores (Table 7).

Table 7. Groundwater results.

Bore	Location	System	Water Level (mbgl)	Electrical Conductivity (µS/cm)	pH	Dissolved Oxygen (% Sat)	Temperature (°C)
MP-BH1	East of the Project	Alluvium	19.4	381.4	6.86	35.4	26.8
MP-BH2	South-east of the Project	Alluvium	19.0	821.8	6.76	79.6	27.5
MP-BH3	Near eastern MPO boundary	Alluvium	22.2	N/R	N/R	N/R	N/R
MP-BH3b	Near eastern MPO boundary	Alluvium	N/R	N/R	N/R	N/R	N/R
18298	South of the Project	Alluvium	10.2	N/R	N/R	N/R	N/R
7000D000(u)	Near eastern MPO boundary	Interburden	12.9	8,000	6.39	31.1	23.2
WRA1L	Near south-western MPO boundary	Permian	19.4	4,877	7.02	21.8	20.1

Note: Pump samples were unable to be collected from MP-BH3, MP-BH3b or 18298. N/R = Not Recorded.

At the time of sampling, groundwater in the alluvial aquifer system was fresh (MP-BH1: 381 µS/cm; MP-BH2: 822 µS/cm) but brackish to moderately saline in the Permian coal measures (WRA1L: 4,877 µS/cm; 7000D000(u): 8,000 µS/cm) (Table 7). The pH measured in the bores ranged from 6.39 to 7.02 and dissolved oxygen concentrations from 21.8% to 79.6% saturation (Table 7).

4.8.2 Stygofauna Taxa

Low numbers of invertebrates were collected from four of the seven bores sampled (MP-BH1, MP-BH2, MP-BH3 and MP-BH3b), all of which are in the alluvial aquifer to the east of the Project (Table 8). No invertebrates were collected from Bore 18298, which is situated in the alluvium on the southern side of the Hunter River. No invertebrates were collected from the bores sampled within the Permian coal measures (i.e. 7000D000(u) and WRA1(L)).

Three likely stygofauna (Cyclopoida, Ostracoda and Isotomidae) were identified from the invertebrate samples collected (Table 8). Each of these taxa are known from previous surveys of stygofauna within the Hunter alluvium (Hancock and Boulton, 2008; Hose *et al*., 2015; ELA, 2013 and 2019).

Table 8. Invertebrates recorded from bores near the MPO.

Order	Lower taxa	MP-BH1	MP-BH2	MP-BH3	MP-BH3b	Likelihood of Stygofauna
Ostracoda	cf Notodromadidae	-	-	-	1	Likely
Cyclopoida	Cyclopidae	1	-	-	-	Likely
Collembola	Isotomidae	1	-	-	-	Likely
Coleoptera	Unidentified larvae	-	1	-	-	Unlikely
Coleoptera	cf Staphylinidae	(1)	-	1	-	Unlikely
Hemiptera	-	-	(2)	-	-	Unlikely
Number of Taxa		**3**	**2**	**1**	**1**	-
Total Individuals		**3**	**3**	**1**	**1**	-

Note[1]: Numbers in brackets represent samples collected using the pump. Pump samples were unable to be collected from MP-BH3 or MP-BH3b.

Note[2]: Macroinvertebrate taxa were not present in samples collected from 18298, 7000D000(u) or WRA1L.

An early instar insect was collected from MP-BH2 (Table 8). Characteristics included: body cylindrical and elongate (1-2 mm long); legs present but segments not distinguishable; antennae not as long as head; general colouration white but eye lightly pigmented; rows of relatively long setae were present at the edge of the first and last abdominal segment and at the top of the fore trochantin. Based on the presence of eye pigmentation, this individual was considered unlikely to be a stygofauna taxon.

Pupae collected from MP-BH1 and MP-BH3 resembled the Coleopteran family, Staphylinidae, which is not a known stygofauna taxon (Table 8). For this reason and due to the presence of eyes, hardened body parts, body pigments and newly developing wings, these individuals were not considered to be a stygofauna taxon.

A Hemipteran species was also collected from MP-BH2 (Table 8). Due to the presence of eyes, hardened body parts, body pigments and wings, this individual was not considered to be a stygofauna taxon.

5.0 ASSESSMENT OF IMPACTS

The following potential impacts from the Project on aquatic habitat and biota are evaluated in this section:

- loss of aquatic habitat (Section 5.1);
- surface water flow and aquatic biota (Section 5.2);
- surface water quality and aquatic biota (Section 5.3);
- barriers to fish movement (Section 5.4);
- impacts to threatened species (Section 5.5);
- invasion of exotic species (Section 5.6);
- impacts to groundwater (Section 5.7);
- impacts to stygofauna (Section 5.8); and
- cumulative impacts (Section 5.9).

5.1 Loss of Aquatic Habitat

A number of small ephemeral drainage lines would be cleared for the Project, including the upper reaches of Rosebrook Creek. No habitat along the Hunter River would be removed as a result of the Project.

There would be a reduction in habitat available to aquatic flora and fauna as a result of the disturbance of drainage lines within the Project area. However, these habitats do not provide any sufficient permanent habitat for aquatic biota as flow likely only occurs during heavy rainfall events.

The unnamed drainage lines are ephemeral, and the integrity of these aquatic systems has been impacted by historical and ongoing agricultural land uses (vegetation clearing and grazing). At the time of the field assessment (November 2018) there was no flow and the drainage lines were poorly connected (i.e. would only connect to habitats upstream and downstream during periods of high flow).

The drainage lines to be impacted provide low aquatic ecosystem value to aquatic flora and fauna. These habitats are highly unlikely to provide habitat for the threatened Southern Purple-Spotted Gudgeon and Darling River Hardyhead.

All aquatic flora and fauna species detected in the vicinity of the Project during the field surveys were common to the region, and none were listed threatened species under the FM Act or EPBC Act. Therefore, their removal is expected to have negligible impacts on aquatic ecology at a regional scale.

5.2 Surface Water Flow and Aquatic Biota

Changes to catchment yield and baseflow has the potential to impact on aquatic ecology.

Rosebrook Creek

The local surface water drainage systems within and adjacent to the MPO are predominately ephemeral. A maximum 63% reduction in average total flow volume in Rosebrook Creek is likely based on the reduction in catchment area. This reduction in total flow volume would be significant during high rainfall periods and discernible from natural flow variability (HEC, 2020). However, this reduction in flow will occur as part of the approved MPO and would be effectively unchanged as a result of the Project (HEC, 2020).

The Project would result in no incremental change to the catchment of Rosebrook Creek relative to the currently approved mine life (2026) as mining is proposed to continue westwards, further up-catchment of Rosebrook Creek (i.e. the additional area that would be mined for the Project would otherwise drain to the open cut) (HEC, 2020). Post-closure, a 20% reduction of the Rosebrook Creek catchment is estimated due to the Project (HEC, 2020).

Sandy Creek

The maximum area captured by the Project from Sandy Creek catchment is estimated at 2.5 km^2 in 2041, equating to 5.3% of the total catchment area of Sandy Creek at Wybong Road (HEC, 2020). This is less than the predicted maximum area captured by the original approved MPO, which included two separate staged Fines Emplacement Areas in the Sandy Creek Catchment (HEC, 2020). MACH's preferred Fines Emplacement Area is a single storage with staged, downstream lifts and upstream clean water diversions, which reduces the area captured in the water management system. The establishment of the new Mine Water Dams post-2026 results in an increase in the area captured from the Sandy Creek catchment, relative to the currently approved mine life (HEC, 2020).

A maximum 5.3% reduction in average total flow volume in Sandy Creek is likely based on the reduction in catchment area associated with the Project. This reduction in total flow volume is not considered material given the ephemeral nature of Sandy Creek and is unlikely to be discernible from natural flow variability (HEC, 2020).

Following rehabilitation, the catchment draining to Sandy Creek would be restored (i.e. there would be no catchment excised from Sandy Creek in the final landform).

Hunter River

Catchment Yield

The maximum area captured by the Project from the Hunter River catchment at the confluence with Dry Creek is estimated at 24.1 km^2 in Year 2047, equating to 0.55% of the total catchment area (HEC, 2020). This represents an increase to the total area captured by the originally approved MPO (previously estimated at 20.1 km^2) (HEC, 2020). The maximum reduction in mean annual flow due to the Project is estimated at 1,570 megalitres (ML) (0.55% of the mean annual flow volume of 287,102 ML in the Hunter River at Muswellbrook [GS 210002]). Based on their modelling, HEC (2020) considered this amount to represent a small and likely indiscernible impact to flow in the Hunter River at the confluence with Dry Creek.

Post-closure, the area captured from the Hunter River catchment would reduce to 8.1 km^2, which HEC (2020) estimate to equate to a reduction of 0.18% (525 ML) of the mean annual flow. This is less than would have been captured by the original approved final landform for the MPO, which was presented in the 1997 EIS (PPK Environment & Infrastructure, 1997). Much of the original MPO final landform drained internally, towards the various final voids (HEC, 2020).

Baseflow

Changes in groundwater-derived baseflow have been predicted by AGE (2020) for the Hunter Regulated River Water Source and the Hunter Unregulated and Alluvial Water Sources.

A maximum of 27 megalitres per year (ML/year) baseflow reduction is predicted during mining for the Hunter Regulated River Water Source and a maximum total of 8 ML/year for Sandy Creek and Dart Brook (AGE, 2020). The total predicted reduction in baseflow from the Hunter River and its tributaries during mining (35 ML/year) amounts to approximately 0.01% of the 287,102 ML mean annual total flow in the Hunter River at Muswellbrook (GS 210002). Accounting for both the predicted reduction in catchment yield and baseflow, the total reduction (1,604 ML/year) amounts to approximately 0.56% of the mean annual total flow in the Hunter River at Muswellbrook (AGE, 2020).

Post-closure, the total predicted baseflow reduction from the Hunter River water source (51 ML/year) amounts to approximately 0.018% of the 287,102 ML mean annual total flow in the Hunter River at Muswellbrook (GS 210002). Accounting for both the predicted reduction in catchment yield and baseflow, the total reduction (576 ML/year) amounts to approximately 0.2% of the mean annual total flow at this location (AGE, 2020).

Conclusion

These forecast flow reductions are considered by HEC (2020) to represent a small and likely indiscernible impact to flow in the Hunter River at Muswellbrook during the Project and post-closure. Based on the above, and in consideration of the poor habitat rating for the ephemeral drainage lines within the Project area, including the upper reaches of Rosebrook Creek, there would be negligible change to the aquatic ecology within the Project area as a result of predicted changes to surface water flow.

5.3 Surface Water Quality and Aquatic Biota

Alteration of the surface water quality in aquatic ecosystems can cause loss of biodiversity and a shift towards more pollution-tolerant taxa. Changes to surface water quality can generally occur due to soil disturbance (sedimentation and mobilisation of nutrients and saline materials), nutrient leachates and pollution leaks (e.g. associated with heavy vehicles and machinery).

The surface water assessment (supported by site water balance modelling) by HEC (2020) concludes that:

- no overflows are predicted to Sandy Creek;
- some overflow of treated water from sediment dams (designed in accordance with the Landcom [2004] and Department of Environment and Climate Change [2008] guidelines) may occur during wet periods, however it is unlikely that this would have a measurable impact on receiving water quality;
- there is a predicted negligible impact on the downstream water quality as a result of the predicted overflow from Environmental Dam 3;
- modelling (AGE, 2020; HEC, 2020) indicates that there would be little impact from the Project to the Hunter River;
- the median levels of turbidity and total aluminium recorded in the Hunter River at Muswellbrook and monitoring site W15 exceed the water quality objectives under baseline conditions;

- the maximum levels of turbidity, total manganese and total aluminium recorded in the Mine Water Dam are lower than the median levels recorded in the Hunter River at Muswellbrook / W15 and, as such, the level of these constituents is not expected to increase as a result of release from the MPO to the Hunter River; and
- the maximum concentration of total nickel recorded in the Mine Water Dam was higher than the maximum concentration recorded in the Hunter River at Muswellbrook / W15, potentially due to elevated levels of nickel that naturally occur in the local catchment (as observed at monitoring sites W8 and W16). As such, a slight increase in the total nickel concentration in the Hunter River at Muswellbrook / W15 may occur under high release conditions. However, the total nickel concentration is expected to remain below the water quality objective.

Based on the implementation of management strategies (e.g. erosion and sediment controls and land contamination controls) and monitoring recommended in the geochemistry assessment (RGS Environmental Pty Ltd, 2020), the risks of elevated dissolved solids and other contaminants impacting downstream waters is considered to be very low (HEC, 2020).

If no measurable impacts on surface water quality are likely to occur, no adverse impacts are likely to occur on surrounding habitats.

5.4 Key Fish Habitat and Fish Passage

The upper reaches of Rosebrook Creek and first and second order drainage lines in the Project area are not mapped as Key Fish Habitat under the DPI Key Fish Habitat mapping for the Muswellbrook LGA (DPI, 2017a). It is therefore concluded that the Project would not result in the removal of any Key Fish Habitat from within the Project area.

5.5 Threatened Aquatic Biota

As stated in Section 4, no aquatic species of conservation significance listed under the EPBC Act, BC Act or FM Act have been recorded within the Project area. One endangered species listed under the FM Act, the Southern Purple-Spotted Gudgeon, and one endangered population listed under the FM Act, the Darling River Hardyhead population, were identified as having the potential to occur downstream of the MPO within the Study Area. Accordingly, assessments of significance were undertaken for these species in accordance with Division 12, Part 7A of the FM Act and the *Threatened Species Assessment Guidelines: The Assessment of Significance* (DPI, 2008). It was concluded that the Project is unlikely to significantly impact Southern Purple-Spotted Gudgeon or the Darling River Hardyhead (Appendix 1).

5.6 Introduced Aquatic Biota

The Project is unlikely to result in the addition of new invasive species of aquatic flora or fauna because it does not involve diversion of waterways into adjacent catchments. Potential impacts from terrestrial weed species are discussed in the Biodiversity Development Assessment Report (Hunter Eco, 2020).

5.7 Aquatic Groundwater Dependent Ecosystems

The GDE Atlas (BoM, 2020b) was developed by the BoM as a national dataset of Australian GDEs to inform groundwater planning and management. Aquatic habitat within the Hunter River is mapped as having high potential for groundwater interaction in the GDE Atlas.

Predicted baseflow reductions represent a small and likely indiscernible impact to flow in the Hunter River at Muswellbrook during the Project and post-closure. Potential impacts to baseflow in Sandy Creek and Dart Brook are predicted to be negligible (AGE, 2020).

The Hunter River alluvial aquifer is not likely to be impacted because no drawdown effects are expected (AGE, 2020). For this reason, it is considered unlikely that the Project would have a measurable impact on aquatic GDEs.

5.8 Subterranean Groundwater Dependent Ecosystems

Three likely stygofauna were recorded in the Hunter River alluvial aquifer, all of which are prevalent elsewhere in the Hunter Valley (Section 4.8.2).

There is no significant drawdown predicted along the Hunter River alluvium (AGE, 2020) and therefore potential impacts to these stygofauna populations are predicted to be negligible. For this reason, it is considered unlikely that the Project would have a measurable impact on subterranean GDEs.

5.9 Cumulative Impacts

Cumulative impacts include the effects from concurrent operations that are close enough to cause additive effect on the receiving environment. Relevant approved or proposed mining operations near the Project include:

- Bengalla Mining Company owns the existing Bengalla Mine, which is an open cut coal mine located immediately south of the MPO;
- Hunter Valley Energy Coal (a wholly owned subsidiary of BHP) owns the existing Mt Arthur Coal Mine, which is an open cut coal mine located approximately 8 km south of the MPO;
- Mangoola Coal Operations Pty Limited (a subsidiary pf Glencore plc) (Mangoola Operations) owns and operates Mangoola Coal, which is an open cut coal mine located approximately 8 km west of the MPO;
- Australian Pacific Coal Limited owns the Dartbrook Mine, which is an approved underground coal mine located immediately north of the MPO;

- Muswellbrook Coal Company (a wholly owned subsidiary of Idemitsu Australia Resources) owns the Muswellbrook Coal Mine which is an open cut and underground coal mine located northeast of Muswellbrook; and
- Malabar Coal owns the existing Maxwell Infrastructure and the proposed Maxwell Project, which is an underground coal mine located approximately 15 km south of the MPO.

Hunter River

The MPO is situated adjacent to the Bengalla Mine and in the vicinity of the Muswellbrook Coal Mine, Dartbrook Mine, Mt Arthur Coal Mine and Mangoola Coal. These mines operate in a highly regulated water system with licensing of water take undertaken in accordance with the *Water Management Act, 2000* and release of water undertaken in accordance with the Hunter River Salinity Trading Scheme, the relevant Development Consent and the Environment Protection License for each site.

Due to the highly regulated system in which the MPO and adjacent mines operate, the cumulative impacts on the Hunter River (and its aquatic ecology) due to the Project are expected to be negligible.

6.0 IMPACT AVOIDANCE AND MITIGATION MEASURES

6.1 Impact Avoidance

A key outcome from planning the design of the Project is that MACH propose to forgo development (clearance) of native vegetation within a number of existing approved disturbance areas which would reduce the residual biodiversity impacts from the Project. This area is referred to as the Relinquishment Area. The native vegetation within the Relinquishment Area was approved for the development of the:

- North West Out-of-Pit Emplacement area;
- South West Out-of-Pit Emplacement area;
- Western Link Road; and
- portions of the infrastructure area and Fines Emplacement Area.

The approved North West Out-of-Pit Emplacement and South West Out-of-Pit Emplacement areas are no longer required because the Project includes development of an integrated waste rock emplacement landform. The Western Link Road is no longer proposed as Wybong Road is no longer proposed to be closed.

6.2 Mitigation Measures

MACH would continue to manage water for the Project in accordance with a Water Management Plan that includes a monitoring strategy, acceptable water quality trigger values, and trigger response actions for surface water and groundwater. The plan would be designed to mitigate potential impacts on aquatic ecosystems on-site and downstream.

Barriers to Fish Movement

The Project would not involve construction of physical barriers within watercourses in the Study Area that might impede fish passage.

Erosion and Sediment Control Measures

An Erosion and Sediment Control Plan has been developed at the MPO to manage potential erosion impacts and to monitor the effectiveness of erosion and sediment controls and is included in the Water Management Plan (MACH, 2019).

The Erosion and Sediment Control Plan would be updated if required for the Project, and the following measures would be adhered to in areas where disturbance from construction occurs:

- relevant internal approvals and permits would be obtained before commencement of surface disturbance (e.g. Ground Disturbance Permits);
- the extent of disturbance (including trafficable areas) would be minimised and identified using appropriate pegging, barriers or signage;
- appropriate erosion and sediment controls would be approved and established prior to land disturbance and would remain in place until exposed areas are stabilised;
- clean water runoff from undisturbed catchments would be diverted around the disturbance areas via diversion drains and banks to discharge into natural watercourses, where practical;
- runoff from disturbed areas would be diverted into sediment dams;
- drains, diversion banks and channels would be stabilised and scour protection would be provided as necessary;
- temporary erosion and sediment control measures would be used and may include silt fences, hay bales, jute mesh, check dams, cross banks, contour banks, armouring and straw mulching; and
- topsoil in disturbance areas would be stockpiled for reuse.

Stream Health Monitoring

Stream health, including assessment of habitat, water quality, aquatic macroinvertebrates and fish, would be monitored regularly as part of the existing Stream Health Monitoring Program. Any significant change in stream health as determined by stream health trigger levels at or immediately downstream of the Project would be investigated to determine the source of the change.

Surface Water Monitoring

Water quality would be monitored regularly in the Hunter River, Dart Brook, Muscle Creek, Rosebrook Creek, Sandy Creek and associated unnamed tributaries as part of the Surface Water and Stream Health Monitoring Programs. Any significant change in water quality at or immediately downstream of the Project would be investigated to determine the source of the change.

Groundwater Monitoring

Water quality and water levels would be monitored regularly in the existing bore network. Any significant, unexpected change in water quality or water level would be investigated to determine the source of change and the risk to groundwater or surface water ecosystems. If the change is significant enough to threaten groundwater or surface water ecosystems, then attempts would be made to reduce the impact.

7.0 OFFSET REQUIREMENTS

As detailed in Section 5, the Project is effectively a continuation and consolidation of the approved MPO, and:

- is unlikely to result in a significant impact to any aquatic threatened species, population or community listed under the BC Act or FM Act, as assessed against the *Threatened Species Assessment Guidelines: The Assessment of Significance* (DPI, 2008);
- is unlikely to result in a significant impact to any Key Fish Habitat as mapped under the DPI Key Fish Habitat mapping for the Muswellbrook LGA (DPI, 2017a); and
- would not result in a significant impact to any aquatic threatened species or community listed under the EPBC Act.

As such, the Project would not require any biodiversity offset or compensatory measures for potential impacts to aquatic ecology in accordance with the DPI (2013) *Policy and Guidelines for Fish Habitat Conservation and Management* or the *EPBC Act Environmental Offsets Policy* (Department of Sustainability, Environment, Water, Population and Communities, 2012).

8.0 CONCLUSION

Aquatic habitat along the creeks and tributaries in the vicinity of the Project is generally poor and highly modified. Many of the waterways appear to be mostly dry for considerable periods (years) of time.

No threatened species listed under the FM Act, BC Act or EPBC Act have been recorded in the Study Area and it is unlikely that any threatened species would be adversely affected by the Project. Stygofauna are known from the Hunter River alluvium. All taxa collected during this survey have previously been found in aquifers of the Hunter River.

In conclusion, the design of the Project, particularly those components related to water management, address many of the potential impacts that might otherwise occur. Consequently, the Project is not likely to have a significant impact on aquatic ecology and the potential indirect impacts on aquatic ecology downstream of the Project would be minimised with the continuation of a number of existing mitigation measures currently implemented at the MPO.

While the design of the Project indicates that impacts to aquatic habitats and biota can generally be managed by implementation of the Water Management Plan (MACH, 2019), it is recommended that surface water and stream health monitoring programs continue to monitor aquatic ecology in the waterways downstream of the MPO.

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APPENDICES

APPENDIX 1

THREATENED SPECIES ASSESSMENTS

The assessments of significance of impacts consider the potential for direct and/or indirect impacts of the Project on the Southern Purple-Spotted Gudgeon and the Darling River Hardyhead.

Seven-Part Test under the *Fisheries Management Act 1994*

Species: Southern Purple-Spotted Gudgeon (*Mogurnda adspersa*)

The following factors are to be taken into account in making a determination under Section 220ZZ of the FM Act as to whether the action proposed is likely to significantly affect threatened species, populations or ecological communities, or their habitats:
a) in the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.
The Hunter River and the lower Rosebrook Creek are mapped as Key Fish Habitat under the DPI Key Fish Habitat Mapping for the Muswellbrook LGA (DPI, 2017a), and provide suitable habitat for the Southern Purple-spotted Gudgeon. Ephemeral drainage lines and the upper reaches of Rosebrook Creek within the Study Area are not mapped as Key Fish Habitat under the DPI Key Fish Habitat Mapping for the Muswellbrook LGA (DPI, 2017a). The Southern Purple-Spotted Gudgeon has not been recorded within the Study Area or surrounding waterways. The closest record of this species is from 2009 in Goorangoola Creek in the Hunter Catchment (DPI, 2013), approximately 50 km south-east from the Study Area. The Project (described in Section 1.1) will not obstruct fish passage at any stage of construction. The risks of elevated dissolved solids and other contaminants impacting downstream waters is considered to be very low (HEC, 2020). It is unlikely that the Project would have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.
b) in the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.
Not applicable.
c) in the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:
i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or
Not applicable.
ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction
Not applicable.

d) in relation to the habitat of a threatened species, populations or ecological community:
i) the extent to which habitat is likely to be removed or modified as a result of the action proposed, and
Although the Southern Purple-Spotted Gudgeon has not been recorded from within the Study Area (OZCAM, 2020), DPI (2017a) consider that the Hunter River and the lower reaches of Rosebrook Creek provide suitable habitat for this species. Ephemeral drainage lines are not expected to provide suitable habitat for this species (DPI, 2017a). No Southern Purple-Spotted Gudgeon have been caught using electrofishing, fyke nets or bait traps in the sites sampled in the Hunter River, or electrofishing in Muscle Creek, Sandy Creek or Dart Brook. The Southern Purple-Spotted Gudgeon has not been recorded within the Study Area or surrounding waterways. The closest record of this species is from 2009 in Goorangoola Creek in the Hunter Catchment (DPI, 2013), approximately 50 km south-east from the Study Area. No known habitat for this species will be removed or modified as a result of the Project.
ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and
No known habitat for this species will be become fragmented or isolated as a result of the Project.
iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species or ecological community in the locality.
In accordance with the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013), the Hunter River is mapped as Type 1 Highly sensitive fish habitat under the Key Fish Habitat Mapping for the Port Stephens LGA (DPI, 2017a), and provides suitable habitat for the Southern Purple-Spotted Gudgeon. Drainage lines within the Study Area are not mapped as Key Fish Habitat under the DPI Key Fish Habitat Mapping for the Muswellbrook LGA (DPI, 2017a). No Southern Purple-Spotted Gudgeon have been caught using electrofishing, fyke nets or bait traps in the sites sampled in the Hunter River, or electrofishing in Muscle Creek, Sandy Creek or Dart Brook. The Southern Purple-Spotted Gudgeon has not been recorded within the Study Area or surrounding waterways. The closest record of this species is from 2009 in Goorangoola Creek in the Hunter Catchment (DPI, 2013), approximately 50 km south-east from the Study Area. The Study Area is not important habitat for this species.
e) whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly.
The Project will not impact on critical habitat.
f) whether the action proposed is consistent with the objective or actions of a recovery plan or threat abatement plan.
The Project will include management measures to manage sedimentation and erosion and minimise potential water quality impacts to downstream environments, including the downstream reaches of Rosebrook Creek and the Hunter River. None of the other priority actions listed in the *Priorities Action Statement – Actions for the Southern Purple Spotted Gudgeon* (DPI, 2020e) apply to the Project.

g) whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of a key threatening process.
The key threatening processes for Southern Purple-Spotted Gudgeon are degradation of native riparian habitat, installation of structures that alter natural flow regimes, introduction of non-indigenous fish and removal of woody debris. The Project is unlikely to result in an increase in the impact of these key threatening processes.
Conclusion
Given that the species is not known to occur within the Study Area or surrounds, the proposed action is considered unlikely to significantly impact the Southern Purple-Spotted Gudgeon.

Species: Darling River Hardyhead (*Craterocephalus amniculus*)

The following factors are to be taken into account in making a determination under Section 220ZZ of the FM Act as to whether the action proposed is likely to significantly affect threatened species, populations or ecological communities, or their habitats:
a) in the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.
The Darling River Hardyhead is found in the upper tributaries of the Darling River including the Border Rivers and the Gwydir and Namoi catchments. The Darling River Hardyhead has been found in the headwaters of the Hunter System in NSW (DPI, 2014). However, despite extensive sampling, no individuals have been detected from the Hunter River catchment since 2003 (DPI, 2014). Ephemeral drainage lines and the upper reaches of Rosebrook Creek within the Study Area are not mapped as Key Fish Habitat under the DPI Key Fish Habitat Mapping for the Muswellbrook LGA (DPI, 2017a). Any potential increase in turbidity and siltation, smothering of beds of aquatic macrophytes, removal of riparian habitat or large woody debris associated with the Project could adversely affect the lifecycle of the Darling River Hardyhead. The risks of elevated dissolved solids and other contaminants impacting downstream waters is however, considered to be very low (HEC, 2020). The Project (described in Section 1.1) will not obstruct fish passage at any stage of construction. It is considered unlikely that the Project would have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.
b) in the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.
Not applicable.
c) in the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:
i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or
Not applicable.
ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction
Not applicable.

d) in relation to the habitat of a threatened species, populations or ecological community:
i) the extent to which habitat is likely to be removed or modified as a result of the action proposed, and
The Darling River Hardyhead has been found in the headwaters of the Hunter System in NSW (DPI, 2014). However, despite extensive sampling, no individuals have been detected from the Hunter River catchment since 2003 (DPI, 2014). No Darling River Hardyhead have been caught using electrofishing, fyke nets or bait traps in the sites sampled in the Hunter River, or electrofishing in Muscle Creek, Sandy Creek or Dart Brook. No known habitat for this species will be removed or modified as a result of the Project.
ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and
No known habitat for this species will be become fragmented or isolated as a result of the Project.
iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species or ecological community in the locality.
Drainage lines within the Study Area are not mapped as Key Fish Habitat under the DPI Key Fish Habitat Mapping for the Muswellbrook LGA (DPI, 2017a). The Darling River Hardyhead has not been recorded within the Study Area. The Darling River Hardyhead has been found in the headwaters of the Hunter System in NSW (DPI, 2014). The Study Area is not important habitat for this species.
e) whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly.
The Project will not impact on critical habitat.
f) whether the action proposed is consistent with the objective or actions of a recovery plan or threat abatement plan.
Based on the implementation of management strategies (e.g. erosion and sediment controls and land contamination controls) and monitoring recommended in the geochemistry assessment (RGS Environmental Pty Ltd, 2020), the risks of elevated dissolved solids and other contaminants impacting downstream waters is considered to be very low (HEC, 2020). If no measurable impacts on surface water quality are likely to occur, no adverse impacts are likely to occur. The Project will include management measures to manage sedimentation and erosion and minimise potential water quality impacts to downstream environments, including the downstream reaches of Rosebrook Creek and the Hunter River. None of the other priority actions listed in the *Priorities Action Statement – Actions for Darling River Hardyhead population in the Hunter River catchment* (DPI, 2020d) apply to the Project.

g) whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of a key threatening process.
The key threatening processes for the Darling River Hardyhead are degradation of native riparian habitat, installation of structures that alter natural flow regimes, introduction of non-indigenous fish and removal of woody debris. The Project is unlikely to result in an increase in the impact of these key threatening processes.
Conclusion
The proposed action is considered unlikely to significantly impact the Darling River Hardyhead.