BOWDENS SILVER

Part 10
Aquatic Ecology Assessment

State Significant Development No. 5765

Prepared by:

Cardno (NSW/ACT) Pty Ltd

May 2020

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Aquatic Ecology Assessment

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COMMONLY USED ACRONYMS

AEP	Annual Exceedance Probability
ANCOLD	Australian National Committee on Large Dams
AoS	Assessment of Significance
AUSRIVAS	Australian River Assessment System
BAM	Biodiversity Assessment Method
BC Act	Biodiversity Conservation Act 2016
BCD	Biodiversity Conservation Division of the Department of Planning, Industry and Environment
CMA	The former Catchment Management Authorities
DECC	Department of Environment and Climate Change
DEWHA	The former Department of the Environment, Water, Heritage and the Arts
DGRs	Director-General's Requirements
DO	Dissolved Oxygen
DoAWE	Commonwealth Department of Agriculture, Water and Environment
DoEE	Commonwealth Department of the Environment & Energy
DoI	Department of Industry
DPI	NSW Department of Primary Industries
DPIE	Department of Planning, Industry and Environment
DSC	NSW Dam Safety Committee
DTVs	Default Trigger Values
EC	Electrical Conductivity
EEC	Endangered Ecological Community
EIS	Environmental Impact Statement
EP&A Act	Environmental Planning and Assessment Act 1979
EPA	Environment Protection Agency
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EPL	Environmental Protection Licence
ESC	erosion and sediment control

FM Act	Fisheries Management Act 1994
GDEs	Groundwater Dependent Ecosystems
KFH	Key Fish Habitat
KTPs	Key Threatening Processes
LGA	Local Government Area
LLS	Local Lands Service
MDBA	Murray-Darling Basin Authority
ML	Megalitres
MNES	Matters of National Environmental Significance
NAF	non-acid forming
NOW	NSW Office of Water (now DoI-Water)
NPW Act	National Parks and Wildlife Act 1974
OEH	NSW Office of Environment and Heritage
ORP	oxidation-reduction potential
PAF	potentially-acid forming
RCE	River, Channel and Environmental Inventory
RO	Reverse osmosis
ROM	Run of Mine
RWC	R. W. Corkery & Co. Pty Limited
SEARs	Secretary's Environmental Assessment Requirements
SIGNAL	Stream Invertebrate Grade Number Average Level
SSD	State Significant Development
SSI	State Significant Infrastructure
TEC	Threatened Ecological Community
TSC Act	The former Threatened Species Conservation Act 1995
TSF	Tailings Storage Facility
WM Act	Water Management Act 2000
WRE	Waste rock emplacement

EXECUTIVE SUMMARY

Introduction

Bowdens Silver Pty Limited (Bowdens Silver), a subsidiary of Silver Mines Limited, intends to submit an Environmental Impact Statement (EIS) and a development application seeking approval to develop and operate an open cut silver mine near Lue, NSW (the Project). Cardno (NSW/ACT) Pty Limited (Cardno) was engaged by R. W. Corkery and Co. Pty. Ltd. on behalf of Bowdens Silver to undertake an aquatic ecology assessment that will form part of the EIS for the Project.

Desktop studies included a review of relevant legislation pertaining to aquatic ecology and a search of records of State and Commonwealth listed threatened aquatic ecology. Five field surveys were undertaken between December 2011 and December 2018. These studies incorporated a habitat description, identification of aquatic macrophytes and riparian vegetation, limited in situ water quality measurements, macroinvertebrate assessments using the AUSRIVAS protocol and / or sampling of fish. Stygofauna were also sampled on four occasions: April, June and December of 2013, and March 2017. These studies focussed on the catchment of Lawsons Creek from just upstream of its confluence with Hawkins Creek downstream to Lue, and the catchment of Hawkins Creek from its confluence with Lawsons Creek to approximately 5 km upstream (the Study Area) These watercourses and several springs were inspected and assessed for aquatic ecology over the course of the investigations, as was the section of Lawsons Creek at the proposed crossing that would be constructed as part of the proposed relocated Maloneys Road.

Existing Environment

- Hawkins and Lawsons Creeks, tributaries of the Cudgegong River, are characterised by a degraded riparian strip containing introduced blackberry and willow. Surrounding land use is primarily agriculture / forest. The absence of significant riparian vegetation probably explains the observed reductions in bank stability and associated erosion and sediment input.
- Threatened species searches indicated that several aquatic species or populations (Murray cod, silver perch, southern purple spotted gudgeon, trout cod, Murray crayfish and the Murray-Darling Basin population of eel tailed catfish), or their habitat, may be present in the wider Cudgegong River catchment area. However, Hawkins and Lawsons Creek likely provide sub-optimal habitat, at best, for these species and they are considered unlikely to occur in these creeks adjacent to the Mine Site. Furthermore, none of these threatened fish and/or Murray crayfish were caught during any of the surveys. Nevertheless, as a precautionary measure, Assessments of Significance / assessment under Significant Impact Criteria were undertaken for those with relatively recent records from close to the Study Area (southern purple spotted gudgeon, Murray cod and eel tailed catfish).
- Both Hawkins and Lawsons Creeks support several native and invasive fish species. The majority of these are common and widespread species and none are listed as threatened. However, river blackfish appears to have experienced a reduction in abundance across its range due to anthropogenic disturbance to its habitat. Both creeks supported several species of native and introduced aquatic macrophytes and, while the macroinvertebrate assemblage includes some pollution-tolerant taxa it was still biologically diverse;

- The limited *in situ* surface water quality data collected by Cardno suggests Hawkins and Lawsons Creeks currently experience impacts to water quality, likely a result of surrounding land use practices. Electrical conductivity often exceeded relevant guidelines and dissolved oxygen concentrations were also below guidelines at some sites. Turbidity was also above guidelines on occasion, possibly likely due to recent high rainfall and flows as well as sediment input due to stock access and associated bankside erosion.
- Associated drainage lines located under or close to the footprints of the various project facilities provided very limited aquatic ecology. In particular, Walkers Creek was almost entirely dry in March 2017 and Blackmans Gully was dry on each occasion it was visited (December 2011, April 2013 and March 2017). Several springs to the west of the proposed open cut area appear to support artificial impoundments which in turn support some limited aquatic ecology.
- Hawkins and Lawsons Creeks, including the section of Lawsons Creek where a new crossing is proposed, are classified as Key Fish Habitat by NSW DPI (Fisheries) and contain Type 1 – Highly Sensitive Key Fish habitats (native aquatic plants and large wood debris). For the purpose of determining the suitability of waterway crossings, these creeks are classified as Class 2 – Moderate Fish Habitat due primarily to their intermittent flow. Bridges, arch structures, box culverts and fords (in this order of preference) are considered suitable crossing structures for this class.
- Stygofauna sampling undertaken within and around the Mine Site indicated that stygofauna occur in the shallow alluvial aquifers associated with Hawkins and Lawsons Creeks. While stygofauna were identified in two bores that access deeper aquifers (around 50 m deep) adjacent to the open cut area, only one individual was caught in each. These taxa were the same as those caught in far greater abundance from the alluvial aquifers associated with Hawkins and Lawsons Creek. Overall, the stygofauna assemblage appears to consist of relatively common and widespread taxa.

Impact Assessment

There would be no direct impacts to Hawkins and Lawsons Creeks and these creeks would not be displaced or re-aligned during construction, operation or decommissioning. Several un-named and ephemeral drainage lines would be displaced and realigned. These watercourses have limited aquatic habitat and their loss/disturbance is expected to result in very minor to negligible associated impacts to aquatic ecology in the context of the local and regional area within which comparable habitat is highly abundant. Further, these would be replaced by newly created watercourses resulting in no net-loss of watercourse habitat. The loss of stygofauna and their habitat within the footprint of the open cut pit and would result in a relatively minor impact to stygofauna given the apparent unsuitability of the associated aquifer for stygofauna, compared with the present within Hawkins and Lawson's creek alluvium. Predicted groundwater drawdown in alluvial aquifers associated with Hawkins and Lawsons creeks would be expected to result in a reduction in the availability of stygofauna habitat here. Given the predicted drawdown is smaller than the thickness of the alluvial aquifers there should not, however, be a complete loss of stygofauna and their habitat associated with Hawkins and Lawsons creek alluvium. There would be a minor (a few %) reduction in surface flow in Hawkins and Lawsons creeks as a result of interception surface flow on-site and groundwater drawdown as a result of excavation of the open cut pit. Associated impacts to aquatic habitat and biota in these creeks would therefore be expected to be minor. Although reductions in surface flow would become more apparent in drought conditions, these creeks are intermittent and consist naturally of a series of disconnected pools. Thus, any additional and temporary reduction in connectivity would not be expected to have significant impacts on aquatic habitat and biota present and that would be expected to be tolerant of intermittent flow conditions. Only water that has met environmental protection licence (EPL) conditional requirements relating to water quality would be released to watercourses.

The greatest potential impact to aquatic habitat and biota presented by the Project is associated with accidental release of poor quality water (potentially with elevated suspended sediments following mobilisation of sediments from disturbed areas during rainfall, containing toxicants in chemicals and hydrocarbons used on site or with low pH due to interaction with waste rock or following processing of mined material). This can be effectively managed by the successful implementation of the inherent components of mine design and ongoing monitoring aimed at preventing the release of such water to watercourses. In particular, controls aimed at preventing release of sediment-laden water during construction and operation of the Project would be incorporated as part of the Erosion and Sediment Control Plan. These controls would also ensure that no impacts to Key Fish Habitat and any threatened species of fish that may occur in Hawkins and Lawsons Creeks would occur. As such, a referral under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is not required.

The current poor condition of riparian vegetation is the result of historic land use practices Substantial potential impacts to aquatic ecology associated with the Project have not been identified, and there would be no further degradation of riparian vegetation along creeks due to the Project. Assuming third order and higher sections of realigned watercourses provide a similar amount and quality of watercourse habitat, associated environmental offsets are unlikely to be required.

Recommendations

Although no more than minor impacts to aquatic habitat and biota are expected, as a precautionary approach, it is recommended the monitoring of aquatic ecology in surface waters should be undertaken well before, then during and if necessary, after the operation of the Project. A monitoring program should be developed for sections of Hawkins and Lawsons Creeks that may be impacted and suitable reference sections upstream of these areas or in other comparable creeks within the vicinity of the Mine Site that would not be affected. The major components include geomorphology and flow, water quality and quantitative and semi-quantitative sampling of aquatic biota. Given that groundwater drawdown is predicted to occur in the vicinity of Hawkins and Lawsons Creeks that could affect stygofauna present in associated alluvial aquifers, the monitoring program should also include stygofauna present in these aquifers. Suitable bores outside of the potential drawdown area should also be identified and sampled to provide reference data. Further details of the monitoring would be described in an Aquatic Ecology Management and Monitoring Plan or as a section within the Biodiversity Monitoring Plan for the Project. Where relevant, the monitoring would include the sites established as part of the existing environment studies.

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1. INTRODUCTION

1.1 BACKGROUND

Bowdens Silver Pty Ltd (Bowdens Silver), a subsidiary of Silver Mines Limited, intends to submit an Environmental Impact Statement (EIS) and associated documents to obtain development consent and secure approval under the *Environmental Planning and Assessment Act 1979* (the EP&A Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) to develop and operate an open cut silver mine near Lue, NSW (the Project). The Mine Site is located approximately 2 km northeast of Lue and approximately 26 km east of Mudgee and is expected to operate over a minimum mine life of 17 years. The Project would involve a conventional open cut mine including a waste rock emplacement, tailings storage facility, ore stockpiles, processing plant, water storage dam and other ancillary infrastructure including the relocated Maloneys Road (Bowdens Silver 2016). The Project is located in the Mid-Western Regional Local Government Area (LGA) of the Central Tablelands Local Lands Service (LLS) area. The Central Tablelands LLS covers a total area of 31,365 km^2 and is home to over 156,000 residents and includes the towns of Bathurst, Mudgee and Lithgow (NSW Government 2014). Industries include agriculture, agribusiness, tourism, mining and viticulture.

Aquatic ecology within, and adjacent to, the Mine Site is provided primarily by Hawkins and Lawsons Creeks that flow east to west along the eastern and southern boundaries of the Mine Site (**Figure 1.1**). Hawkins Creek is approximately 20 km long from its source just west of Nullo Mountain State Forest, west of the Great Dividing Range, to where it joins Lawsons Creek 3 km east of Lue. Lawsons Creek is approximately 50 km long from its source near Nullo Mountain State Forest to where it joins the Cudgegong River 25 km West of Lue, ultimately flowing into Burrendong Dam and the Macquarie River near Wellington. Several named and unnamed watercourses flow into Hawkins and Lawsons Creeks from agricultural and forested areas to northeast and southeast of Lue. The Macquarie River Catchment includes the Macquarie Marshes, an internationally recognised RAMSAR wetland. The Macquarie Marshes are located 250 km downstream to the northwest of Mine Site, and are not an issue of concern for this assessment.

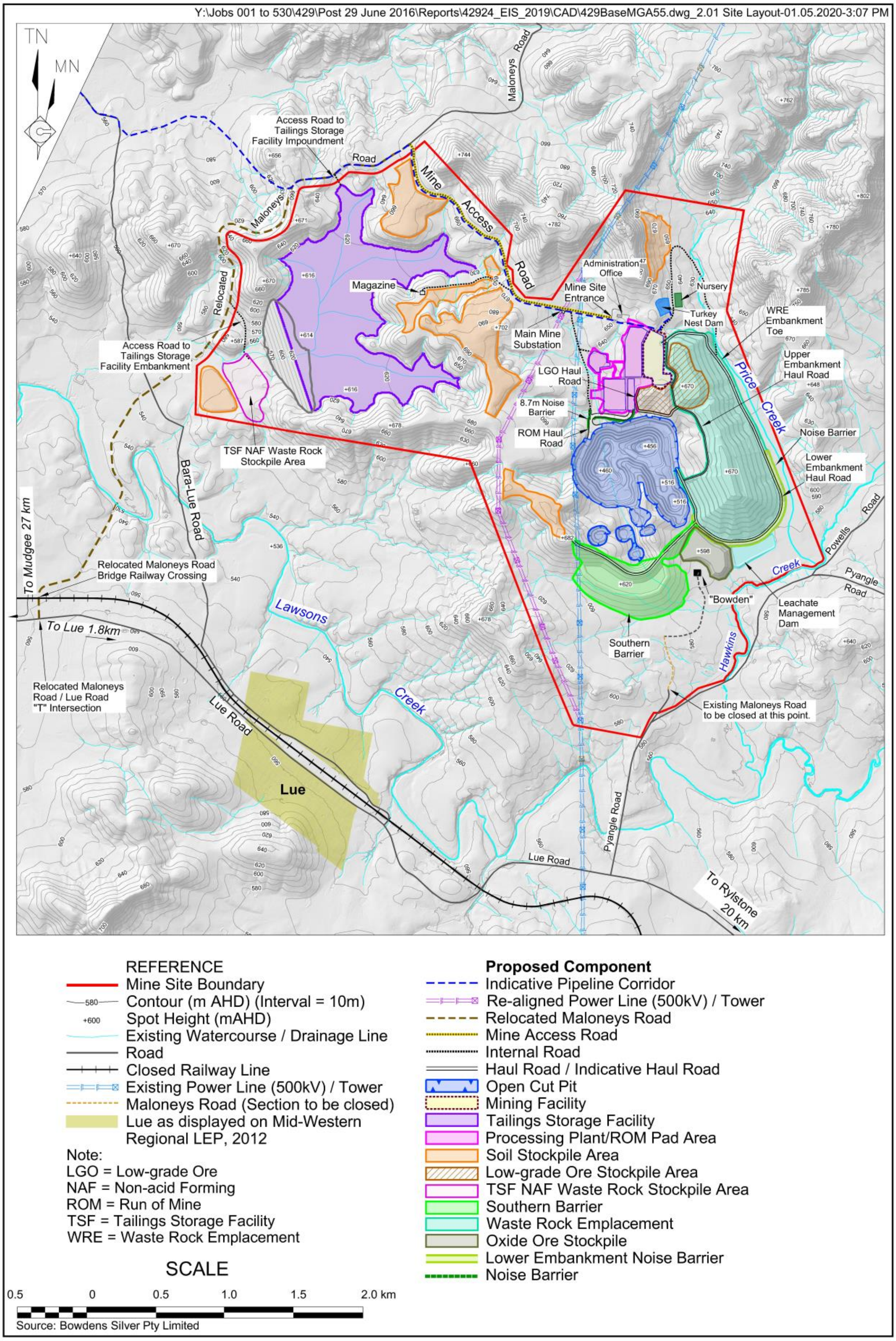
Cardno NSW/ACT Pty Ltd (Cardno) was engaged by R. W. Corkery & Co. Pty Limited (RWC), on behalf of Bowdens Silver, to undertake the Aquatic Ecology Assessment to support to the EIS for the Project.

1.2 PROJECT OVERVIEW

1.2.1 Introduction

The Project would incorporate conventional open cut pits (one main and two smaller, satellite pits), from which overburden/waste rock is removed from above and around the silver-zinc-lead ore and either used for on-site construction activities or placed in the out-of-pit WRE or the southern barrier. The mined ore would be transported by haul trucks to the on-site processing plant where it would be crushed, milled and processed to liberate the silver, zinc and lead minerals. These minerals would be collected by conventional froth flotation to produce two concentrates that would be dewatered and transported off site by truck. The residual materials from processing (tailings) would be pumped in the form of a slurry to a TSF located to the west of the main open cut pit.

Figure 1.1 Proposed Mine Site Layout



For the purpose of this document, the Study Area includes the Mine Site and the following principal components:

i) Main open cut pit and two satellite open cut pits (the open cut pit) collectively covering up to approximately 52ha;

ii) Processing plant and related infrastructure covering approximately 22ha;

iii) Waste rock emplacement (WRE) covering approximately 77ha;

iv) Low grade ore stockpile covering approximately 14ha (9ha above WRE)[1];

v) Oxide Ore Stockpile covering approximately 8ha;

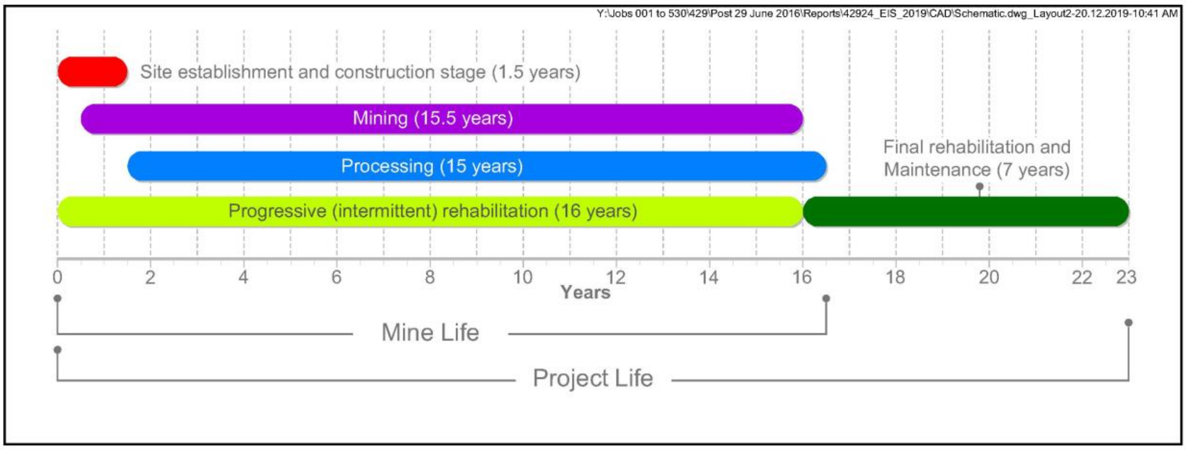
vi) Tailings storage facility (TSF) covering approximately 117ha; and

vii) Southern barrier to provide visual and acoustic protection to properties south of the Mine Site covering approximately 32ha.

The above components would be supported by a range of on-site and off-site infrastructure. The on-site infrastructure comprises haul roads, water management structures, power/water reticulation, workshops, stores, compounds and offices/amenities. The off-site infrastructure comprises a relocated section of Maloneys Road (including a new railway crossing and new crossing of Lawsons Creek) and a water supply pipeline for the delivery of water from the Ulan Coal Mine and/or Moolarben Coal Mine.

The Project would require a site establishment and construction period of approximately 18 months during which the processing plant and all related infrastructure and the initial embankment of the TSF would be constructed. Once operational, Bowdens Silver anticipates the mine would produce concentrates for approximately 15 years. In total, it is proposed the mine life would be approximately 16.5 years, i.e. from the commencement of the site establishment and construction stage to the completion of concentrate production. It is envisaged rehabilitation activities would be completed over a period of approximately 7 years, i.e. from Year 16 to Year 23. **Figure 1.2** displays the duration of each of the main components throughout the mine life and Project life.

Figure 1.2 Mine Life and Project Life



1 The low grade ore stockpile would be constructed adjacent to but largely upon the northern sections of the WRE

1.2.2 Construction Activities

The site establishment and construction activities for the Mine Site would be sequenced to achieve the commencement date of concentrate production approximately 18 months after the commencement of construction. Residences and related farm buildings within the proposed disturbed areas within the Mine Site would either be relocated for use as offices or demolished, with the useful building materials recycled.

A program of initial earthworks would be undertaken firstly to establish the surface water management system and associated erosion and sediment controls, and secondly, to develop the required operational areas. All substantial earthworks would commence in each operational area only following the installation and sign-off that all required erosion and sediment controls are in place. Vegetation clearing would be undertaken by contractors only in areas for approved mine components. Subsoil and topsoil removed during the site establishment and construction stage would either be re-used as part of the initial stabilisation / rehabilitation activities or stockpiled in the nominated soil stockpile locations.

A construction office comprising transportable buildings would be established in the vicinity of the proposed administration offices and all necessary communications and other services installed. The contractor would also install temporary workshop and materials management facilities and construct internal roads required for site establishment and construction activities generally within the areas or alignments of the long term mine components.

The following would also occur with regard to flows in tributaries (see Section 3.2.4 for the location of these watercourses):

- Surface water flows (clean water) in the upper Blackmans Gully catchment, above the mine access road, would be directed to Price Creek;
- Surface water flows in Blackmans Gully would be directed around the open cut pit area and allowed to pass through the base of the Southern Barrier to a sediment basin for treatment and release once suitable quality is achieved;
- Price Creek (catchment area 5.2 km2), with the exception of the WRE section of the contributing catchment (approx. 65 ha) would be undisturbed and allowed to continue discharging into Hawkins Creek; and
- Walkers Creek (catchment 4.9 km^2), with the exception of the TSF section of the contributing catchment (approx. 313 ha) would be undisturbed and allowed to continue discharging into Lawsons Creek.

Construction activities also include the following components:

- **Open cut pit**: Vegetation clearing and soil stripping would be undertaken on a campaign basis to provide for the development of each stage of the mining operations. Topsoil and subsoil stripping would follow each vegetation removal campaign.
- **Processing Plant**: The construction of the processing plant and mining facility would involve vegetation clearing (seed, fence post and firewood recovery), topsoil and subsoil removal and storage and the excavation/placement (i.e. cut and fill). It would also include Construction of a 8ML raw water pond to store water received from the water supply pipeline from the Ulan Coal Mine and/or Moolarben Coal

Mine and the decant return from the TSF. A 1ML capacity pit dewatering pond of similar construction to the raw water pond would be constructed for storage of water pumped from the open cut pits. This would receive water pumped from sumps located in the floor of the open cut pits that would collect groundwater seepage and rainfall from the pit floor.

- **Tailings Storage Facility**: The TSF would be designed and constructed in accordance with the Australian National Committee on Large Dams Inc. (ANCOLD) 2012 Guidelines on Tailings Dams under the supervision of NSW Dam Safety Committee (DSC). Construction activities would include the removal of ground cover vegetation from the entire footprint of the embankment and impoundment, construction of the decant system to enable the return of decant water from the TSF to the processing plant, and construction of the embankment and an emergency spillway including suitable armouring. The spillway would accommodate the peak design discharge during the 0.00001% rainfall annual exceedance probability (AEP) equivalent to a 1 in 100 000 year rainfall event determined using the Australian Rainfall and Runoff (AR&R 2016) methodology for peak discharge estimation in NSW. Additionally, an earthen dam would be located downstream of the TSF embankment initially to operate as a sediment dam to manage suspended solids during the initial and subsequent construction. Ultimately, this dam would be utilised for agricultural activities and would be incorporated into the surface water management program and monitoring program for the TSF (Section 1.2.3.4) to ensure that water sourced from this dam does not pose a threat to livestock, crops or other water users.
- **Waste Rock Emplacement**: The construction of the WRE would be staged with each stage involving vegetation clearing, topsoil and subsoil removal and storage and the creation of the required area within each cell for placement of waste rock. A setback from Hawkins and Price Creeks has been included in the design of the WRE so that the toe of the WRE remains above the modelled water surface level of the 1% Annual Exceedance Probability (AEP) flood event.
- **Off-Site road network**: The southern section of Maloneys Road that traverses the proposed main open cut pit would be relocated to the west of its current alignment. The required erosion and sediment controls would be installed prior to any activities in the relevant section of the road and signed off prior to the commencement of construction. The relocated Maloneys Road would include a new crossing over Lawsons Creek via a new floodway that would be constructed approximately 1.2 km downstream of the current Bara-Lue Road crossing of Lawsons Creek. In order to maintain habitat connectivity for aquatic fauna, the floodway would be constructed in conjunction with a series of reinforced concrete box culverts, whereby the culverts would be designed to pass a lesser flood and sustain flows whilst the floodway would provide access during those lesser flood events.
- **Water Supply**: During the site establishment and construction stage, Bowdens Silver would draw water from groundwater bores and existing or new dams within the Mine Site. A number of water storage dams/water quality control ponds/interception dams have been included to provide sufficient storage capacity for all potentially contaminated runoff generated within the Mine Site which in turn would be used on site.

  A water supply pipeline would be constructed to supply make-up water from the Ulan Coal Mine and/or Moolarben Coal Mine. The pipeline would be constructed below perennial watercourses using underbore methods with the drill rig positioned at an appropriate set back from the watercourse. Other watercourses where significant water flows are present at the time of construction would also be underbored. Trenching could be used to cross ephemeral watercourses and mapped perennial watercourses where water is not present. The pipe would be buried completely before the watercourse bed and without any changes to watercourse profiles. In the event temporary watercourse diversions or coffer dams are required to manage minor flows, NSW DPI (Fisheries) would be consulted on appropriate methodology and no permanent barriers to fish passage would occur. The appropriate set back would be determined in consultation with the relevant authority in each case. All crossings beneath watercourses would be constructed in accordance with the DPI-Water guideline: *Controlled activities on waterfront land and Guidelines for laying pipes and cables in watercourses on waterfront land* (DPI-Water, 2012).

- **Soil Stockpiles**: topsoil and subsoil removed during construction activities would be placed in various stockpiles on the Mine Site.

1.2.3 Operation

1.2.3.1 Mining Operations

Waste rock and ore would be extracted from the open cut pits using principally drill and blast methods. The fragmented rock would then be loaded into haul trucks using a hydraulic excavator and transported to the Run of Mine (ROM) pad, WRE, or any infrastructure component being constructed using NAF waste rock.

1.2.3.2 Waste Rock Management

During mining operations, potentially-acid forming (PAF) waste rock containing insufficient quantities of silver, zinc and/or lead to justify processing would be placed within the WRE. The WRE would provide for the long term storage and encapsulation of compacted PAF waste rock in a designed landform that would be developed via a sequence of seven cells. The WRE would effectively form an integrated landform between the ridge immediately east of the main open cut pit and Price Creek. A leachate drainage system would be installed to collect the low pH liquor generated by the ingress of incident rainfall that would percolate into the PAF waste rock emplaced in the WRE. WRE leachate would be captured in a dedicated Leachate Management Dam (65 ML) designed to contain the 100yr 24 hr rainfall event for the entire WRE catchment however, this design volume is conservative, i.e. considerably larger than conventionally required, as only leachate from active cells would be directed to this storage. Captured leachate would be returned to the process circuit for use. The leachate management dam would remain upon closure until cessation of leachate generation.

Low grade ore and oxide ore materials generated by the mining operations would be stockpiled within two dedicated stockpile areas throughout the mine life. Quantities of unprocessed oxide ore and low grade ore materials may remain in part, or in full at the end of the Project life. Any low grade ore stockpiled within the low grade stockpile area that is not processed at the end of the Project life would be capped and covered as part of the WRE closure and rehabilitation activities and shaped to produce the final WRE landform.

1.2.3.3 Processing Operations

Bowdens Silver proposes to process all ore extracted from the open cut pits within an on-site processing plant to produce two mineral concentrates (a silver/lead concentrate and a zinc concentrate (with a small content of silver)). The processing plant has been designed to process approximately 2 million tonnes per annum of ROM ore to produce the concentrates using sequential flotation. The processing includes ROM stockpiling and primary crushing, milling and pebble crushing, flotation circuits (requiring the use of several reagents including flocculants to assist fine particle settling) and concentrate thickening, filtration and handling / packaging for shipment off-site.

Tailings from the flotation circuits would be pumped to the tailings thickener where flocculent would be added. The thickened tailings would be pumped to the TSF for storage and further water (decant) recovery.

All reagents would be transported to the Mine Site by road, unloaded, stored in the reagent shed and used on site in accordance with manufacturers' specifications, relevant Australian Standards and regulations.

1.2.3.4 Tailings Management

Design and Methods

As part of the processing operation, a thickened tailings slurry (from which the majority of the silver, zinc and lead minerals have been removed) would be pumped to the TSF situated in the western section of the Mine Site, in the valley of Walkers Creek. The tailings would be deposited as either a non-plastic, silty sand or a low plasticity sandy clay.

The results of the test work program for the TSF indicate that the tailings are classified as PAF due to the presence of trace/accessory sulphide minerals (e.g. pyrite) and an absence of reactive carbonate minerals (e.g. calcite). Work undertaken for the Project's Feasibility Study established that concentrations of free cyanide and weak acid dissociable cyanide in the tailings would be less than 3mg/L and 7mg/L respectively, levels substantially lower than the EPA's limit for NSW mines of 30mg/L for weak acid dissociable cyanide.

Key operation design objectives of the TSF are to:

- Minimise water losses through seepage;
- Provide tailings, decant and rainfall storage capacity with sufficient freeboard to prevent overtopping of the TSF embankment;
- Provide a robust and serviceable structure, in particular the embankment, under operational and earthquake loadings;
- Provide capacity for the controlled discharge via a spillway in rare and extreme rainfall events whilst maintaining the structural integrity of the TSF embankment;
- Manage the available storage volume effectively to maximise the return of decant water to the processing plant for recycling and reuse; and
- Maximise the utilisation of construction materials drawn from the open cut pit.

Water management within the TSF would include installation of a compacted clay liner and bitumen liner on the embankment inner wall and a seepage collection system. Rainfall runoff from the external embankment slopes would be collected by drainage infrastructure and directed to a sediment basin to prevent discharge of sediment-laden water into Walkers Creek. The TSF would be operated with a minimum storm storage allowance volume based on 100 yr 72 hr design rainfall event plus freeboard and ability to reinstate the minimum storm storage allowance within 7 days. Captured runoff and decant would be returned to the process circuit for use. To manage the risk from pipeline failure, the tailings pipeline would be positioned in a manner that utilises local topography where possible, to direct any spill flowing from the tailings pipeline towards the TSF via gravity. In those areas where local topography or other factors prevent the pipeline being positioned in the above manner, the tailings pipeline would be located in a bunded corridor that would collect and contain any spill. Within this corridor, spill would be contained within scour sumps that would have sufficient capacity to contain any spill for a period of time that is equal to the time taken to respond to a pressure drop (recorded at the control room). The pipeline would be shut down until such time as the cause can be investigated and, if required, any repairs made.

Following the completion of tailings deposition at the end of the Project life, the TSF would be rehabilitated with waste rock, subsoil and topsoil placed to establish a vegetated store and release cover to minimise rainfall runoff infiltrating into the deposited tailings profile. Minimising infiltration reduces the risk of mobilising potential contaminants and their subsequent transport in seepage from the TSF.

The TSF would be operated in accordance with the ANCOLD 2012 Guidelines on Tailings Dams under the supervision of the DSC for the provision of secure and safe tailings storage and to meet the design objectives outlined above.

It is noted that the emergency spillway is to cater for extreme weather events only and is not expected to discharge during the Project life of the TSF.

Monitoring

Bowdens Silver would adopt the following inspection and auditing requirements for the TSF.

- Daily inspections of the tailings delivery and discharge pipelines, water return pipeline, discharge points, decant system and decant pond;
- Weekly inspections of the external embankment and associated structures, the tailings beach, decant pond level and all monitoring installations;
- Monthly survey of monuments installed on the crest of all embankments (Stages 1, 2 and 3) to monitor the settlement of the fill materials used in construction of the embankment;
- Operational, safety and environmental aspects would be periodically reviewed during an inspection by a suitably qualified and experienced engineer. This inspection would be undertaken at the frequency specified by ANCOLD (2012) and the DSC for a High C Consequence Category Dam; and
- TSF monitoring instrumentation would be calibrated in accordance with requirements.

A series of vibrating wire and standpipe piezometers would be installed to monitor the performance of the TSF and its embankment. The standpipe piezometers would be used to provide information on the depth and quality of the groundwater downstream of the embankment whilst the vibrating wire piezometers would provide similar information (with the exception of groundwater quality) from locations both beneath and upstream of the embankment. This information would be used to verify the design parameters and timely implementation of remedial measures should unexpected conditions arise.

Surface water monitoring locations have been established along Lawsons Creek, as part of Bowdens Silver's environmental monitoring network upstream of the proposed TSF. Data would continue to be collected from this location and another, yet to be determined location downstream, to identify any trends in water quality and inform management decisions.

1.2.3.5 Supporting Infrastructure

Water Supply

Water for the mining operation would be obtained from the following sources listed preferentially in order of use:

- Groundwater and surface water accumulating within the open cut pit;
- Surface water collected by the on-site environmental or sediment dams;
- TSF return water; and
- Mine water from Ulan Coal Mine and/or Moolarben Coal Mine.

Potable water requirements during construction would be delivered to the Mine Site by water tanker until such time as a reverse osmosis (RO) plant is installed. The RO plant would be used during operations to treat a combination groundwater, surface water and mine water to produce potable water.

During production, Bowdens Silver would supplement water sourced from the Ulan and/or Moolarben Coal Mines by:

- Maximising the use of groundwater collected in the open cut pit and sediment-laden water collected in the on-site sediment dams;
- Maximising the recovery and re-use of water in the processing operations; and
- Where appropriate and warranted, the use of chemical dust suppressants on the internal road network to reduce annual water usage.

Consumables Storage

The workshop and warehouse facilities would incorporate storage areas for all mine consumables and would have properly designed and constructed drainage systems incorporating adequate hydrocarbon management and storage facilities designed in accordance with relevant Australian Standards, including an oily water separation facility and waste oil storage areas.

Appropriate spill response measures and equipment would be maintained for hydrocarbons and any chemical storage.

Waste and Water Management

Waste oil would be stored in a 5 000L self-bunded waste oil tank from which it would be collected and removed from site for disposal/reuse by an appropriately licensed waste recycler. All other waste hydrocarbons associated with equipment maintenance would be stored in a concrete bunded area, designed in accordance with relevant Australian Standards, to await collection. An oily water separation facility would be installed, with the separated hydrocarbons sent to the recycling tank and the treated water reporting to the process water tank.

For the operational period, it is proposed to construct and operate an appropriately sized sewage management system within the footprint of the processing plant, capable of managing sewage from up to 150 persons per day. All water treated through the system would either be irrigated or used as process water (treated waste water discharged to TSF for recycle to the processing plant). Any waste water used for irrigation from the systems would be undertaken in compliance with the EPA's guidelines "*The Use of Effluent by Irrigation*" with the remaining water treated in compliance with Australian Standard AS/NZS 1547:2012 "*On-site Domestic Wastewater Management*".

The following water management strategies would be applied:

- Clean water runoff diverted around areas disturbed by mining-related activities would be discharged without treatment;
- Sediment-laden runoff from disturbed areas but outside the containment zone (e.g. the southern barrier and the TSF embankment) would be collected in sediment dams and treated in accordance with erosion and sediment control (ESC) best management practices and discharged once water quality criteria are met. In the event that the ongoing program of geochemical testing and characterisation of runoff determines that runoff must be contained on site to ensure the water source is not contaminated, sufficient storage capacity would be provided to minimise the likelihood of discharge by returning captured runoff to the containment zone; and
- Runoff in contact with processing residues (tailings) and / or potentially-acid forming material (e.g. waste rock, open cut pit) would managed within the Containment Zone not be released.

1.2.4 Decommissioning

Rehabilitation activities within the Mine Site would be planned and undertaken in accordance with a Rehabilitation Management Plan to be submitted to the Resources Regulator and approved following the issue of development consent and grant of the mining lease for the Project, and prior to the commencement of any mining-related activities within the Mine Site.

Store and release capping layers, specifically designed for the climatic conditions of the Mine Site and constructed in a manner that encourages water shedding and establishment of vegetation, would be installed to cover the TSF and WRE post mining operations. These layers would prevent rainfall and surface water from ponding and subsequently infiltrating into the encapsulated tailings within the TSF and the PAF waste rock within the WRE. Completed WRE cells would be progressively capped and rehabilitated (i.e. leachate generation progressively reduces from those cells that have been rehabilitated). The TSF would be rehabilitated and capped (store and release) with excess runoff from the rehabilitated surface being directed to the closure spillway.

The processing plant and mining facility, as well as the ROM pad, crusher pad and crushed ore stockpile area would be rehabilitated. Once rehabilitation outcomes have been met, runoff would be allowed to discharge to the receiving environment, either via Price Creek or Blackmans Gully. The Southern Barrier would be removed (material used for rehabilitation) and satellite pits and some of the shallower sections of the open cut pit (southern sections) would be backfilled and revegetated. Once satisfactory rehabilitation has been achieved, runoff from these areas would be allowed to discharge to the receiving environment.

1.3 SCOPE OF WORKS

The Study Area for the Aquatic Ecology Assessment includes the catchment of Lawsons Creek from just upstream of its confluence with Hawkins Creek downstream to Lue, and the catchment of Hawkins Creek from its confluence with Lawsons Creek to approximately 5 km upstream. The Study Area (**Figure 1.3**) includes tributaries of Hawkins and Lawsons Creeks (including Blackmans Gully and Price Creek) that traverse the Mine Area (and aquatic Groundwater Dependent Ecosystems (GDEs) located here. The scope of works for the Aquatic Ecology Assessment includes the following tasks:

1. Identification of legislative requirements, policies and guidelines that are relevant to the effects of the Project on aquatic ecology (including consideration of NSW State and Commonwealth legislation);
2. Compilation and synthesis of information on the location and extent of existing aquatic habitats and biota within, and adjacent to, the Study Area, based on desktop searches and field surveys. This includes Identification of threatened aquatic species, populations, ecological communities, GDEs and key threatening processes that could be affected by the Project;
3. Assessment of the potential impacts of the Project on aquatic habitats and their biota, particularly threatened species, populations and communities, and GDEs occurring within, and adjacent to, the Study Area; and
4. Recommendations on measures to avoid, mitigate or offset potential impacts associated with the Project on aquatic ecology within, and adjacent to, the Study Area.

The Aquatic Ecology Assessment also addresses the specific requirements of NSW DPI (Fisheries), NSW DPI (Water), and NSW Office of Environment and Heritage (OEH) and other government agencies and relevant groups.

1.4 PROJECT SEARS

Project Secretary's Environmental Assessment Requirements (SEARs) directly applicable to aquatic ecology are listed in **Table 1.1** together with the relevant section of this document where each requirement is addressed.

Figure 1.3 Aquatic Ecology Study Area

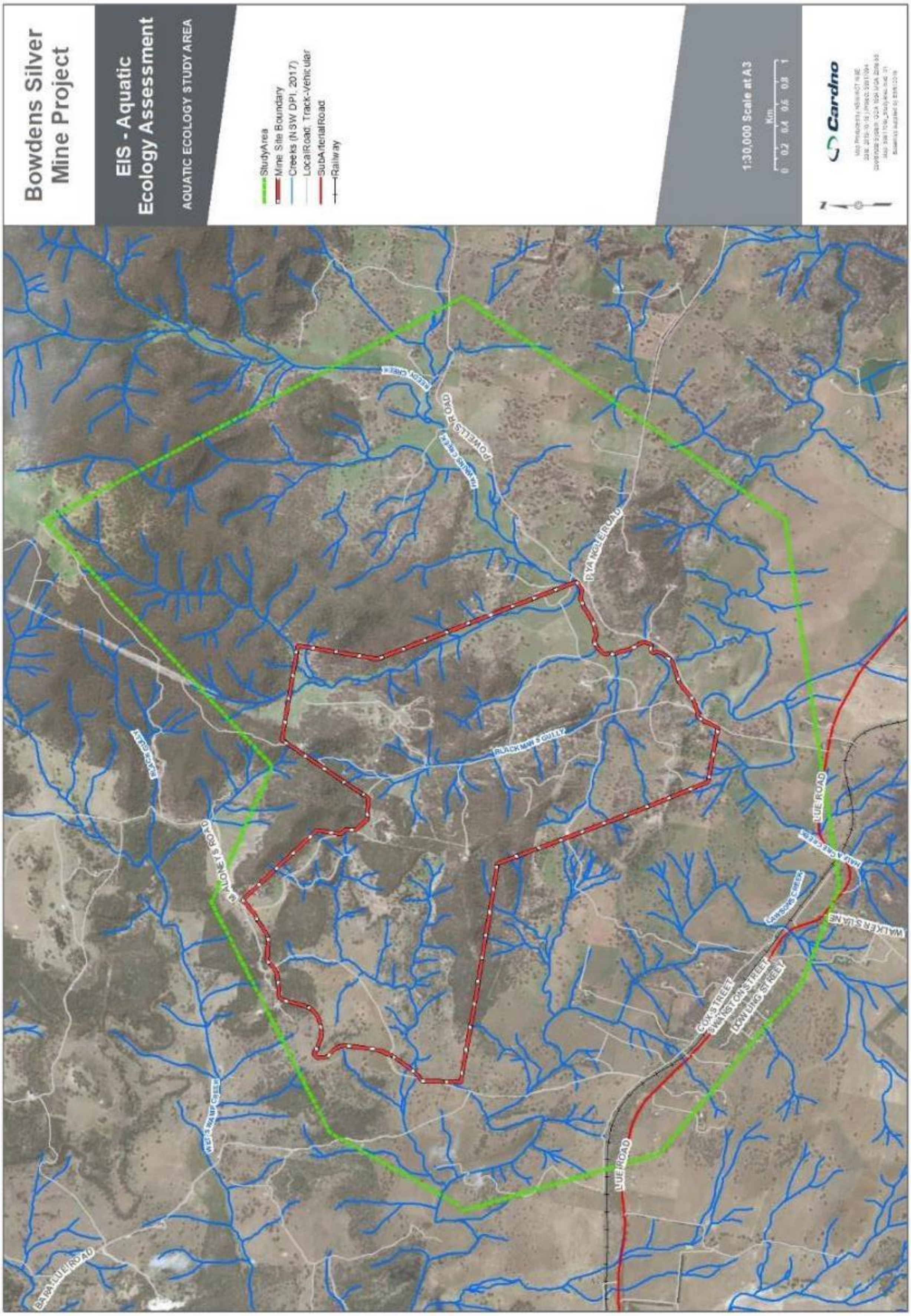


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Table 1.1
Project Secretary's Environmental Assessment Requirements Applicable to Aquatic Ecology

Page 1 of 3

Relevant Requirement(s)		**Coverage in Report**
Secretary's Environmental Assessment Requirements		
The EIS must include: • A strategy to offset any residual impacts of the development in accordance with the *NSW Biodiversity Offsets Policy for Major Projects*.		Sections 4.2.3.1 and 5
• NSW Biodiversity Offsets Policy for Major Projects (OEH)		Sections 4.2.3.1 and 5
• Threatened Species Assessment Guidelines (DoPI)		Section 2.2.1
• Policy and Guidelines for Aquatic Habitat Management and Fish Conservation (Fisheries NSW)		Section 2.3.1
• NSW State Groundwater Dependent Ecosystem Policy (NOW)		Section 2.3.3.1
• Risk Assessment Guidelines for Groundwater Dependent Ecosystems (NOW)		Section 2.3.3.2
• Why Do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (DPI)		Section 2.3.2
Relevant Requirements Nominated by Other Government Agencies		
NSW Office of Water 19/12/14	The EIS must consider the potential impacts on any Groundwater Dependent Ecosystems (GDEs) at the site and in the vicinity of the site and: Identify any potential impacts on GDEs as a result of the proposal including:	Sections 4.3.3.1 and 4.3.3.4*
	• the effect of the proposal on the recharge to groundwater systems;	See Jacobs (2020)
	• the potential to adversely affect the water quality of the underlying groundwater system and adjoining groundwater systems in hydraulic connections; and	See Jacobs (2020)
	• the effect on the function of GDEs (habitat, groundwater levels, connectivity).	Sections 4.3.3.1 and 4.3.3.4*
	Provide safeguard measures for any GDEs.	Section 4.3.3.1
Department of Primary Industries (Fisheries) 12/12/2016	The aquatic ecological environmental assessment should include the following information;	
	• A recent aerial photograph (preferably colour), map or GIS of the locality which maps the key fish habitat of the development site, and the waterway classes as defined in Tables 1 and 2 of the Policy & Guidelines document above.	Section 3.2.4, and Figure 3.5
	• Aerial extent of the key fish habitat types to be affected either directly or indirectly by the development or activity should be identified and shown on recent aerial photograph map or GIS.	Figure 3.5
	• Description and quantification of aquatic and riparian vegetation should be presented and mapped. This should include an assessment of the extent and condition of riparian vegetation and the extent and condition of freshwater aquatic vegetation and the presence of significant habitat features (e.g. gravel beds, snags, reed beds, etc.)	Figure 3.5 and Sections 3 and 4.2.3.1**

Table 1.1 (Cont'd)
Project Secretary's Environmental Assessment Requirements Applicable to Aquatic Ecology

Page 2 of 3

Relevant Requirement(s)		Coverage in Report
Relevant Requirements Nominated by Other Government Agencies (Cont'd)		
Department of Primary Industries (Fisheries) 12/12/2016 (Cont'd)	• Quantification of the extent of aquatic and riparian habitat removal or modification which will result from the proposed development, and impacts on fish passage.	Figure 3.5 and Sections 3 and 4.2.3.1**
	• Determination of aquatic biodiversity offsets required (see NSW Biodiversity Offsets Policy for Major Projects, Fact Sheet: Aquatic Biodiversity) at http://www.environment.nsw.gov.au/resources/biodiversity/14817aqoffs.pdf.	Sections 4.2.3.1 and 5
	• Targeted on-ground surveys for threatened species (see below)	Section 3.2, 3.3.2
	• Detailed maps outlining the proposed realignment of new waterways within the project area.	EIS Appendix 5 – A5.10 (Figures A5.11, A5.12, A5.13 and A5.15)
	• Detailed maps outlining compensatory habitats and significant habitat features that will be created to offset the loss of aquatic and riparian habitat.	EIS Appendix 5 – A5.10 (Figures A5.11, A5.12, A5.13 and A5.15)
	• Detailed maps that outline and assess the geomorphic stability of the proposed realignments of the new waterways including re-creation of the sinuosity/complexity of the new waterways.	EIS Appendix 5 – A5.10 (Figures A5.11, A5.12, A5.13 and A5.15)
	• Details of the location of all waterways crossings and construction designs, such as bridges or culverts, access tracks, gauging stations or water pipelines.	EIS Section 2.9.2
	• Details of the location of all waterway realignments, including a detailed rehabilitation plan for the aquatic environment and the adjacent riparian zone, and a timetable for construction of the proposal with details of various phases of construction.	EIS Appendix 5 - A5.10 (Figures A5.11, A5.12, A5.13 and A5.15)
	• Aspects of the management of the proposal, both during construction and after completion, which relate to impact minimisation e.g. Environment Management Plans, e.g. monitoring geomorphic stability of the system and mitigation strategies in place to address any bed lowering, scouring or other impacts that arise as a result of the project. Monitoring of the water quality in receiving waters such as the diverted creeks, particularly during the construction phase, and also during the operational phase.	Aspects relevant to aquatic ecology outlined in Sections 4 and 5
Mid-Western Regional Council 14/02/13	Council would like to see details on proposed native fish waterway crossings that are likely to be obstructed and altered as a result of the proposal and any critical habitats likely to be affected by the proposal.	Section 4.3.3.6

Table 1.1 (Cont'd)
Project Secretary's Environmental Assessment Requirements Applicable to Aquatic Ecology

Page 3 of 3

Relevant Requirement(s)		Coverage in Report
Relevant Requirements Nominated by Other Government Agencies (Cont'd)		
Environment Protection Authority 14/05/19	Describe how predicted impacts on surface water, groundwater and aquatic ecosystems will be monitored and assessed over time, including monitoring locations, relevant parameters and sampling frequency.	Section 5
Office of Environment and Heritage 14/05/19	The EIS must assess the impact of the development on hydrology, including … impacts to natural processes and functions within rivers, wetlands, estuaries and floodplains that affect the river system and landscape health such as nutrient flow, aquatic connectivity and access to habitat for spawning and refuge (e.g. river benches).	Section 4 (impacts on aquatic habitat and biota only)
	Effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems.	Section 4
Relevant Requirements Nominated by Lue and District Community		
Potential impacts from dust and any associated metals on drinking water supplies, livestock and aquatic environments.		Section 4.3.3.3
What are the potential impacts of silver on aquatic species?		Section 4.3.3.3
How would exposure to cyanide and other toxins impact aquatic organisms?		Section 4.3.3.3
Will a detailed assessment of the existing population of aquatic species using the AUSRIVAS approach be undertaken?		Section 3.2.7

* Only subterranean GDEs are considered in the Aquatic Ecology Assessment. Surface GDEs are considered in the Biodiversity Assessment Report (EnviroKey 2020).

** Quantification and detailed assessment of impacts to riparian vegetation undertaken in the Biodiversity Assessment Report (EnviroKey 2020).

2. LEGISLATIVE REQUIREMENTS, POLICIES AND GUIDELINES

2.1 COMMONWEALTH LEGISLATION

The EPBC Act is the Australian Government's key instrument of environmental legislation, focusing on Matters of National Environmental Significance (MNES), with States and Territories having responsibility for matters of State and local significance. The EPBC Act provides a legal framework for the protection and management of nationally and internationally important flora, fauna, ecological communities and heritage places. It also includes provisions for nationally threatened species of plants, fish, birds, frogs, reptiles, mammals and other animals. These conservation assets are referred to collectively as MNES or "protected matters". The Department of Agriculture, Water and Environment (DoAWE) is also responsible for the development and implementation of recovery plans for threatened fauna, threatened flora (other than conservation dependent species) and threatened ecological communities listed under the EPBC Act.

Under the EPBC Act, any action that will have, or is likely to have, a significant impact on a MNES must be referred to the Commonwealth Minister for a decision on whether assessment and approval is required under the EPBC Act. To assist proponents in determining whether an action is likely to have a significant impact on a MNES, DoAWE (formerly DEWHA) has developed Significant Impact Guidelines 1.1 (DEWHA 2009). Approval is required from the Commonwealth Environment Minister for any actions on Commonwealth land that are likely to have a significant impact on MNES or protected matters.

The Project has been referred to the former Department of Environment and Energy (DoEE) and it was subsequently determined the Project is a controlled action under the EPBC Act. It is noted that the basis for the determination did not relate to any aquatic species.

2.2 NSW LEGISLATION

2.2.1 Environmental Planning and Assessment Act 1979

The *Environmental Planning and Assessment Act 1979* (EP&A Act) institutes a system of environmental planning and assessment in NSW and is administered by the NSW Department of Planning and Environment. Part 4 (Division 4.1) of the EP&A Act sets out the approvals process for State Significant Development (SSD) and State Significant Infrastructure (SSI).

Division 4.1, Part 4 of the EP&A Act indicates some of the authorisations required under other Acts are not required for SSDs. These include provisions under the *Fisheries Management Act 1994* (FM Act) with respect to permits for dredging and reclamation work, harm to aquatic vegetation and blockage of fish passage. A controlled activity approval issued under section 91 of the *Water Management Act 2000* (WM Act) (which confers a right on its holder to carry out a specified controlled activity at a specified location in, on or under waterfront land), is also not required. An aquifer interference approval that confers a right on its holder to carry out one or more specified aquifer interference activities at a specified location, or in a specified area, in the course of carrying out specified activities, is required.

Section 5(A) of the EP&A Act outlines the factors that must be taken into account when deciding whether a project would be likely to have a significant impact on threatened species, populations or communities or their habitats listed under the FM Act (Section 2.2.2) and the *Biodiversity Conservation Act 2016* (BC Act) (Section 2.2.3), known as the *Assessment of Significance* (AoS), and previously known as the *eight-part test*. The AoS is slightly different for species, populations or ecological communities listed under the FM Act (i.e. a '7-part test') compared to species, populations or ecological communities listed under the BC Act (i.e. a '5-part test'). Both tests consider the following factors when determining effects on threatened species, populations or communities or their habitats, and the AoS includes two additional considerations specific to listed 'endangered populations' or 'endangered ecological communities':

- Whether the proposed action is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction;
- The extent to which the species habitat is likely to be removed or modified as a result of the action proposed, whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and whether the habitat to be removed, modified, fragmented or isolated is important to the long-term survival of the species in the locality;
- Whether the proposed action is likely to have an adverse effect on critical habitat (either directly or indirectly;
- Whether the proposed action is consistent with the objectives or actions of a recovery plan or threat abatement plan; and
- 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 *Threatened Species Assessment Guidelines* (DoPI 2008) provides a framework to ensure a consistent and systematic approach to undertaking AOS for threatened species and have been used during the preparation of this report.

2.2.2 Fisheries Management Act 1994

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

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

- Permanently flowing rivers and creeks including those where the flow is modified by upstream dam(s), up to the top of the natural bank regardless of whether the channel has been physically modified;
- Intermittently flowing rivers and creeks that retain water in a series of disconnected pools after flow ceases including those where the flow is modified by upstream dam(s), up to the top of the natural bank regardless of whether the channel has been physically modified; and
- Any waterbody if it is known to support or could be confidently expected (based on predictive modelling) to support threatened species, threatened populations or threatened communities listed under the provisions of FM Act.

The Mid Western map of Key Fish Habitat available on the NSW DPI (Fisheries) website (NSW DPI (Fisheries) (2014j) indicates that Hawkins Creek and Lawsons Creek, and many of their 3rd order tributaries, including those that traverse the Study Area, are considered to be Key Fish Habitat.

2.2.3 Biodiversity Conservation Act 2016

In November 2016, the BC Act was passed and the State is currently developing supporting regulations and other subordinate instruments. On 25 August 2018, the BC Act was gazetted replacing the *Threatened Species Conservation Act 1995* (TSC Act) and sections of the *National Parks and Wildlife Act 1974* (NPW Act). The BC Act modernises the process for listing threatened plants and animals and aligns categories of threatened species with international best practice. It also provides greater coordination among Australian jurisdictions. The BC Act establishes a new risk-based approach to managing wildlife through a tiered framework. Certain interactions with wildlife (such as harming animals) will continue to be criminalised, however some actions may be permitted explicitly through the draft BC Regulation (i.e. low risk activities), through an adopted code of practice (i.e. moderate risk activities) or through a biodiversity conservation licence (i.e. high risk activities). Government has been undertaking targeted consultation to develop wildlife codes of practice. The Biodiversity Assessment Method (BAM), an instrument of the BC Act, is currently being implemented and replaces the current process for threatened species and offsets assessments. The BAM would be required for all local development that exceeds the clearing thresholds outlined in Part 7 of the *Biodiversity Conservation Regulation 2017* (draft yet to be finalised) or is within areas of sensitive regulated land and some vulnerable regulated land (identified in the Native Vegetation Regulatory Map) and major projects. Transitional arrangements have been introduced for development consent or approvals that are underway or have been made already. These are set out in the *Biodiversity Conservation (Savings and Transitional) Regulation 2017*. It is not compulsory for projects assessed under Part 5 of the EP&A Act to adopt the BAM under the BC Act.

The provisions of the BC Act apply to most algae, aquatic plants, invertebrates and all major vertebrate groups except fish and marine vegetation under the definitions of the FM Act.

2.3 POLICIES AND GUIDELINES

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

The NSW DPI Policy and Guidelines for Fish Habitat Conservation and Management (Update 2013) (NSW DPI 2013a) replaces the Policy and Guidelines for Aquatic Habitat Management and Fish Conservation (NSW DPI 1999) and the former Fisheries NSW Policy and Guidelines for Fish Friendly Waterway Crossings (NSW DPI 2003). These updated policies and guidelines are applicable to all planning and development Projects and various activities that affect freshwater, estuarine and marine ecosystems. The aims of the updated policies and guidelines are to maintain and enhance fish habitat for the benefit of native fish species, including threatened species, in marine, estuarine and freshwater environments. The updated document assists developers, their consultants and government and non-government organisations to ensure their actions comply with the legislation, policies and guidelines that relate to fish habitat conservation and management. It is also intended to inform land use and natural resource management planning, development planning and assessment processes, and to improve awareness and understanding of the importance of fish habitats and how impacts can be mitigated, managed or offset. The policies and guidelines outlined in this document are taken into account when NSW DPI assesses Projects for developments and other activities that affect fish habitats.

The document contains:

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

NSW DPI focuses the application of the FM Act and FM Regulations and the policies and guidelines on KFH. It is important to note that aquatic habitats within first and second order gaining watercourses, sections of stream that have been concrete-lined or piped (excluding waterway crossings) and artificial ponds are not regarded as KFH unless they support a listed threatened species, population or ecological community or critical habitat. Categorisation and classification of KFH is achieved by determining fish habitat sensitivity (Type) and functionality (Class). The term ‘sensitivity’ refers to the importance of the habitat to the survival of fish and its ability to withstand disturbance while ‘functionality’ refers to the ability to provide habitat that is suitable for fish.

Fish habitat 'Type' is used within the policy and guideline to differentiate between permissible and prohibited activities or developments and for determining value in the event offsetting is required. Waterway 'Class' is used to assess the impacts of certain activities on fish habitats in conjunction with 'Type'. The waterway 'Class' can also be used to make management recommendations to minimise impacts on different fish habitats (e.g. waterway crossings). Sensitivity 'Types' and waterway 'Class' classifications are provided in (**Annexure A**) and have been used to classify waterways in the Study Area.

2.3.2 Why Do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings

NSW DPI (Fisheries) *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (Fairfull and Witheridge, 2003) provides practical guidelines for the planning, design, construction and maintenance of waterway crossings aimed at minimising impacts on fish passage and aquatic ecology in general. It should be used in conjunction with the *Policy and Guidelines for Fish Conservation and Management* (NSW DPI, 2013a) by outlining potential impacts of instream structures and design specifications/recommendations for crossings to avoid erecting barriers to fish passage.

2.3.3 Groundwater and Groundwater Dependent Ecosystems (GDEs)

2.3.3.1 NSW State Groundwater Dependent Ecosystem Policy

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

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

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

2.3.3.2 NSW DPI (Water) Risk Assessment Guidelines for GDEs

NSW DPI (Water) (formerly The NSW Office of Water) and the former OEH have developed comprehensive risk assessment guidelines to manage the effects of land and water use activities on GDEs (Serov *et al.* 2012*)*. These guidelines are available in four volumes:

- Volume 1 - Risk assessment guidelines for groundwater dependent ecosystems – the conceptual framework;
- Volume 2 – Risk assessment guidelines for groundwater dependent ecosystems. Worked examples for seven pilot coastal aquifers;
- Volume 3 – Identification of high probability groundwater dependent ecosystems on the Coastal Plains of NSW and their ecological value; and
- Volume 4 – The ecological value of groundwater sources on the Coastal Plains of NSW and the risk from groundwater extraction.

The conceptual framework provides:

- Definitions of groundwater, GDEs and high priority GDEs;
- A classification of different types of GDEs;
- A description of the relevant policy and legislative framework;
- Information on ecological valuation and risk assessment process and activities that threaten aquifers and/or their associated GDEs;
- A method for determining the ecological value of an aquifer and associated GDEs to assist in reporting against the state-wide Target for Groundwater (i.e. "*By 2015 there is an improvement in the ability of groundwater systems to support groundwater dependent ecosystems and designated beneficial uses*");
- A method for assessing the risk of an activity to the ecological value of an aquifer and associated GDEs; and
- A method for developing management strategies for aquifers and identified GDEs based on a Risk Matrix Approach.

The accompanying appendices contain background information, including:

- A method to identify the type and location of GDEs within an aquifer or defined area;
- A method for inferring the groundwater dependency of identified ecosystems; and
- A description of surface and subsurface activities that threaten aquifers and associated GDEs, including the effects of subsidence and bedrock / streambed fracturing on overlying aquifers and river systems.

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

2.3.3.3 Aquifer Interference Policy

In 2011 the NSW Office of Water (now NSW DPI (Water)) began implementing the *NSW Aquifer Interference Policy* (AIP), which places a significant emphasis on potential impacts to groundwater associated with the coal and coal seam gas industries, and any other activity that interferes with an aquifer would also be affected. The AIP was given legal effect via the *Water Management (General) Amendment (Aquifer Interference) Regulation 2011* under the *Water Management Act 2000*, which was enacted on 30 June 2011. The *Water Management Act 2000* defines an aquifer interference activity as that which involves any of the following:

- The penetration of an aquifer;
- The interference with water in an aquifer;
- The obstruction of the flow of water in an aquifer;
- The taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations; and
- The disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

Examples of aquifer interference activities include mining, coal seam gas extraction, injection of water, and commercial, industrial, agricultural and residential activities that intercept the water table or interfere with aquifers.

2.4 KEY THREATENING PROCESSES

A KTP is a process that threatens, or may have the capability to threaten, the survival or evolutionary development of species, population or ecological community. KTPs are listed under the FM Act, BC Act and EPBC Act. At present, there are currently eight listed KTPs under the FM Act, 38 listed under the BC Act and 21 listed under the EPBC Act. Broadly, the KTPs include threats to threatened species, populations and ecological communities as well as activities that may cause other species, populations or ecological communities to become threatened.

The KTPs listed under the *FM Act* that may be relevant to the effects of the Project on aquatic ecology are:

- Removal of large woody debris from NSW rivers and watercourses;
- Degradation of native riparian vegetation along New South Wales watercourses; and
- Installation of instream structures and other mechanisms that alter natural flows.

The following KTPs listed under the *BC Act* may also be relevant:

- Alteration to the natural flow regimes of rivers and watercourses and their floodplains and wetlands;
- Clearing of native vegetation; and
- Predation by *Gambusia holbrooki* (plague minnow or mosquito fish).

Two KTPs listed under the EPBC Act may be relevant to the Project with respect to aquatic ecology, these are:

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

These KTPs are concerned with the potential for invasive organisms to spread to the detriment of native ecosystems. The risk to aquatic ecosystems associated with these KTPs is considered to be low due to the nature of the Project, however, these are addressed in the impact assessment as a precautionary measure.

2.5 CRITICAL HABITAT

Critical habitats are areas of land or water that are crucial to the survival of particular threatened species, populations and ecological communities. Registers of critical habitats are maintained by Biodiversity Conservation Division (BCD) of the Department of Planning, Industry and Environment (DPIE) and DPI.

As of 1 July 2019, none of the critical aquatic habitats listed under the *BC Act* or *FM Act* are found within the Study Area.

3. EXISTING ENVIRONMENT

3.1 DESKTOP REVIEW

3.1.1 Overview

The following databases were searched for records of listed threatened aquatic species, populations and communities in a search area of at least 10 km radius from the Study Area (The Locality):

- NSW DPI Fish communities and threatened species distribution of NSW (NSW DPI, 2016a);
- BioNet the website for the Atlas of NSW Wildlife: http://www.bionet.nsw.gov.au;
- BCD Threatened Species Profile Database: http://www.environment.nsw.gov.au/threatenedspecies;
- NSW DPI Listed threatened species, populations and ecological communities website: http://www.dpi.nsw.gov.au/fishing/species-protection/conservation/what-current#key;
- Department of the Agriculture, Water and Environment (DoAWE) (formerly DoEE and DoE) Protected Matters Search Tool (PMST): http://www.environment.gov.au/epbc/protected-matters-search-tool;
- Atlas of Living Australia: http://www.ala.org.au/;
- The NSW DPI (Fisheries) Threatened and Protected Species Record Viewer (developed by the Threatened Species Unit of the former I&I NSW and now superseded by NSW DPI, 2016a).

The Protected Matters Search Tool, a database maintained by DoAWE, was used to identify threatened aquatic species and communities of national environmental significance that occur or may occur in the Mid-Western Regional LGA. A search was undertaken over the entire LGA to ensure that mobile, threatened species that may periodically move into the Study Area were taken into consideration. A search for information regarding records and distribution of threatened and protected species of fish in the Mid-Western Regional LGA and the former Central West CMA was undertaken using the *Listed Threatened Species, Populations and Ecological Communities* website (NSW DPI (Fisheries) 2016b) and *Fish Communities and Threatened Species Distribution of NSW* (NSW Dpi (Fisheries) 2016a) managed/published by NSW DPI (Fisheries).

NSW BioNet managed by the BCD, was used to search for records of flora and fauna sightings within Mid-Western Regional LGA held in the Atlas of NSW Wildlife. This Atlas contains records of plants, mammals, birds, reptiles, amphibians, some fungi, some invertebrates (such as insects and snails listed under the *BC Act*) and some fish. The Atlas was also searched for information on known and predicted distributions of vegetation communities, endangered populations and key threatening processes listed under the BC Act occurring within the Mid-Western Regional LGA. The Atlas of Living Australia, the Australian node of the Global Biodiversity Information Facility, was searched for additional records of species listed under the FM Act and the BC Act in the Mid-Western Regional LGA.

Information on the occurrence of threatened amphibians, terrestrial fauna and flora and migratory species and assessments of potential impacts on these are presented in the report prepared by other specialist consultants.

3.1.2 Fish

3.1.2.1 Previous Studies

NSW Fisheries undertook a survey of fish throughout NSW in 1996 (NSW Fisheries 1997). Eleven native and six introduced fish species were recorded from the Macquarie River Catchment, including, Murray cod and eel tailed catfish (**Table 3.1**). NSW fisheries (1997) also included information on fish species recorded by Llewellyn (1983). Ten native and seven introduced species were recorded in this survey, including Murray cod and silver perch.

Table 3.1
Species of Fish Recorded Previously in the Study Area

Scientific Name	Common Name	Llewellyn (1983)	NSW Fisheries (1997)	Goldney et al. (2007)	Regional Conservation Assessment (Goldney et al. 2007)
		Macquarie River Catchment	Macquarie River Catchment	Central West Catchment	
Ambassis agassizii	Olive perchlet		•	•	RE
Bidyanus	Silver perch	•		•	D / RV
Carassius auratus	Goldfish	•	•	•	
Craterocephalus fluviatilis	Murray hardyhead	•			
Craterocephalus stercusmuscarum	Flyspecked hardyhead			•	D / RV
Cyprinus carpio	Common carp	•	•	•	
Gadopsis marmoratus	River blackfish	•		•	RV
Galaxias olidus	Mountain galaxias	•	•	•	D / RV
Gambusia holbrooki	Eastern gambusia	•	•	•	
Hypseleotris spp.	Carp gudgeon	•	•		
Hypseleotris klunzingeri	Western carp gudgeon			•	D
Leiopotherapon unicolor	Spangled perch	•	•	•	RV
Maccullochella macquariensis	Trout cod			•	RE
Maccullochella peelii	Murray cod	•	•	•	RV
Macquaria ambigua	Golden perch	•	•	•	Se
Macquaria australasica	Macquarie perch			•	RE
Melanotaenia fluviatilis	Rainbowfish		•	•	RE
Nannoperca australis	Southern pygmy perch			•	RE
Nematalosa erebi	Bony bream	•	•	•	D / RV
Oncorhynchus mykiss	Rainbow trout	•	•	•	
Perca fluviatilis	Redfin perch	•	•	•	
Philypnodon grandiceps	Flathead gudgeon		•	•	RV
Retropinna semoni	Australian smelt	•	•	•	Se / D
Salmo trutta	Brown trout	•	•	•	
Salvelinus fontinalis	Brook trout	•		•	
Tandanus	Eel-tailed catfish	•	•	•	RE
	Grey shading indicates non-native or introduced species				
Se = Secure as a species, D = Declining, RV = Regionally Vulnerable, RE = Regional Endangered.					

A literature review by Goldney *et al.* (2007) found records for 16 native and seven introduced fish species in the Central West Catchment (**Table 3.1**). The review included records held in the NSW Fisheries database of observational results from fish surveys and release sites for their re-stocking programme made available for the study. The review also included an assessment of the regional conservation status of recorded native species based on relative abundances and expert opinion.

3.1.3 Threatened Species

3.1.3.1 Flathead Galaxias

Flathead galaxias, listed as critically endangered under the FM Act and the EPBC Act, are endemic to the southern tributaries of the Murray-Darling River system and their tributaries and the upper Macquarie River catchment (NSW DPI (Fisheries) 2014). They used to be intermittently widespread and locally abundant (Fisheries Scientific Committee 2008). However, this species has experienced declines in distribution and abundance throughout NSW and is thought to be locally extinct in the lower Murray, Murrumbidgee, Macquarie and Lachlan Rivers (NSW DPI (Fisheries) 2014). The closest records are from a lagoon near Bathurst in the Macquarie River catchment in pre-2007 (DoE 2015). Very small numbers have also been recorded in the wetlands of the Murray River floodplain between Hume Dam and Lake Mulwala and the upper Murray River near Tintaldra (NSW DPI (Fisheries) 2014). This species is generally found mid-water in still/slow moving waters of small watercourses, lakes, lagoons, billabongs and backwaters with a substratum of coarse sand or mud and aquatic vegetation. It forages for aquatic insects and crustaceans and spawns in spring when water temperatures are above 10.5 °C. The transparent, demersal eggs hatch approximately nine days later, and fry are likely to reach maturity within the first year. This species is also listed as critically endangered under the FM Act and its indicative distribution has recently been mapped in *Fish Communities and Threatened Species Distributions of NSW* (NSW DPI (Fisheries) 2016a). The indicative distribution of the flathead galaxias does not overlap with the Mid-Western Regional LGA hence, the Protected Matters Search Tool was likely to be reflective of the isolated records of this species within the Macquarie River catchment. Based on existing records and the predicted distribution, this species is considered unlikely to occur in Hawkins and Lawsons creeks.

3.1.3.2 Macquarie Perch

Macquarie perch, listed as endangered under the FM Act and the EPBC Act, are found in the Murray-Darling Basin (particularly upstream reaches) and parts of south-eastern coastal NSW, including the Hawkesbury and Shoalhaven catchments (NSW DPI 2011), where they are found in rivers and lakes, but particularly the upper reaches of rivers and their tributaries. This species prefers clear water and deep, rocky holes with extensive cover in the form of aquatic vegetation, large boulders, debris and overhanging banks (DOE 2014a). They spawn in spring or summer and lay their eggs in shallow, fast-flowing water over stones and gravel in shallow upland watercourses or flowing parts of rivers. Macquarie perch have been stocked or translocated into a number of reservoirs including Talbingo, Cataract, Khancoban and Coliban reservoirs, and translocated into watercourses including the Yarra, Mongarlowe and Wannon rivers, and Sevens Creek (MDBA 2011b). Macquarie perch were also recorded as present in the Central West CMA by Goldney et al. (2007) but no records of Macquarie perch in the Mid-Western Regional LGA or the Central West CMA occur on the NSW DPI (Fisheries) online Record Viewer. Historic records exist for this species in the Macquarie River in the 1800s, however, there are no NSW DPI (Fisheries) records for this species in the river despite suitable habitat being present in upstream reaches (Andrew Bruce, NSW DPI (Fisheries) Pers. Comm. 20/10/2014). The indicative distribution of Macquarie perch occurs within the Central West CMA along sections of Macquarie, Turon and Campbells Rivers, approximately 53 km south of the Study Area (NSW DPI (Fisheries) 2016a). The results of the Protected Matters Search Tool most likely reflect these historical records and/or the presence of suitable habitat in the Macquarie River. Based on existing records and the predicted distribution, this species is considered unlikely to occur in Hawkins and Lawsons Creeks.

3.1.3.3 Trout Cod

Trout cod, listed as endangered under the FM Act and the EPBC Act, are usually associated with deeper pools and instream cover such as logs and boulders. Trout cod were described originally from the Macquarie River, but there are now only three self-sustaining populations of Trout cod remaining in the wild (MDBA 2011c). The largest is in the Murray River between Yarrawonga and Barmah (approximately 200 km of river). The other populations are small translocated populations present in Cataract Dam, and in about 15 km of the upper reaches of Sevens Creek near Euroa in Vic. This species has been reintroduced to several rivers in the Murray-Darling Basin as part of a long term stocking program that began in the late 1980s and the NSW DPI (Fisheries) online Record Viewer includes 2006 and 2007 records of this species in the Macquarie River downstream of Lake Burrendong and Study Area near Dubbo and Wellington. Unfortunately, these reintroductions have not resulted in the establishment of viable populations (MDBA 2011a). More recently in late 2011, several thousand trout cod fingerlings were introduced to the Macquarie River upstream of Lake Burrendong (NSW DPI 2014). This upstream section of Macquarie River forms part of the species' indicative distribution (NSW DPI (Fisheries) 2016a). However, its predicted distribution does not include the Cudgegong River catchment. Based on existing records and the predicted distribution, this species is considered unlikely to occur in Hawkins and Lawsons creeks.

3.1.3.4 Australian Grayling

Australian grayling, listed as a protected species under the FM Act and vulnerable under the EPBC Act, occurred historically in coastal watercourses from the Grose River west of Sydney, southwards through NSW, Victoria and Tasmania (DOE 2014b). The Australian grayling is diadromous and has a freshwater and marine/estuarine phase to its lifecycle. The construction of dams, weirs and other barriers to fish passage has had a major impact on their populations in some river systems. Burrendong Dam would constitute such a barrier. It is currently found in watercourses and rivers, on the eastern and southern flanks of the Great Dividing Range from Sydney southwards to the Otway Ranges in Victoria (NSW DPI 2014a), reflective of its indicative distribution (NSW DPI (Fisheries) 2016a) and is absent from the inland Murray-Darling system (McDowall 1996; NSW DPI 2014; and Goldney *et al.* 2007). Hence, this species is unlikely to occur within the Central West CMA and the Mid-Western Regional LGA and its identification by the Protected Matters Search Tool is likely to be reflective of its historical distribution. Based on existing records and the predicted distribution, this species is considered unlikely to occur in Hawkins and Lawsons creeks.

3.1.3.5 Murray Cod

Murray cod, listed as vulnerable under the EPBC Act, was formerly widespread and abundant in the lower and mid-altitude reaches of the Murray-Darling Basin but now has a patchy distribution and abundance across its historic range (MDBA 2011d). Both hatchery-bred and wild-caught individuals have been translocated and stocked outside this natural distribution range. This species has been found in flowing and standing waters, including small, clear, rocky watercourses on the inland slopes and uplands of the Great Diving Range, to large, turbid, meandering slow-flowing rivers, creeks, anabranches, and lakes and larger billabongs, of the inland plains of the Murray-Darling Basin (National Murray Cod Recovery Team 2010). Murray Cod are usually found in association with large rocks, large snags and smaller structural woody habitat, undercut banks and over-hanging vegetation, but also frequent the main river channel and larger tributaries and anabranches. Commercial fisheries data indicate that natural populations declined in the 1920s and then again dramatically in the 1950s. This species is stocked in Lake Burrendong during 2010 to 2017 an in Lake Windermere during 2011 to 2016 (NSW DPI 2019) and the NSW DPI (Fisheries) Threatened and Protected Species Record Viewer included a 2009 record of a Murray cod in the Cudgegong River approximately 6 km downstream of Mudgee and the confluence with Lawsons Creek Based on these records, it is considered possible that Murray cod could occur in the catchment of Lawsons Creek.

3.1.3.6 Southern Purple Spotted Gudgeon

Southern purple spotted gudgeon, (*Mogurnda adspersa*), listed as endangered under the FM Act, is a benthic species usually found in rivers, creeks and billabongs with slow moving or still waters, often amongst weeds, rocks and snags. Two populations of this species historically occurred in NSW, an eastern population in the coastal catchments north of the Clarence River, and a western population patchily distributed throughout Murray-Darling Basin drainages (NSW DPI (Fisheries) 2013b). Both populations have experienced significant declines in distribution and abundance, and the western population of purple spotted gudgeon, which was previously widespread in the Murray, Murrumbidgee and Lachlan rivers and tributaries of the Darling, is largely confined to drainages in the Gwydir and Border Rivers. Although this species was not recorded in the Macquarie River drainage basin during the NSW River Fish Survey (NSW DPI Fisheries 1997) and no historic records were found the Central West CMA by Goldney et al. (2007), a new population was recently discovered in the Macquarie River Catchment (MDBA 2011e) and the Record Viewer contains a 2005 record for this species in Wuluuman Creek, a tributary of the Macquarie River. However, as this record is downstream of Burrendong Dam, where no fishway currently exists, individuals of this population would be unable to move upstream to the Study Area. Despite this, the presence of purple spotted gudgeon in Wuluuman creek, suggests that remnant populations could conceivably be present further upstream. The predicted distribution of the purple spotted gudgeon includes Hawkins and Lawsons Creeks adjacent to the Study Area (NSW DPI (Fisheries) 2016a). Based on existing records and the predicted distribution, this species it is considered possible this species occurs in Hawkins and/or Lawsons creeks.

3.1.3.7 Silver Perch

Silver perch, listed as vulnerable under the FM Act, were once widespread and abundant throughout most of the Murray-Darling river system and are found in lowland, turbid and slow flowing rivers (MDBA 2011a). They have now declined to small numbers and disappeared from most of their former range. Silver perch were recorded in the Macquarie River drainage basin in 1983 (NSW DPI (Fisheries) (1997) and as historically present in the Central West CMA, which encompasses the Study Area, by Goldney *et al.* (2007). Although only one remaining secure and self-sustaining population occurs in NSW in the central Murray River downstream of Yarrawonga Weir, and in several anabranches and tributaries (NSW DPI (Fisheries) 2014), this species is stocked in Lake Burrendong and has been caught relatively recently in the Cudgegong River upstream of Mudgee (Dr Dean Gilligan, NSW DPI (Fisheries), 20/10/14). The NSW DPI (Fisheries) Threatened and Protected Species Record Viewer) also included a 2006 record of a silver perch in the Macquarie River approximately 100 km downstream of the Mine Site and Lake Burrendong at Narromine. Silver perch were also stocked in Lake Burrendong in 2011 and in Lake Windermere in 2010 and 2016 (NSW DPI 2019). The predicted distribution of the silver perch occurs within Macquarie River, approximately 60 km south-west of the Study Area, and does not include Hawkins and Lawsons Creeks (NSW DPI (Fisheries) 2016a). Based on existing records and the predicted distribution, this species is considered unlikely to occur in Hawkins and Lawsons creeks.

3.1.3.8 Darling River Snail

Darling River snail (*Notopala sublineata*), listed as critically endangered under the FM Act, are endemic to the Murray-Darling Basin. They are now restricted to a few populations in irrigation pipes near Mildura, having once been common and widely distributed throughout the basin where they were found along the river banks attached to logs and rocks or crawling in the mud (NSW DPI (Fisheries) 2014e). While this species' distribution once included part of the Macquarie River Catchment, the upstream extent of this distribution was several hundred kilometres downstream of the Study Area and the Mid-Western Regional LGA. Based on existing records and the predicted distribution, this species is considered unlikely to occur in Hawkins and Lawsons creeks.

3.1.3.9 Hanley's River Snail

Hanley's river snail (*Notopala hanley*), listed as critically endangered under the FM Act, was once common and widespread in the Murray River catchment, including the Lachlan and Murrumbidgee Rivers. Populations of this species have declined rapidly over the last few decades, apparently as a result of weir building and other activities associated with river flow management. Living snails survive in artificial habitat at three locations: Banrock Station and Kingston Squatters Tank in South Australia and an irrigation pipeline at Dareton in NSW. Based on existing records and the predicted distribution, this species is considered unlikely to occur in Hawkins and Lawsons creeks.

3.1.3.10 Giant Dragonfly

The search undertaken using NSW BioNet showed that one endangered semi-aquatic invertebrate species, the Giant Dragonfly (*Petalura gigantea*), listed as endangered under the *BC Act*, has been recorded in the Mid-Western Regional LGA to the east of the Study Area in

Wollemi National Park and the south of the Study Area in the Newnes State Park. The Giant Dragonfly is considered to be an obligate groundwater dependent mire (peat-forming wetland) dwelling species because its breeding success is dependent on sites with a groundwater regime that provides enough surface moisture to minimise desiccation of eggs and early larval instars, peatland soils suitable for burrowing by larvae, and that have a water table height that allows larvae to access or extend their burrows (Benson and Baird 2012). This species is typically found in permanent swamps and bogs containing some free water and open vegetation (OEH 2011). The larval stage is unusually long, from at least 10 to 30 years, with larvae occupying permanent long chambered burrows, built under swamps. No swamps have been identified within the terrestrial ecology Study Area (EnviroKey 2020). Based on this and the absence of existing records, giant dragonfly are not expected to occur here.

3.1.3.11 Murray Crayfish

The Atlas of Living Australia includes 1967 and 1991 records of the Murray crayfish (*Euastacus arrnatus*), listed as vulnerable to extinction under the FM Act, in the Cudgegong River upstream of Lake Windermere. This species, which is found in a variety of habitats, ranging from pasture to sclerophyll forest in a variety of stream sizes, is endemic to the southern tributaries of the Murray-Darling Basin and some or all of these upper Macquarie River Catchment populations may be the result of unauthorised translocations (NSW DPI (Fisheries) 2014f). The predicted distribution of Murray crayfish includes only the Murray River and Murrumbidgee River and not the Macquarie River catchment. Based on existing records and the predicted distribution, this species is considered unlikely to occur in Hawkins and Lawsons creeks.

3.1.3.12 Southern Pygmy Perch

Southern pygmy perch, listed as endangered under the FM Act, were once widely distributed throughout the Murrumbidgee and Murray rivers and in coastal watercourses in South Australia and Victoria, north-eastern Tasmania and King and Flinders islands in Bass Strait. There have been large reductions in their range since European settlement, particularly in inland regions. Populations of southern pygmy perch have recently been discovered in tributaries of the upper Lachlan and upper Murray River catchments (NSW DPI (Fisheries) 2014d). In NSW, only two other populations are currently known, near Holbrook and Albury (MDBA 2011d). The predicted distribution of southern pygmy perch does not include the Study Area, with the nearest predicted distribution within the upper Lachlan River Catchment approximately 150 km south (NSW DPI, 2016a).

3.1.4 Threatened Populations

3.1.4.1 Western Population of Olive Perchlet

Olive perchlet (*Ambassis agassizii*) occur in both eastern (coastal) and western drainages, but these populations may be genetically distinct. The western population of the olive perchlet, listed as endangered under the FM act, once widespread throughout the Murray-Darling system of South Australia, Victoria, western New South Wales and southern Queensland, has faced serious decline. The population is now only found in limited sites within the Darling River drainage catchment and an isolated population in the central Lachlan catchment (NSW DPI

(Fisheries) (2014g); MDBA 2011e). Olive perchlet were recorded in the Macquarie River drainage basin during the NSW River Fish Survey (NSW DPI Fisheries 1997) and as historically present in the Central West CMA by Goldney *et al.* (2007). However, this population has suffered a serious decline and in NSW is now found only at a few sites in the Darling River drainage. The Threatened and Protected Species Record Viewer contained a 2002 record of this species on the Bogan River Catchment at Nyngan, over 250 km west of the Study Area. The olive perchlet is usually found in the slow-flowing or still waters of rivers, creeks, ponds and swamps. They prefer to shelter in overhanging and instream vegetation, woody debris (snags) and boulders during the day emerging to feed during the night. This population feeds on zooplankton and aquatic and terrestrial insects and breeds between October and December when water temperatures reach 23 °C. The predicted distribution of the western population of olive perchlet includes the Macquarie River Catchment upstream to and including Lake Burrendong, but not the Cudgegong River Catchment (NSW DPI, 2016a).

3.1.4.2 Murray-Darling Basin population of eel tailed catfish

Eel tailed catfish (*Tandanus tandanus*) have been recorded in a wide range of habitats, from clear to turbid waters and over a broad range of substrata. Catfish numbers declined substantially following the invasion of carp during the 1970s and 80s and other factors including habitat degradation, cold water pollution and fishing pressure have contributed to a decline in numbers (NSW DPI (Fisheries) 2014h). This species was found in the Macquarie River drainage basin (NSW DPI (Fisheries) 1997) and assessed as present in the Central West CMA by Goldney *et al.* (2007). The Threatened and Protected Species Record Viewer included relatively recent records for this species from the Macquarie River downstream of Lake Burrendong, and on the Macquarie and Turon Rivers upstream of the dam. This species was also recorded in the Cudgegong River and Lawsons Creek in 2012 (NSW DPI (Fisheries) Pers. Comm. 20/10/14). This is a sedentary, demersal species with a typical home range of 5 km occupying a range of rivers, creeks, lakes, billabongs and lagoons. It prefers clear, slow-flowing or still waters but has been recorded in flowing watercourses with turbid waters. It forages for small fish, freshwater prawns, yabbies, snails, aquatic insects and zooplankton and is more active at night than during the day. The indicative distribution of this species encompasses Lawsons Creek (NSW DPI (Fisheries) 2016a) and it is considered possible that this species occurs in the catchment of Lawsons Creek.

3.1.5 Lowland Darling River Aquatic Ecological Community

The Lowland Darling River aquatic ecological community, listed as endangered under the FM Act, includes all native fish and aquatic invertebrates within all natural creeks, rivers, watercourses and associated lagoons, billabongs, lakes, flow diversions to anabranches, the anabranches, and the floodplains of the Darling River within the State of New South Wales. This area includes the Macquarie River downstream of Burrendong Dam and the Cudgegong River downstream of Windermere Dam. Non listed watercourses above 500 m AHD elevation are not included. Hawkins and Lawsons creeks are located upstream of these dams and their reaches in the vicinity of the Mine Site are above 500 m AHD elevation, thus, they are not considered to form part of this community. Other listed endangered ecological communities do not occur within the Study Area or in the aquatic environment directly downstream.

Swamps and other vegetation communities are addressed by EnviroKey (2020).

3.1.6 Groundwater Dependent Ecosystems

3.1.6.1 Background

The definition and classification of GDEs adopted in this report are those from the Risk Assessment Guidelines for GDEs produced by the NSW Office of Water (Serov et al. 2012). GDEs are ecosystems in which the species composition and natural ecological processes are wholly or partially influenced by groundwater. The classification scheme recognises three broad types of GDEs associated with underground ecosystems:

- Karst and caves;
- Subsurface phreatic aquifer (saturated aquifer) ecosystems; and
- Baseflow stream (hyporheic - area where there is a mixing of shallow groundwater and surface water, or subsurface water ecosystems).

Four broad types of GDEs are associated with above ground ecosystems:

- Groundwater dependent wetlands;
- Baseflow watercourses (surface water ecosystems);
- Estuarine and near-shore marine ecosystems; and
- Phreatophytes (plants that obtain a significant amount of water from groundwater) – Groundwater dependent terrestrial ecosystems.

Each of these GDE types comprises a number of distinct subtypes.

The Project could potentially impact on two GDEs:

- Baseflow watercourses (surface water ecosystems); and
- Subsurface phreatic aquifer ecosystems.

GDEs can include terrestrial vegetation, baseflow in watercourses, aquifer and cave systems and wetlands and have many values, including biodiversity, water quality benefits, bio-indicators, social and economic (e.g. recreation and tourism) and are likely to perform important ecosystem roles that are not fully understood (NOW, 2014). Threats to GDEs arise from contamination and over-extraction of groundwater, particularly due to urban development, contamination from industry, intensive irrigation, elevated EC, clearing of vegetation and filling or draining of wetlands.

Stygofauna are a particular type of aquatic, sub-surface GDEs made up predominantly of many kinds of crustaceans, worms, snails, insects and a few other invertebrate groups that live in groundwater systems. Stygofauna are found in aquifers that may be associated with existing features of the land surface such as permanent, seasonal or ephemeral watercourses (typically referred to as alluvium aquifers), or, more rarely, deeper features which may or may not be partitioned from the existing land surface (e.g. deeper hydrological units not connected directly to surface waters). Most stygofauna spend their entire lives in groundwater (stygobites), although some groups are recognised that are capable of living in epigean habitats (stygophiles) or require access to surface environments to complete part of their lifecycle (Humphreys 2006). As with other GDEs, stygofauna contribute to biodiversity and are likely to perform many important ecological roles and may also exhibit high levels of endemism (i.e. species that are restricted to particular localities). They are also threatened by disturbances to groundwater systems, particularly those related to water abstraction and contamination.

Other sub-surface GDEs include hyporheic fauna (fauna inhabiting water in the hyporheic zone, the area of interaction between surface and groundwater). Hyporheic habitat is usually associated with creek beds and can exist in creeks that cease to flow on the surface, but maintain subterranean flow (Pryce *et al*. 2010). Hyporheic fauna may occur in alluvial substrata associated with ephemeral creeks.

3.1.6.2 Existing Information on GDEs

The Atlas of GDEs on the Bureau of Meteorology website was searched for occurrences of surface GDEs within, or adjacent to, the Study Area. The Atlas of GDEs uses spatial environmental data to indicate potential interaction between groundwater and both terrestrial vegetation communities (phreatophytes) and surface aquatic ecosystems (baseflow watercourses). The Atlas of GDEs does not provide information on sub-surface GDEs in the vicinity of the Mine Site.

According to the Atlas of GDEs, Hawkins and Lawsons Creeks are surface water systems with a moderate potential for groundwater interaction. These ecosystems are therefore likely to be reliant on groundwater recharge and surface expression of groundwater, and thus be baseflow creeks, or GDEs, to some extent. Blackmans Gully, located under the footprint of the proposed open-cut area, is considered to have a high potential for groundwater interaction, and thus be relatively more reliant on the surface expression of groundwater. It should be noted that no surface flow was observed in Blackmans Gully in December 2011, despite recent rainfall and evidence of recent high flows in Hawkins and Lawsons Creeks. Other watercourses traversing the Mine Site and Study Area, including Price Creek located adjacent to the proposed Waste Rock Emplacement, are not identified on the Atlas of GDEs. Surface GDEs are addressed by EnviroKey (2020).

Information on the distribution of stygofauna within NSW aquifers is sparse and scattered (Serov *et al.* 2012). Preliminary research indicates stygofauna diversity could be high and that some species may be locally endemic (i.e. restricted to certain areas or sections thereof) (Eberhard and Spate 1995, Hancock and Boulton 2008). The highly localised occurrence of some species combined with their high degree of adaptation to life in subterranean aquatic systems suggests that they may be highly sensitive to changes in the characteristics of the groundwater they inhabit and that disturbance of their habitat could pose a threat to their survival.

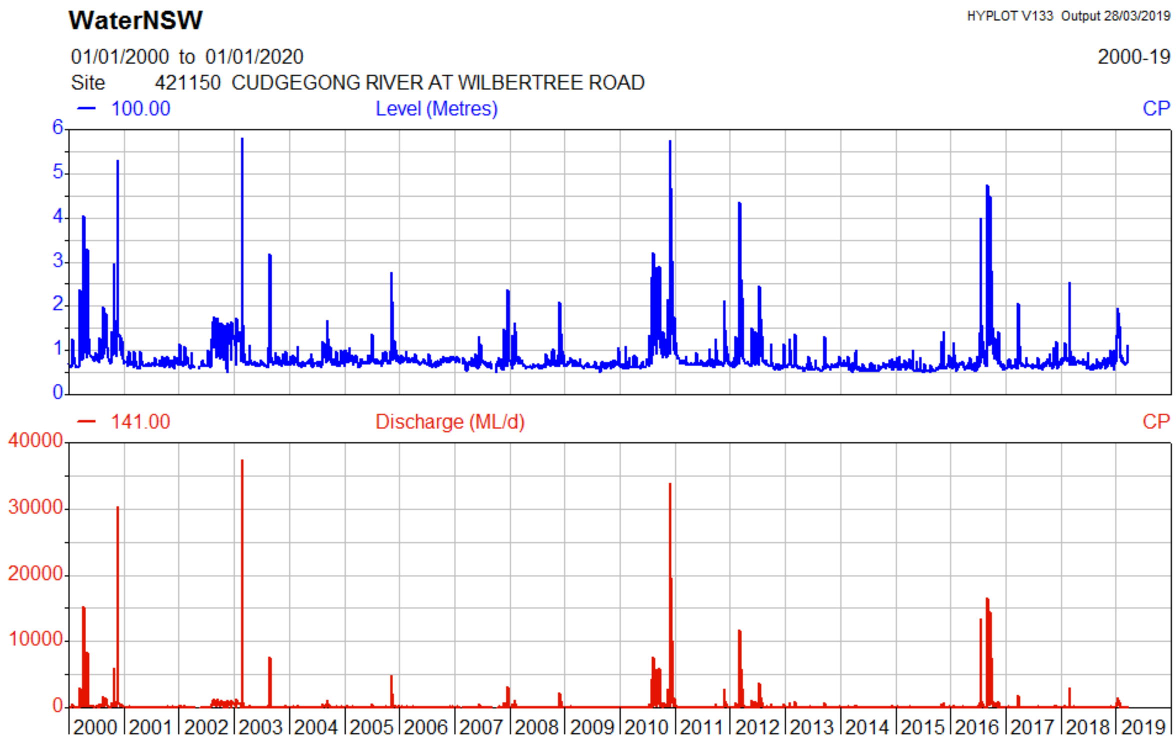
Relatively diverse stygofauna assemblages have been found in alluvial aquifers in Queensland and the Hunter Region of New South Wales (Tomlinson and Boulton 2010, Hancock and Boulton 2008, 2009). In the latter studies, stygofauna were more common in bores with low electrical conductivity (i.e. EC < 1500 µS/cm), shallow water table (10 m below ground) associated with alluvium and phreatophytes, and in geological units with cavities, fractures or interstices.

No known stygofauna studies have been undertaken in the Study Area. Aside from sampling undertaken in the Hunter Region by Hancock and Boulton (2008), other known NSW stygofauna studies include those by Cardno Ecology Lab near Gloucester (Cardno Ecology Lab 2011), Braidwood (south of Goulburn) (Cardno Ecology Lab 2012) and Lithgow (Cardno Ecology Lab 2013), and studies undertaken near Gunnedah (Eco Logical Australia 2012a) and Muswellbrook in the Upper Hunter Valley (Eco Logical Australia 2012b). In all studies, stygofauna were either absent or present in very small numbers.

3.1.7 Creek Hydrology

Hydrological data were sourced from the NSW Water Information website administered by the NSW DPI (Water) (2019) for the gauging station on the Cudgegong River at Wilbertree Road (Station No. 421150), which is located downstream of the confluence with Lawsons Creek and approximately 9 km north of Mudgee and 50 km downstream of Lue. This is the nearest station downstream of the Mine Site. Water level and daily discharge (flow) from 1 January 2000 to 28 March 2019 are shown in **Figure 3.1**.

Figure 3.1 Water Level and Discharge at the Cudgegong River at Wilbertree Road (Station No. 421150) 2011 to 2019



It is apparent that several large flow events occurred from late 2010 to 2012 and in the second half of 2016. While these hydrological data were measured in the Cudgegong River, it is assumed that a similar flow regime would likely have been experienced in Hawkins and Lawsons Creeks. The elevated flows are likely to have influenced the aquatic environment and biota, particularly in the weeks and months after these events. The relatively dry conditions observed in March 2017 were despite the large flows in late 2016 and are suggestive of intermittent watercourses.

3.2 FIELD SURVEYS

3.2.1 Overview

The objective of the field investigations was to establish the existing condition of the aquatic ecology that could potentially be affected by the Project. This included assessment of the aquatic ecology supported by Hawkins and Lawsons Creeks, their tributaries, freshwater springs within and adjacent to the Mine Site and stygofauna samples in groundwater bores accessing aquifers. A brief outline of the sites and methods used for the field surveys is provided in Section 3.2.2 to assist the reader. More detailed field survey methodology is presented in **Annexure B**.

3.2.2 Sites and Timing

3.2.2.1 Hawkins and Lawsons Creeks

Hawkins and Lawsons Creeks were visited on three occasions: 13 and 14 December 2011, 3 to 5 April 2013 and 20 to 24 March 2017. Three 100 m (200 m for fish sampling) sites were surveyed on Hawkins Creek (Sites 1, 2, 3 and 7) and Lawsons Creek (Sites 4, 5 and 6). Sites 1 to 7 were all visited in December 2011 and April 2013. During low flow in March 2017, water was largely absent at all sites on Hawkins Creek except Site 1. As a result, two additional sites were visited on this creek (Sites 8 and 9), where water was present. Also, a further site, Site 10, was visited on Lawsons Creek in March 2017 as Site 4 could not be accessed. The site of the proposed relocated Maloneys Road crossing on Lawsons Creek was also visited on 10 December 2018 (Site 11). The location of these sites is shown in **Figure 3.2** and their geographic coordinates are presented in **Table 3.2**. These sites were selected to provide a general characterisation of the aquatic habitat and biota in these watercourses.

Sites 1 to 7 were also visited in November 2014 to undertake mapping of macrophytes. The dam on Price Creek was also visited at this time.

Table 3.2
Hawkins and Lawsons Creek Site locations and GPS coordinates (Datum: GDA 94 Zone 55 H)

Site Number	Watercourse	Easting	Northing
1	Hawkins Creek	0769697	6384704
2	Hawkins Creek	0770667	6385522
3	Hawkins Creek	0772017	6386346
4	Lawsons Creek	0767066	6383881
5	Lawsons Creek	0768652	6383486
6	Lawsons Creek	0769971	6383512
7	Hawkins Creek	0769867	6383459
8 (Price's Pool)	Hawkins Creek	0771617	6386150
9 (Just upstream v-notch weir)	Hawkins Creek	0770302	6384978
10	Lawsons Creek	0765708	6385410
11	Lawsons Creek	0765236	6385419
GPS coordinates of the centre of each site were recorded using an Etrex 12 channel GPS unit with accuracy of 4-6 m			

3.2.2.2 Major Tributaries

Three of the major tributaries of Hawkins and Lawsons Creek (Walkers Creek, Blackmans Gully and Price Creek) were also visited on one or more of the creek survey events and assessed for aquatic ecology.

3.2.2.3 Springs

Several springs that support surface aquatic ecology occur in the Study Area. These could potentially be affected by the Project and may also support sub-surface aquatic ecology. On 3 to 5 April 2013, nine of these springs (BSW17, 18, 23, 24, 25, 27, 29, Battery Creek Spring (associated with groundwater bore BGW16) were visited and assessed for aquatic ecology (**Figure 3.3**). These springs were visited a second time in March 2017.

3.2.2.4 Groundwater Bores

A total of twenty-four groundwater bores located on and around the Mine Site were sampled for stygofauna across April, June and December 2013 and in March 2017 (**Figure 3.3**). BGW 55 and BGW 56 were sampled in March 2017 only. The geographic coordinates and the general location of the groundwater bores selected for sampling of stygofauna are presented in **Annexure G**.

3.2.3 Survey Methods

3.2.3.1 Aquatic Habitat and Macrophytes

On Hawkins and Lawsons Creeks, a description of creek habitats and vegetation including assessment using a modified version of the River, Channel and Environmental Inventory (RCE) inventory (Chessman *et al.* 1997) was undertaken. RCE scores of 13 to 22, 23 to 32, 33 to 42 and 43 to 53 indicate poor, fair, good and excellent aquatic habitat and vegetation condition, respectively (see **Annexure B** for further details of the assessment criteria). Creeks were also classified according to the NSW DPI fish habitat assessment criteria (NSW DPI (Fisheries) 2013a) (see **Section 2.3.1** for further details). Aquatic macrophytes were also identified during the habitat assessment. More detailed mapping of aquatic macrophytes (Sites 1 to 7 and the dam on Price Creek in November 2014) was undertaken using a handheld GIS enabled mapping device.

The assessments of major tributaries and springs were undertaken visually, looking for aquatic macrophytes and other biota such as fish, which may suggest permanent habitat supported by the springs and any associated drainage lines.

3.2.3.2 Water Quality

Two replicate measurements of dissolved oxygen (DO), electrical conductivity (EC), oxidation-reduction potential (ORP), pH, temperature and turbidity of the water were taken from just below the surface of the water using a YSI multiprobe at each site on Hawkins and Lawsons Creeks. The measurements taken were used to assist in interpretation of the results of biotic sampling. The EC, DO, pH and turbidity measurements were compared with the upper and lower default trigger values (DTVs) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000). These trigger values provide an indication of risk to environmental value, with measurements within the upper and lower DTV range indicative of a low risk and those outside the range indicating that the environmental value may not be protected. Specific guidelines are not available for temperature and ORP measures.

Figure 3.2 Aerial photo overlain with the location of sites sampled for aquatic ecology on Hawkins and Lawsons Creeks

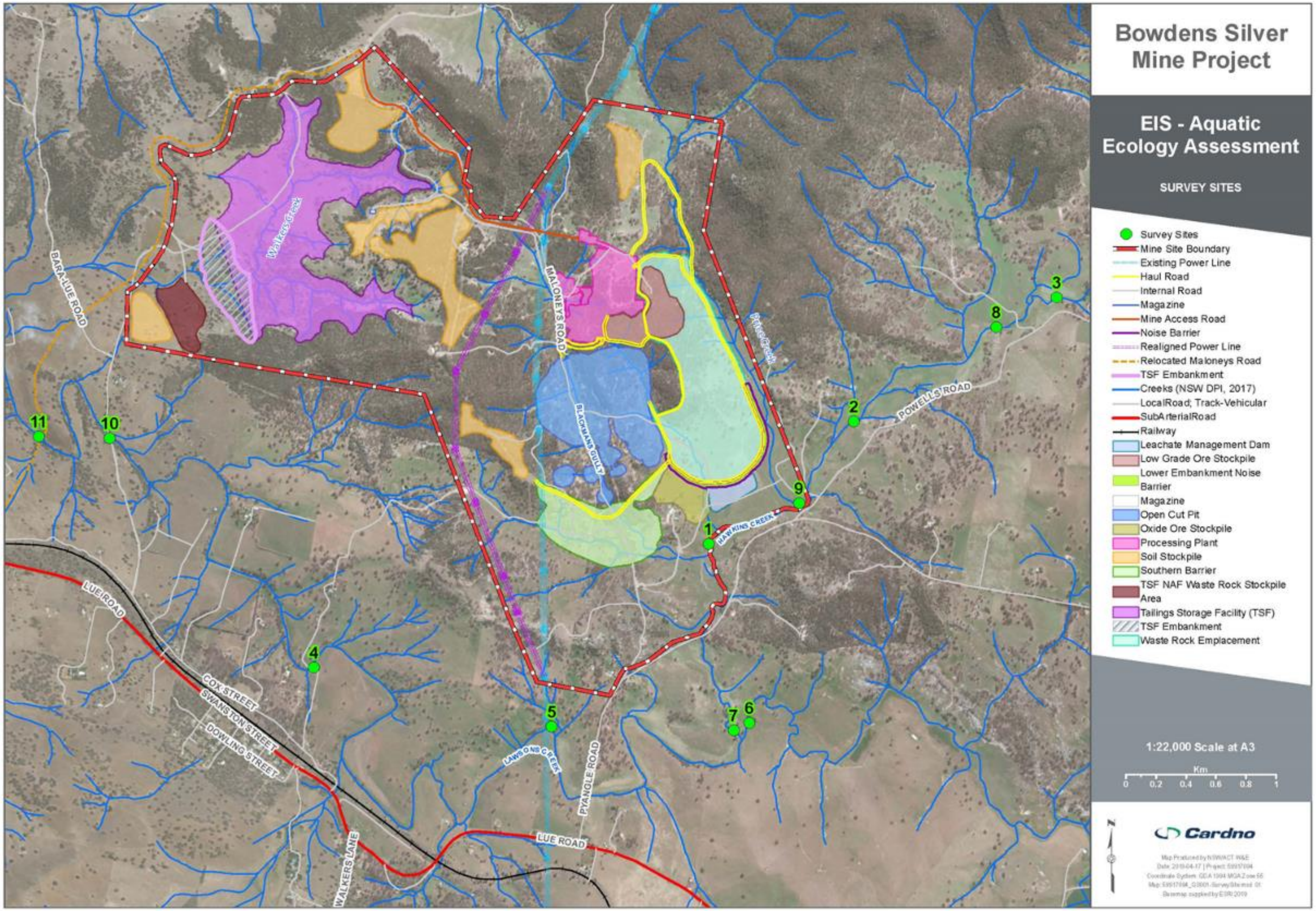


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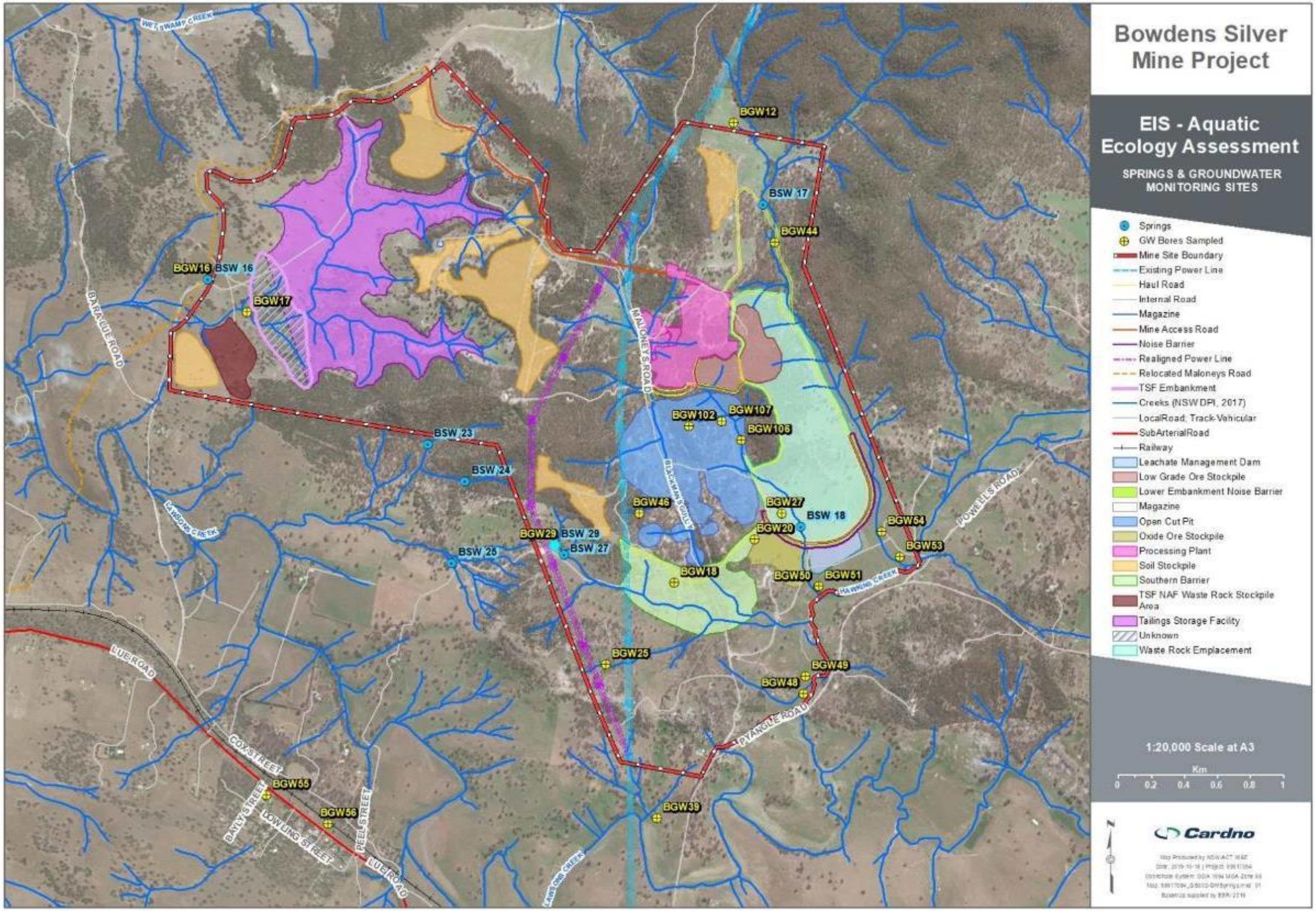
Figure 3.3 **Aerial Photograph Overlain with Location of Springs Assessed for Aquatic Ecology and Groundwater Bores Sampled for Stygofauna**



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3.2.3.3 AUSRIVAS Macroinvertebrates

Sampling of macroinvertebrates from edge habitats at each site on Hawkins and Lawsons Creeks was undertaken using the NSW Australian Rivers Assessment System (AUSRIVAS) sampling methods (Turak *et al.* 2004) **(Annexure B**). One AUSRIVAS edge sample was collected from each site, except Site 11 in December 2018 when two replicate samples were collected. It is noted that the alkalinity values (see **Annexure B**) had to be reduced to enable the AUSRIVAS model to run.

3.2.3.4 Fish

Sampling of fish was undertaken using a backpack electrofisher (April 2013, March 2017 and December 2018). Eight 150 second shots were undertaken at each site on Hawkins and Lawsons Creeks (1,200 seconds total per site). Fish stunned by the current were collected in a scoop net, identified and measured. All captured fish were handled with care to minimise stress, and released as soon as possible. Sampling was undertaken with consideration of the Australian Code of Electrofishing Practice (NSW Fisheries 1997), including the presence of an experienced electrofishing operator at all times.

3.2.3.5 Stygofauna

Groundwater bores were selected for stygofauna sampling based on the following criteria:

- Spatial Coverage: Bores were selected based on their location with respect to the extent of the proposed open cut area, their proximity to Hawkins and Lawsons Creeks and their proximity to springs west of the proposed open cut pits;
- Aquifer Type: Bores were selected to represent the range of aquifers present in and around the Mine Site;
- Water Quality: Bore water quality data were examined prior to sampling to help identify bores most likely to support stygofauna and where sampling effort should be directed;
- Accessibility: Bores could only be sampled where access was available at the time of sampling and where the construction of the bore was compatible with the sampling method; and,
- Groundwater sampling regime: Bores that are in continuous use for water supply or are purged on a regular basis are likely to be unsuitable for stygofauna sampling.

Details of the bores sampled are provided in **Annexure G**. Stygofauna were sampled from each bore using modified plankton nets (aperture 50 micron) deployed within the groundwater bore, with consideration given to the recommendations contained in the Western Australia Environmental Protection Authority – Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia (WAEPA 2007) and The Cooperative Research Centre for Contamination Assessment and Remediation of the Environment – Sampling Strategies for Biological Assessment of Groundwater Ecosystems (Hose and Lategan 2012). The sampling effort varied somewhat among bores (on occasion sampling was aborted part way through sampling due to obstructions in the bore damaging the sampling nets) though the majority of bores were sampled fully following the procedure described in **Annexure F**.

3.2.4 Aquatic Habitat

3.2.4.1 Hawkins Creek and Lawsons Creek

3.2.4.1.1 General Observations

The flow regime of the sections of Hawkins and Lawsons Creeks adjacent to the Mine Site has been impacted by the historic clearing of native vegetation. While there are no major impoundments on these creeks upstream of the Mine Site, several farm dams have been constructed on their tributaries and several minor abstraction points (i.e. wind driven water pumps) were observed on Hawkins and Lawsons Creeks during the field surveys.

During December 2011, there was evidence of recent high flows at Hawkins and Lawsons Creeks; water was turbid, and water levels appeared slightly elevated and bankside terrestrial vegetation was partially submerged. These conditions may have obscured some habitat features and flora. In April 2013, water levels were lower compared with December 2011 and water appeared relatively clear. This was most evident at sites on Hawkins Creek where surface flow was much less obvious than in December 2011. Water levels during March 2017 were relatively low, with aquatic habitat in Hawkins and Lawsons Creeks consisting largely of a few disconnected pools. Some limited flow was evident between a few pools. Water levels at Site 11 in December 2018 were also low with water present in a series of disconnected pools with no obvious surface flow.

The sections of Hawkins and Lawsons Creeks sampled shared many common characteristics. Both creeks flow through predominantly pasture/farmland for much of their reach, with few bankside trees and other bank-stabilising plants and the riparian strip consists primarily of grasses with some shrubs / bushes. Bank erosion and slumping, such as steep, overhanging and unvegetated banks consisting of unconsolidated material were observed at each site. These observations may be explained partly by the lack of significant root systems provided by riparian vegetation such as large trees and shrubs that would otherwise help consolidate bank material. The historic removal of this vegetation has led to a direct loss of riparian floral biodiversity along creek banks. Its removal has also likely resulted in a reduction in the diversity of associated native fauna and the proliferation of introduced flora. Creek bed material generally consists of fine sediment and often felt loose, soft and muddy underfoot with few pebbles / cobbles. Bedrock formed a proportion of the creek banks and substratum at Sites 1, 2 and 5.

Hawkins and Lawsons Creeks are classified as Key Fish Habitat by NSW DPI (Fisheries) and contain Type 1 – Highly Sensitive Key Fish habitats (native aquatic plants and some large wood debris) (**Figure 3.4** and **Figure 3.5**). For the purpose of determining the suitability of waterway crossings, these creeks are classified as Class 2 – Moderate Fish Habitat due primarily to their intermittent flow. Bridges, arch structures, box culverts and fords (in this order of preference) are considered suitable crossing structures for this class.

Creek crossings observed included a box culvert on Lawsons Creek, just upstream of Site 5 at Pyangle Road (**Plate 1a**) and a ford just downstream of Site 4 (**Plate 1b**). A causeway was also visited on Hawkins Creek (Bingman Crossing) (**Plate 1c**). Water levels during December 2011 were below the level of structure at Pyangle Road and Bingman Crossing, indicating that fish would be unable to navigate these structures during normal flows. While these structures may impede or prevent fish passage during normal flow, in high flow events fish should be able to navigate up and downstream with little difficulty. Several other creek crossings on sections of Hawkins and Lawsons Creeks upstream and downstream of the Study Area are visible on topographic maps of the area, but were not visited.

Figure 3.4 Stream Order within and around the Mine Site

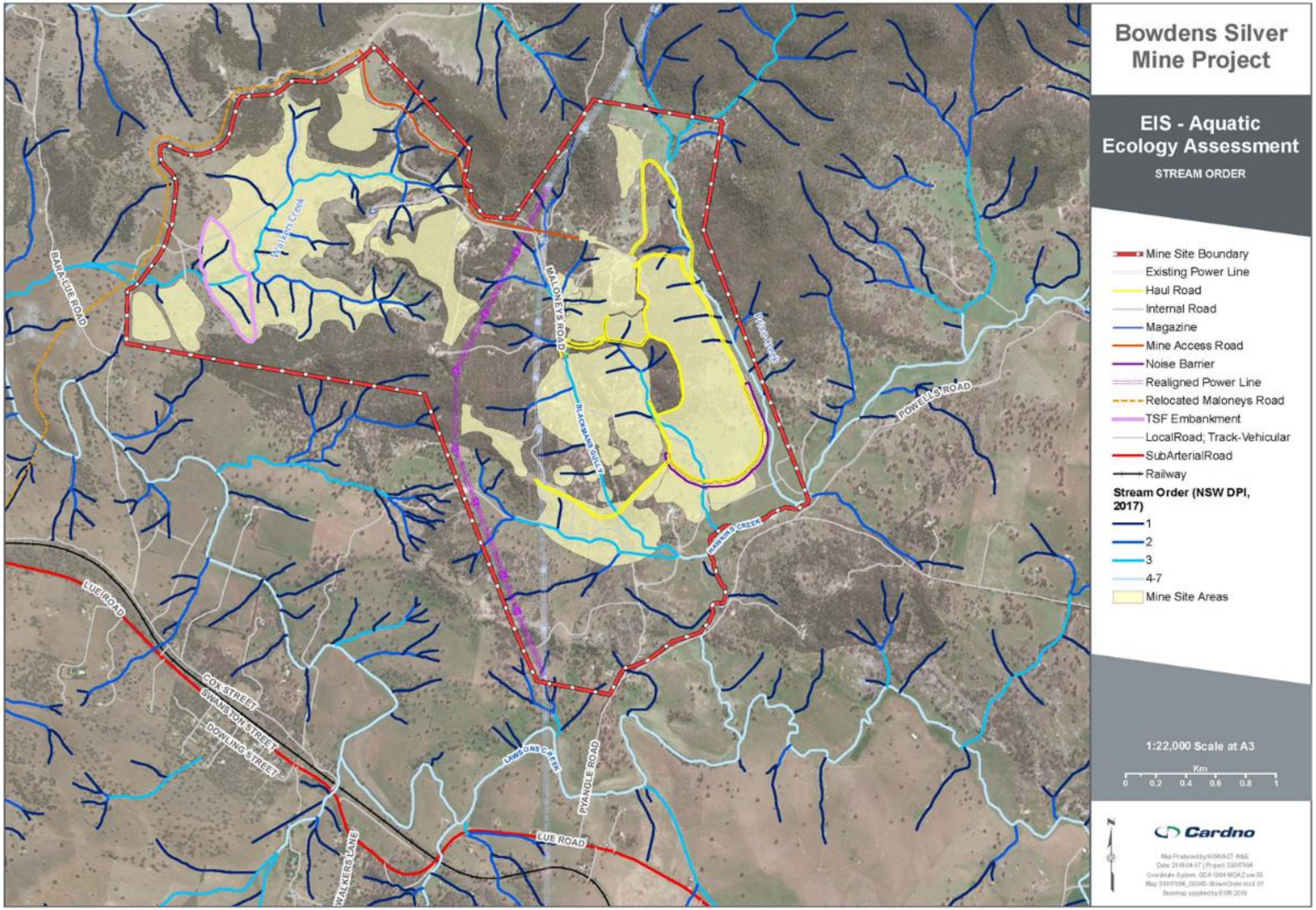

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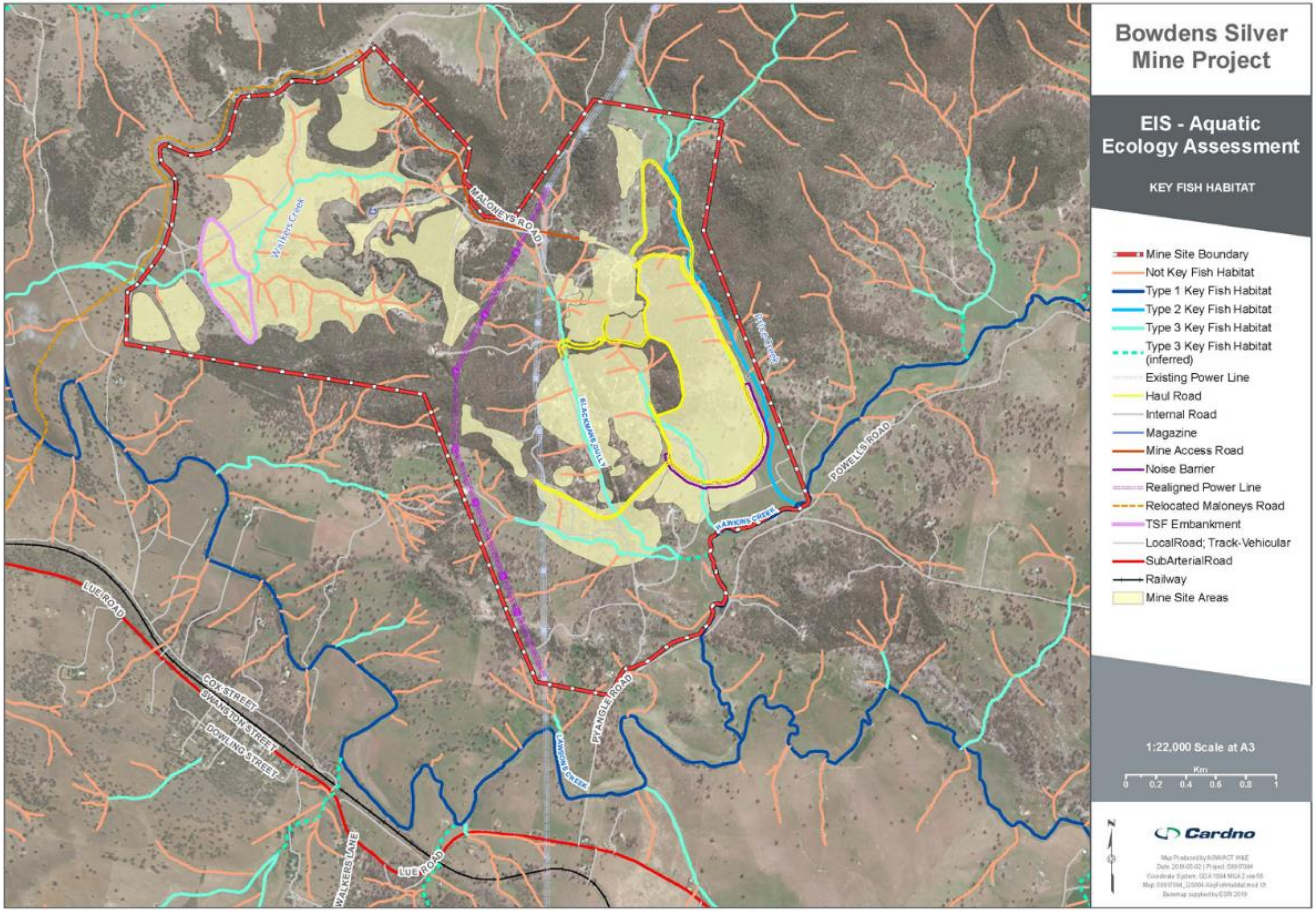
Figure 3.5 Key fish habitat within and around the Mine Site



a)

b)

c)

Plate 1 a) Current Pyangle Road crossing on Lawsons Creek, b) ford just downstream of Site 4 on Lawsons Creek and c) Bingman Crossing (a causeway) on Hawkins Creek

In December 2011, no water was observed in Blackmans Gully Creek adjacent to Maloneys Road. As water levels in both Hawkins and Lawsons Creeks were slightly elevated, this observation suggests that Blackmans Gully Creek is ephemeral and provides limited aquatic habitat. The absence of aquatic plants also suggests this creek is ephemeral.

Aquatic macrophytes occupied a significant proportion of each site. Twelve species of macrophytes and two species of algae were identified across the December 2011, April 2013, March 2017 and December 2018 surveys (see Sections 0 to 3.2.4.1.12 for species identified at each site). An unidentified filamentous alga was abundant at each site and frequently covered submerged portions of macrophytes and the surface of substrata.

3.2.4.1.2 Site 1

Site 1 (**Plate 2a-c**) is located on the section of Hawkins Creek bordering the southern extent of the Mine Site. Stream width ranged from approximately 4 to 10 m. Bank erosion and slumping were evident along a significant proportion of the site. Riparian vegetation consisted primarily of grasses, with some small patches of roses (*Rosa sp.*), introduced blackberry (*Rubus fruticosus* aggregate) and a few mature eucalypt trees (*Eucalyptus sp.*).

Eight macrophyte and two algae species were recorded. River clubrush (*Schoenoplectus validus*) and common spike-rush (*Eleocharis acuta*) were the most abundant macrophytes along creek edges, interspersed with smaller patches of cumbungi (*Typha orientalis / domingensis*). Coarse water milfoil (*Myriophyllum elatinoides*), a submerged/emergent species, was also relatively abundant. Umbrella sedge (*Cyperus eragrostis*), an introduced species, was also present. Umbrella sedge, which is introduced from North and South America, can quickly form dense beds that can restrict water flow and retain sediment.

a)

b)

c)

Plate 2 Site 1 on Hawkins Creek in a) December 2011, b) April 2013 and c) March 2017

3.2.4.1.3 Site 2

Site 2 (**Plate 3a-c**) is located on Hawkins Creek approximately 1.0 km upstream of Site 1, just north of Powells Road. Stream width ranged from approximately 6 m to 12 m. Bank erosion was evident however slumping was not observed, possibly due to the relatively short bank height. Riparian vegetation consisted primarily of grasses.

Four species of macrophytes were identified with river clubrush and cumbungi the most abundant. At upstream sections cumbungi covered the entire creek bed. The introduced umbrella sedge was also present.

This site was dry in March 2017.

a)

b)

c)

Plate 3 Site 2 on Hawkins Creek in a) December 2011, b) April 2013 and c) March 2017

3.2.4.1.4 Site 3

Site 3 (**Plate 4a-c**) is located on Hawkins Creek approximately 1.5 km upstream of Site 2. There was little variation in stream width which ranged from approximately 4 to 5 m. Unstable banks with obvious signs of erosion, slumping and bank undercutting were also observed. Grasses comprised the majority of riparian vegetation along with a few eucalypt trees.

Eight macrophyte species were identified. River clubrush and common spike-rush were the most common emergent species. Floating pondweed (*Potamogeton tricarinatus*), a floating leaved and rooted species, was also relatively abundant. Introduced umbrella sedge was present.

This site was dry in March 2017.

a)

b)

c)

Plate 4 Site 3 on Hawkins Creek in a) December 2011, b) April 2013 and c) March 2017

3.2.4.1.5 Site 4

Site 4 (**Plate 5a-c**) is located on Lawsons Creek upstream of an un-named ford road crossing approximately 0.6 km directly north of Lue Station and adjacent to a section of Crown Reserve. Stream width ranged from 6 m to 12 m and there were signs of bank slumping and erosion. The riparian strip consisted primarily of grasses together with patches of invasive blackberry, a few eucalypt trees and a few introduced willow trees (*Salix* sp.).

Two macrophyte species were identified, river clubrush and common rush (*Juncus usitatus*). These species were present along the majority of the site. No introduced macrophytes were observed.

This site was not visited in March 2017 due to access restrictions.

a)

b)

c)

Plate 5 Site 4 on Lawsons Creek in a and b) December 2011 and c) April 2013

3.2.4.1.6 Site 5

Site 5 (**Plate 6a-c**) is located on Lawsons Creek approximately 3.0 km upstream of Site 4 and just west of Pyangle Road. Creek width ranged from 6 m to 10 m and there was significant bank erosion and slumping present and banks were relatively steep in places. Riparian vegetation consisted primarily of grasses and a few eucalypt trees. Woody debris was relatively common throughout this site.

Four species of macrophyte were identified. River clubrush and cumbungi were abundant and formed dense beds that in places covered the entire creek. Small patches of introduced watercress (*Rorippa nasturtium-aquaticum*) were also present. Arrowgrass (*Triglochin* sp.) was also present. This plant is similar in appearance to *Maundia triglochinoides*, which is listed as vulnerable under the *BC Act*, however, this listed species is restricted to coastal NSW and Central Queensland (OEH 2014) and thus does not occur in the Mine Site.

a)

b)

c)

Plate 6 Site 5 on Lawsons Creek in a) December 2011, b) April 2013 and c) March 2017

3.2.4.1.7 Site 6

Site 6 (**Plate 7a-c**) is located on Lawsons Creek approximately 100 m upstream its confluence with Hawkins Creek. Creek width ranged from approximately 2 m to 12 m. Evidence of bank erosion was present on both banks. Riparian vegetation consisted primarily of grasses with a few eucalypt trees.

Five macrophyte species were identified with river clubrush, common spike-rush and cumbungi the most abundant. No introduced macrophyte species were observed.

a)

b)

c)

Plate 7 Site 6 on Lawsons Creek in a) December 2011, b) April 2013 and c) March 2017

3.2.4.1.8 Site 7

Site 7 (**Plate 8**) is located on Hawkins Creek approximately 200 m upstream of the confluence of Hawkins and Lawsons Creeks. The creek width was approximately 3 to 4 m and banks were often steep with signs of erosion. Riparian vegetation consisted primarily of grasses and invasive blackberry.

Seven macrophyte species were identified with floating pondweed the most abundant. Umbrella sedge was also present.

This site was dry in March 2017.

Plate 8 Site 7 on Lawsons Creek in March 2017

3.2.4.1.9 Site 8

Site 8 is located on Hawkins Creek and was visited in March 2017 only. This site was selected as it was one of the few areas on Hawkins Creek that retained water. The aquatic habitat at the time of sample consisted of a few disconnected pools. These would provide refuge for fish and other aquatic biota during times of low flow. Unstable banks with obvious signs of erosion, slumping and bank undercutting were observed. Grasses comprised the majority of riparian vegetation along with a few eucalypt trees.

3.2.4.1.10 Site 9

Site 9 is located on Hawkins Creek just upstream of the V-notch weir and was visited in March 2017 only. Aquatic habitat consisted of one relatively large pool that appeared to have been constructed to facilitate the installation and operation of the weir and / or was due to the installation of the weir. The banks were vegetated by cumbungi.

3.2.4.1.11 Site 10

Site 10 is located on Lawsons Creek at the Bara-Lue road crossing and was visited in March 2017 only (**Plate 9**). The riparian strip consisted primarily of grasses together with patches of invasive blackberry, a few eucalypt trees and a few introduced willow trees (*Salix* sp.).

Plate 9 Site 10 on Lawsons Creek in March 2017

3.2.4.1.12 Site 11

Site 11 (**Plate 10**) is located on Lawsons Creek at the location of the proposed relocated Maloneys Road crossing. The riparian strip consisted primarily of grasses together with patches of invasive blackberry, and a few eucalypt trees. Emergent macrophytes observed were tall spike rush (*Eleocharis sphacelata*) and cumbungi. Filamentous green algae was present in the pools.

Plate 10 Site 11 on Lawsons Creek in December 2018

3.2.4.1.13 Riparian, Channel and Environmental Inventory (RCE)

Total RCE scores ranged between 20 and 26 (**Table 3.3**). The RCE score at each site did not change between surveys. Low overall scores were largely explained by the poor condition of the riparian strip and banks. Each creek scored consistently low in categories examining the health of riparian vegetation and the stability of banks, reflecting the loss of large stabilising vegetation such as trees and an associated increase in erosion. These findings are consistent with general observations of the poor condition of banks and riparian vegetation made at each site.

Table 3.3
Total RCE scores (Chessman *et al.*1997) for sites sampled on Hawkins and Lawsons Creeks

Site*	Score
Hawkins Creek	
Site 1	22
Site 2	23
Site 3	20
Site 7	23
Site 8	23
Site 9	23
Lawsons Creek	
Site 4	26
Site 5	25
Site 6	24
Site 10	26
Site 11	26
* Site locations displayed (**Figure 3.2**)	

3.2.4.2 Major Tributaries

Walkers Creek and Blackmans Gully are located partly under the proposed TSF and open cut pits, respectively. Each creek supported very limited aquatic ecology. Walkers Creek (**Plate 11a** and **b**) and Blackmans Gully (**Plate 11c** and **d**) were dry during March 2017, with no pools present in the sections visited, except for a few in in the flow path of and adjacent to Walkers Creek. Both these creeks appeared ephemeral and would likely flow for short periods following rainfall only. Some limited flow was present in Price Creek (**Plate 11e** and **f**) upstream of the footprint of the WRE during the site visits. Aquatic ecology of Price Creek upstream and adjacent to the WRE was very limited, and consisted of patches of hydrophilic reed / sedgeland vegetation, suggesting relatively moist sub-surface conditions. These creeks are largely third order.

Blackmans Gully and Walkers Creek are Type 3 (minimally sensitive KFH) due to their ephemeral flow and absence of wetland and in-stream aquatic plants. Price Creek and the dam on Price Creek are Type 2 (Moderately sensitive KFH) due to the presence apparent intermittent flow and wetland plant species (albeit no in-stream aquatic plants). All are Class 3 waterways due to their connection to Hawkins Creeks or Lawsons Creek. The section of the third order tributary of Blackmans Gully located within the footprint of the southern barrier and the third order tributary of Hawkins Creek located within the footprint of the WRE and oxide ore stockpile are Type 3 (minimally sensitive KFH) and Class 3 (inferred based on catchment area and observations from nearby Blackmans Gully). No flow was observed in these watercourses at their confluences with Hawkins Creek during any survey and they are likely to be highly ephemeral.

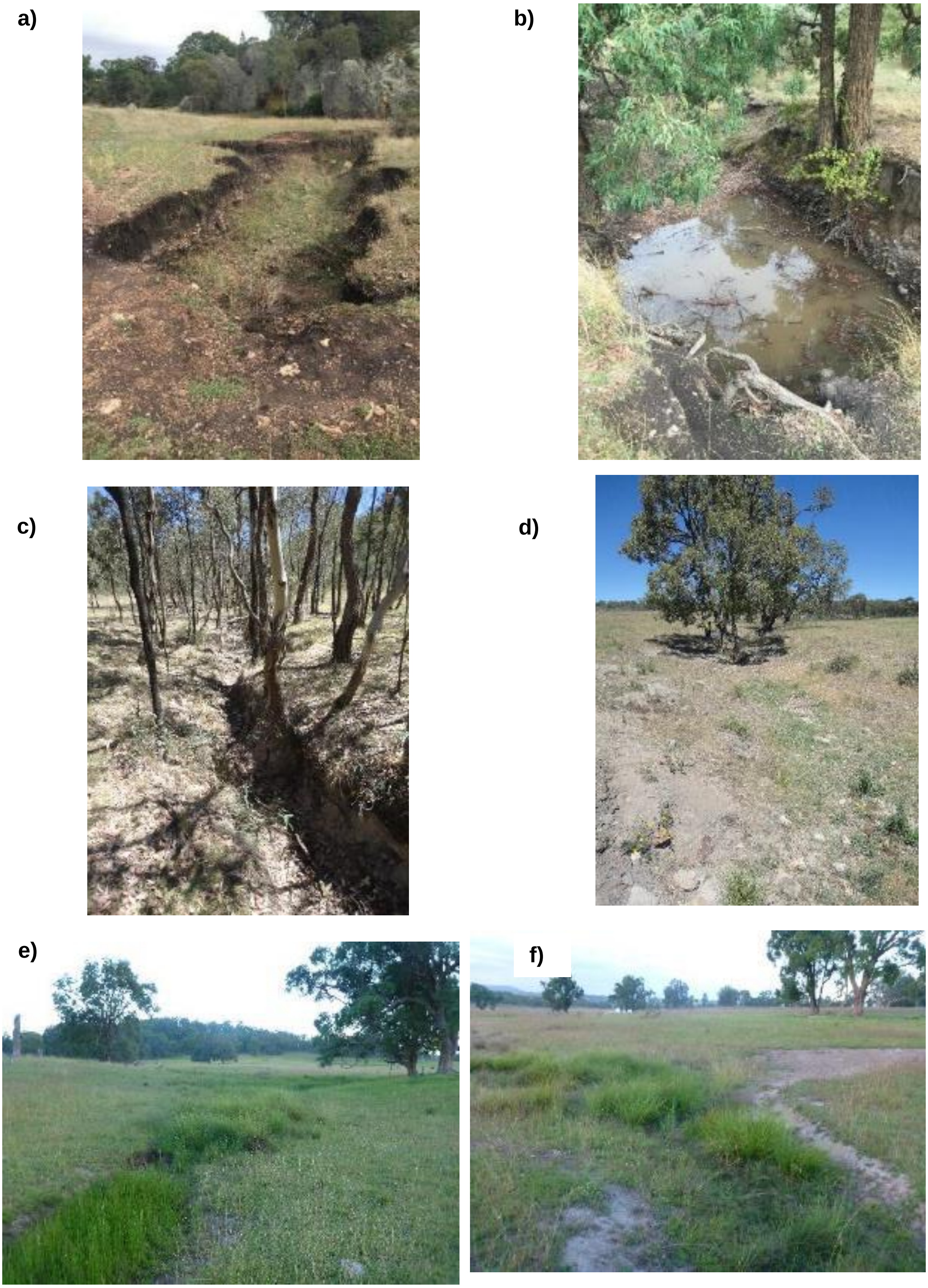


Plate 11 a) and b) Walkers Creek, c) and d) Blackmans Gully and e) and f) Price Creek in March 2017

3.2.4.3 Springs and Associated Waterbodies

Four of the springs visited: Battery Creek Spring/BSW16 (associated with BGW 16) (**Plate 12a**), BSW25 (**Plate 12b**), BSW27 (**Plate 12c**) and BSW29 (**Plate 12d**) appeared to support artificial water impoundments which in turn provided some aquatic habitat. Aquatic macrophytes (such as *Juncus* sp., *Eleocharis* sp., *Potamogeton tricarinatus* and *Myriophyllum* sp.) were present to varying degrees, in terms of species and coverage, suggesting these impoundments are relatively permanent features. Eastern gambusia was observed in the impoundment associated with BSW29. These impoundments would provide habitat for aquatic macroinvertebrates, birds and possibly also some native fish species. Examination of topographic maps and aerial images indicate these features are common locally and regionally. These artificial water impoundments are not KFH under NSW DPI (Fisheries) (2013a), which exclude artificial waterbodies.

The aquatic habitat supported by the other springs visited- BSW18 (**Plate 12e**), BSW23 (**Plate 12f**) and BSW24 (**Plate 13a**) was very limited and consisted of small isolated pools or waterlogged drainage lines with no observable flow or aquatic plants. These areas appear to be highly ephemeral. The isolated pools and first and second order drainage lines associated with BSW23 and BSW24 are not KFH described in NSW DPI (Fisheries) (2013a). The third order drainage line associated with BSW18 is Type 3 (minimally sensitive KFH). As a conservative measure, the associated drainage lines are considered Class 3 waterways. At the time of the April 2013 site visit, flow was present in Price Creek (**Plate 13b**) at the location of spring BSW17. Although no aquatic macrophytes were observed, some green filamentous algae was present suggesting it may be a relatively permanent waterway. Flow was also present farther upstream of this location in March 2017.

3.2.5 Macrophyte Mapping

The results of the macrophyte mapping are provided in **Annexure C**. The species of plant (aquatic and non-aquatic) identified within the channel of the creeks at Sites 1 to 7 and at the dam on Price Creek are provided in **Table 3.4**.

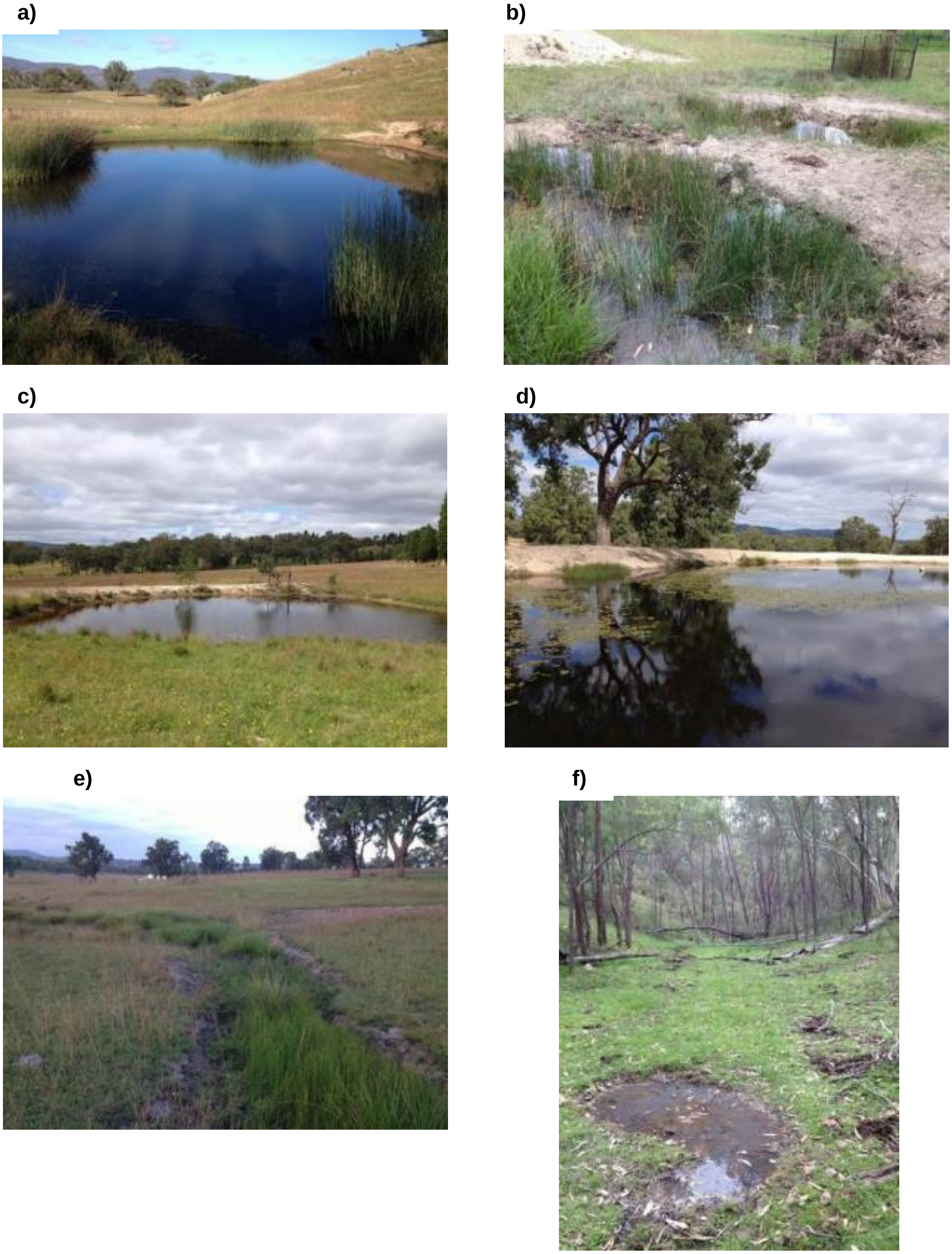


Plate 12 **a) Battery Creek Spring (associated with BGW 16), b) BSW25, c) BSW27, d) BSW29, e) BSW18 and f) BSW23**

a)

b)

Plate 13 a) BSW24 and b) Price Creek upstream of the WRE

Table 3.4
Species of plant identified across the Study Area (combined data across Sites 1 to 7 and the dam on Price Creek) in November 2014

Family	Scientific Name	Family	Scientific Name
Asteraceae	*Carduus* sp./ *Cirsium* sp.	Thistles	Non-native
Brassicaceae	*Rorippa nasturtium-aquaticum*	Watercress	Non-native
Cyperaceae	*Schoenoplectus validus*	River clubrush	Native
Cyperaceae	*Bolboschoenus fluviatilis*	marsh club-rush	Native
Cyperaceae	*Carex appressa*	tall sedge	Native
Cyperaceae	*Cyperus eragrostis*	Umbrella Sedge	Non-native
Cyperaceae	*Eleocharis acuta*	Common spikerush	Native
Fabaceae	*Trifolium* sp. 1	Clover	Poss. Non-native
Haloragaceae	*Myriophyllum variifolium*	Water milfoil	Native
Haloragaceae	*Myriophyllum verrucosum*	Red Water-milfoil	Native
Juncaceae	*Juncus articulatus*	Joint-leaf rush	Non-native
Juncaceae	*Juncus* sp. 1, poss. *J. usitatus*	Rush	Native
Juncaginaceae	*Triglochin* sp., poss. *T. procera*	Arrow grass	Native
Poaceae	*Paspalum distichum*	Water Couch	Native
Poaceae	*Phragmites australis*	Common reed	Native
Poaceae	Poaceae	Grasses*	
Polygonaceae	*Persicaria decipiens*	Slender knotweed	Native
Polygonaceae	*Rumex crispus*	Curled Dock	Non-native
Potamogetonaceae	*Potamogeton tricarinatus*	Floating pondweed	Native
Rosaceae	*Rubus fruiticosus* sp. agg	Blackberry	Non-native**
Typhaceae	*Typha orientalis*	Broadleaf Cumbungi	Native***
Verbenaceae	*Verbena* sp., poss. *V. bonariensis*	Purpletop	Non-native

* Pasture grasses and weeds in ephemeral habitat. May contain other grass-like plants (e.g. sedges/rushes) and occasional broadleaf weeds
** Weed of national significance
*** Native, through considered a water weed

3.2.6 Water Quality

The mean water quality data for the December 2011, April 2013, March 2017 and December 2018 surveys are presented in **Annexure D**. It should be noted that the water quality data presented here is limited and that more detailed surface water quality data is presented and discussed by WRM (2020). The main findings were as follows.

- Conductivity ranged between 347 and 1517 µS/cm and exceeded the upper (ANZECC/ARMCANZ 2000) Default Trigger Value (DTV) at each site aside from Site 7 in December 2011. Elevated conductivity may be due to runoff containing high levels of dissolved salts or local geology and may also be associated with evaporation of disconnected pools during periods of low flow. The absence of riparian vegetation and associated root systems may also reduce the retention of runoff in sediments, resulting in increased rates of runoff entering creeks, especially during high rainfall events when surrounding land may become saturated with water.
- pH ranged between 6.9 and 8.1. It exceeded the upper DTV at Site 2 in April 2013. pH influences the availability and solubility of all chemical forms and may contribute to detrimental effects associated with elevated nutrient concentrations. For example, a change in pH may increase the solubility of phosphorus or nitrates, increasing their availability and encouraging plant growth resulting in a greater long-term demand for dissolved oxygen. Small changes in pH are not, however, likely to have a direct impact on aquatic life.
- ORP ranged between 94 mV and 242 mV. The oxidative/reductive state of water can predict the dominant type of microorganisms present. Strictly aerobic microorganisms are generally active at positive values, while anaerobes are generally active at negative values. ORP values between 300 and 340 mV are generally considered ideal for freshwater ecosystems. With higher concentrations of DO, the stream will be oxidizing and have a positive ORP. Similarly, at higher pH levels, systems will tend more toward oxidation, and at lower pH levels, systems will tend toward reduction (Baird and Cann 2005).
- DO ranged between 55.2 % and 93.1 % saturation and was below the lower DTV on several occasions. In April 2013 DO ranged between 63.0 % and 101.6 % saturation and was below the lower DTV at each site aside from Site 2. Low DO may be indicative of elevated nutrient levels. Fertilisers and/or faecal matter from livestock contain nutrients such as nitrates and if these pollutants enter aquatic ecosystems they can encourage the growth and proliferation of oxygen-consuming algae.
- Turbidity ranged from 0.0 ntu to 39.7 ntu and was above the upper DTV on several occasions. Elevated turbidity may be due to rainfall, which can mobilise sediments and result in elevated turbidity. Bank erosion may also contribute to elevated turbidity due to the release of sediment. This may be exacerbated during high flows and relatively high water velocities following rainfall. Trampling by livestock, lack of riparian vegetation and surrounding land use may also influence turbidity levels.

3.2.7 AUSRIVAS Macroinvertebrates

3.2.7.1 General Findings

A total of 51 macroinvertebrate taxa were identified in AUSRIVAS edge samples collected in December 2011, 37 from those collected in April 2013, 35 from those collected in March 2017 and 18 from those collected in December 2018 (Annexure E). Physidae (freshwater snails), Caenidae (squaregill mayflies), Dytiscidae (diving beetles), Chironominae (non-biting midge), Coenagrionidae (damselflies) and Corixidae (water bugs) were common and found at all or most (two thirds or more sites), sites sampled in December 2011, April 2013 and March 2017 (i.e. when six or more sites sampled). These taxa are relatively pollution tolerant (Gooderham and Tsyrlin 2002). Corixidae are air breathers and have an adult flying stage that helps them inhabit waters with small concentrations of DO and helps them utilise ephemeral water bodies. Physidae are also air breathers and particularly pollution-tolerant. It should be noted that these taxa are not restricted to pollution-affected areas. Leptoceridae (caddisflies), Leptophlebiidae (prong-gilled mayflies), and Atyidae (freshwater shrimp) were also common and found in at least half the sites sampled in December 2011, April 2013 and March 2017. Leptophlebiidae are relatively sensitive to pollution and have been assigned a SIGNAL grade value of 8. All other taxa sampled, excluding Telephlebiidae (a family of dragonflies), which was sampled at Site 4 on Lawsons Creek in December 2011 and has been assigned a SIGNAL grade value of 9, have been assigned SIGNAL grade values of 6 to 1.

Several taxa sampled during December 2011 were absent from samples collected in April 2013 and March 2017. However, the majority of these taxa were sampled from only one site in December 2011. Four taxa sampled in April 2013 were not sampled in December 2011.

3.2.7.2 AUSRIVAS Indices

The results of the AUSRIVAS analysis are presented in **Table 3.5**. The analysis indicates the following.

- The condition of the macroinvertebrate assemblage sampled in Hawkins Creek has ranged from band B (significantly impaired compared with the reference condition) to band X (richer macroinvertebrate fauna than the reference condition) and that sampled in Lawsons Creek has ranged from Band A (equivalent to reference condition) to Band B. Examination of OE50 Taxa Scores suggested that there was an overall slight reduction in the health of the macroinvertebrate fauna in both creeks between December 2011 and April 2013. In December 2011, the health of the macroinvertebrate fauna supported by Hawkins Creek appeared to be better than that supported by Lawsons Creek. In April 2013, there was little difference between the health of the macroinvertebrate fauna sampled in each of the two creeks, and in March 2017 there was a suggestion that creek health was better in Lawsons Creek.
- The SIGNAL2 Index at sites on Hawkins Creek ranged from 3.1 (indicative of severe pollution) to 4.1 (indicative of moderate pollution) and that at sites on Lawsons Creek ranged from 2.6 to 4.2. There was little difference in SIGNAL2 Indices between the sampling events.

- The OE0 SIGNAL Score at sites on Hawkins Creek ranged from 0.87 to 1.00 and the OE0 SIGNAL Score at sites on Lawsons Creek ranged from 0.87 to 1.09, indicating that the SIGNAL2 Index for these sites was close to that expected at reference sites selected by the AUSRIVAS model.

Table 3.5
Results of AUSRIVAS Analysis on Macroinvertebrate Data Collected from Sites in Hawkins and Lawsons Creeks in December 2011, April 2013, March 2017 and December 2018

Site	OE50 Taxa Score	Band Score	SIGNAL2 Index	OE0 Signal Score
December 2011				
Hawkins Creek				
Site 1	1.29	X	3.8	0.93
Site 2	1.09	A	3.8	1.00
Site 3	1.09	A	3.5	0.92
Site 7	ns	ns	ns	*ns*
Lawsons Creek				
Site 4	0.91	A	4.2	0.92
Site 5	1.09	A	3.9	1.02
Site 6	0.82	B	3.6	0.97
April 2013				
Hawkins Creek				
Site 1	0.80	B	3.8	0.92
Site 2	0.79	B	3.7	0.93
Site 3	0.96	A	3.6	0.93
Site 7	0.70	B	4.1	0.97
Lawsons Creek				
Site 4	0.88	A	4.2	1.01
Site 5	0.70	B	3.4	0.87
Site 6	0.87	A	3.5	0.90
March 2017				
Hawkins Creek				
Site 1	0.70	B	3.8	1.03
Site 8	0.61	B	3.3	0.87
Site 9	0.70	B	3.1	0.94
Lawsons Creek				
Site 5	0.87	A	3.6	0.93
Site 6	0.78	B	3.4	0.91
Site 10	nr	nr	2.6	nr
Dec 2018				
Lawsons Creek				
Site 11a (Rep 1)	1.00	A	3.8	1.08
Site 11b (Rep 2)	0.82	B	3.9	1.09
ns = not sampled, nr = not reported due to data outside the experience of the model				

3.2.8 Fish

The results of the April 2013, March 2017 and December 2018 fish surveys are presented in **Table 3.6, Table 3.7** and **Table 3.8**, respectively. In total, four native and three introduced fish species were recorded along with three macroinvertebrate taxa.

Table 3.6
Numbers and species of fish and macroinvertebrates caught using backpack electrofishing at sites on Hawkins and Lawsons Creeks 3 to 5 April 2013

Scientific Name	Common Name	Site 1	Site 2	Site 3	Site 7	Site 4	Site 5	Site 6
		Hawkins Creek				Lawsons Creek		
Fish								
Carassius auratus	Wild goldfish				1	5	3	
Cyprinus carpio	Carp		1			1		
Gadopsis marmoratus	Rive blackfish						1	
Galaxias sp.*	Galaxiid					2		
Gambusia holbrooki	Eastern gambusia	>100	>100	>100		>100	>100	>100
Hypseleotris spp.	Carp gudgeons	11	4	18		1	12	
Retropinna semoni	Australian smelt						2	
Macroinvertebrates								
Cherax sp.	Yabbie	P				P	P	P
Macrobrachium sp.	Freshwater shrimp					P	P	P
Family: Atyidae	Freshwater shrimp	P	P	P	P	P	P	P
Grey shading indicates non-native species, P = present								

Table 3.7
Numbers and Species of Fish and Macroinvertebrates caught using Backpack Electrofishing at Sites on Hawkins and Lawsons Creeks 21 to 24 March 2017

Scientific Name	Common Name	Site 1	Site 8	Site 9	Site 5	Site 6	Site 10
		Hawkins Creek			Lawsons Creek		
Fish							
Carassius auratus	Wild goldfish			>25	5	3	
Cyprius carpio	Carp			1			
Gadopsis marmoratus	River blackfish	2					
Gambusia holbrooki	Eastern gambusia	>100	>100	>100	>100	>100	>100
Hypseleotris spp.	Carp gudgeons	1		1	1		
Retropinna semoni	Australian smelt				1		
Macroinvertebrates							
Cherax sp.	Yabbie	P	P	P	P	P	P
Family: Atyidae	Freshwater shrimp	P	P	P	P	P	P
Grey shading indicates non-native species, P = present							

Table 3.8
Numbers and species of fish and macroinvertebrates caught using backpack electrofishing at Site 11 on Lawsons Creek 10 December 2018

Scientific Name	Common Name	Site 11
Lawsons Creek		
Fish		
Carassius auratus	Wild goldfish	2
Gambusia holbrooki	Eastern gambusia	>100
Macroinvertebrates		
Cherax sp.	Yabbie	P
Family: Atyidae	Freshwater shrimp	P
Grey shading indicates non-native species, P = present		

One river blackfish (*Gadopsis marmoratus*), also known as northern river blackfish, was caught at Site 5 on Lawsons Creek in April 2013 and March 2017 and at Site 1 on Hawkins Creek in March 2017 (**Plate 14a**). This species is known from the Murray and the mid to upper reaches of the Murrumbidgee, Macquarie, Lachlan, Gwydir and Namoi drainages in NSW (MDBA 2011g). It is found in a diverse range of stream types, from upland and lowland small creeks to large rivers, and prefers habitats with good instream cover such as woody debris, aquatic vegetation or boulders (woody debris was relatively common at Site 5). Although not listed as a threatened species in NSW (the Snowy River Catchment population of river blackfish is listed as an endangered population under the FM Act), river blackfish were once considered to be highly threatened across the Murray-Darling Basin. Its numbers and distribution have declined and its abundance in some locations appears to fluctuate considerably from year to year. Southern Australia populations are considered precarious and threatened (MDBA 20011g). Major threats to this species include smothering of eggs and spawning sites due to sedimentation and interaction with invasive fish species. Habitat modifications such as cold-water pollution, de-snagging (i.e. the FM Act listed Key Threatening Process: Removal of large woody debris from NSW rivers and watercourses) and altered flows due to river regulation are also likely to impact on this species.

Other native fish species caught included Australian smelt (*Retropinna semoni*) and two Galaxiids, likely mountain galaxias (*Galaxias olidus*) in Lawsons Creek in April 2013 and several carp gudgeons (*Hypseloetris* spp.) in Hawkins and Lawsons Creeks. Australian smelt and carp gudgeons are common and widespread in the Murray-Darling Basin. Mountain galaxias, while widespread, have experienced reductions in numbers in lowland and upland watercourses, likely the result of predation from trout. Carp gudgeons are a relatively undescribed genus and genetic studies have shown that at least four taxa are present, as well of a range of hybrids (MDBA 20011h).

The invasive eastern gambusia (*Gambusia holbrooki*) (**Plate 14b**) was by far the most numerous species, occurring in large numbers at each site sampled during each survey. Predation by eastern gambusia is listed under the BC Act as a Key Threatening Process. The introduced wild goldfish (*Carassius auratus*) (**Plate 14c**) and carp (*Cyprinus carpio*) (**Plate 14d**) were also present in Hawkins and Lawsons Creeks. Eastern gambusia (outside the greater Sydney region) and carp are Class 1 and Class 3 noxious species, respectively. Numerous eastern gambusia were also seen and inadvertently caught in AUSRIVAS dip nets at all sites in December 2011 and April 2013. A wild goldfish was also caught in a dip net at Site 6 in December 2011 and at Site 11 during electrofishing in December 2018. **Table 3.9** provides a summary of the management actions that apply for each class of live noxious fish in NSW.

a)

b)

c)

d)

Plate 14 a) River black fish (*Gadopsis marmoratus*) caught at Site 5 in Lawsons Creek, b) eastern gambusia (*Gambusia holbrooki*) caught in abundance at each site, c) wild goldfish (*Carassius auratus*) caught at Site 7 in Hawkins Creek and Sites 4 and 5 in Lawsons Creek, d) carp (*Cyprinus carpio*) at Site 1 on Hawkins Creek and at Site 4 on Lawsons Creek

Table 3.9
Summary of the Rules and Management Actions that apply for each Class of Live Noxious Fish in NSW

	Possession					
Class	**Aquarium**	**Garden Pond**	**Farm Dam**	**Sale**	**Destruction Required**	**Management**
1	No	No	No	No	Yes	Strategies developed for rapid response to any outbreaks.
2	Yes	No	No	No	Yes* *destruction of fish is not required if kept in fully contained aquarium	Control/Eradication where possible
3	Yes	Yes	No	Yes	No	Education and awareness campaign to discourage possession and sale.

3.2.9 Stygofauna

The full results of the stygofauna sampling, including identified stygofauna and non-stygofauna taxa, are presented in **Annexure H**. The non-stygofauna taxa are surface dwelling taxa, including terrestrial taxa that likely entered the bore water accidentally, possibly washed in during wet weather events or blown in, and aquatic taxa associated with surface waters, and are not considered in this assessment.

Stygofauna were found in nine of the 23 bores sampled, with a total of five stygofauna taxa identified (**Table 3.10**). *Psammaspides* sp. (Family: Psammaspididae) (also known as anaspid shrimps) and Clyclopidae (a family of crustaceans of the sub class Copepod) were the most widespread taxa and were each found in five bores. Paramelitidae (a family of amphipods) were found in two bores, and Candonidae and Cyprididae (families of ostracod) were found in one and two bores, respectively. All stygofauna taxa are typical of alluvial aquifers in eastern Australia. Psammaspididae and Paramelitidae have been found in coarse alluvial aquifers known from the alluvium of the Peel River near Tamworth, the Hunter Valley near Aberdeen, and the Macquarie River near Dubbo. Cyclopoid copepods are one of the most common taxa encountered in Australian alluvial aquifers. Copepods can be endemic to individual aquifers at the species level, but are generally fairly widespread within aquifers (Dr Peter Hancock, Ecological Australia Pty Ltd, Pers. Comm.). Both of the ostracod families are widespread through eastern Australia. Groundwater representatives occur in many alluvial aquifers between the Pioneer Valley in Queensland, and the Hunter Valley upstream of Singleton.

Table 3.10
Summary of groundwater quality data in bores associated with Hawkins and Lawsons Creeks (or their tributaries) alluvium and other aquifers on the Mine Site (Site) and outside the Mine Site (Regional)

Indicator	Alluvium	Site	Regional
EC (µS/cm)			
Count	123	518	184
Mean	802.0	1420.3	1819.9
Min	121.0	153.0	310.0
Max	2620.0	5680.0	4060.0
pH			
Count	123	518	187
Mean	6.7	6.9	7.2
Min	5.6	5.2	6.3
Max	7.7	8.9	8.6
Adapted from Jacobs (2020). See Table 3.11 for specific bores and further detail			

Psammaspides sp. was the only taxon to be identified from bores within, or close to, the open cut pit, albeit in relatively low abundance (1 individual was sampled from each of bores BGW18 and BGW20). All other stygofauna were identified from bores adjacent to Lawsons Creek (BGW39 and BGW56) and Hawkins Creek (BGW48, BGW49 and BGW54) and from those associated with the springs to the west of the open cut pit (BGW16 and BGW17). The bores adjacent to Hawkins Creek and one adjacent to Lawsons Creek (BGW56) targeted shallow (1 m to 7 m below ground) alluvial aquifers associated with the creeks. BGW39 on Lawsons Creek targeted deeper (30 m to 42 m below ground) coal measures over fractured rock.

Table 3.11
Stygofauna Taxa Identified from Samples Collected from GROUNDWATER bores on and Adjacent to the Mine Site April, June and December 2013 and March 2017

Bore:	**12**	**16**	**17**	**18**	**20**	**25**	**27A**	**27**	**29**	**39**	**44**	**46**	**48**	**49**	**50**	**51**	**53**	**54**	**55**	**56**	**102**	**106**	**107**
	(1)	**(4)**	**(4)**	**(2)**	**(4)**	**(1)**	**(1)**	**(2)**	**(1)**	**(3)**	**(1)**	**(2)**	**(4)**	**(3)**	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(1)**	**(1)**	**(2)**	**(2)**
Taxa																							
Psammaspides sp.				1	1								13	14				1					
Family: Paramelitidae													1	1									
Family: Cyclopidae		6	>100										>100	78						15			
Family: Candonidae										2													
Family: Cyprididae		1	>180																				
Bore Characteristics																							
Drilled date	Un	Un	Un	Sep 2012	Sep 2012	Sep 2012	Un	Jul 2012	Sep 2012	Sep 2013	Un	Sep 2012	Oct 2012	Oct 2012	Oct 2012	Oct 2012	Oct 2012	Oct 2012	Un	Un	Un	Un	Un
Screened interval (mbg)	Un	Un	Un	45-48	42-48	Un	Un	58-70	1-6	30-42	73-79	168-174	1-6	1.5-3.5	21-27	3-9	3-9	2.5-6.5	Un	Un	Un	Un	Un
Screen mesh diameter (mm)	Un	Un	Un	2	2	2	Un	2	2	2	Un	2	2	2	2	2	2	2	Un	Un	Un	Un	Un
Aquifer type	Un	FR	FR	RV	RV	Un	Un	SA	Un	CM	VB	RV	FR/A	FR/A	FR/A	FR/A	FR/A	FR/A	Un	Un	Un	FR	Un
Depth to water level (mbg)	Un	0.0-0.3	0.0-0.5	9.4	1.3-2.0	9.3	Un	18.6-18.7	5.8-7.0	6.0-7.5	76-78	24.9	2.7-3.5	4.0	3.3	3.6-4.1	2.3	4.5-7.2	Un	Un	55.7	4.9	18.6-18.8
Comments		Spring	Spring									Anoxic			Anoxic								
Designation in Jacobs (2020)	Sit	Sit	Si	Si	Si		Si	Si	Si	Si	Si	Si	Alu	Alu	Si	Alu	Alu	Alu	Reg	Reg			

ns = Not sampled, nt = Sampled, but no taxa caught, Un = Unknown, mbg = metres below ground
Aquifer type: CM = Coal measures over fractured rock, FR =Fractured Rock, FR/A = Fractured rock and alluvium, SA = Shale and alluvium, RV = Rylstone Volcanics, VB = Volcanic Breccia
Designation: Si = Site, Alu = Aluvium, Reg = Regional. Used for summary of groundwater quality data **Table3.10**
Numbers in parenthesis below bore number indicate number of sampling events.

Those within, or close to, the open cut area targeted Rylstone Volcanic aquifers 42 m to 48 m below ground. The construction details of bores BGW16 and BGW 17, which are associated with springs, are unavailable. The water level in these bores was at, or very near to, the surface when sampled for stygofauna. The distributions of four of the five taxa (Paramelitidae, Cyclopidae, Candonidae and Cyprididae could suggest that taxa are found only in bores associated with Hawkins Creek, Lawsons Creek and springs just downstream of the TSF, respectively. However, in the cases of Paramelitidae and Candonidae, such conclusions must be made with caution due to the low number of individuals caught. The aquifer, or aquifers, associated with bores BGW48 and BGW49 appear to support a relatively diverse stygofauna assemblage, with three of the five stygofauna taxa present in these bores. Psammaspides sp., found in two bores just down gradient of the open cut pit, were also found in bores associated with Hawkins Creek. No stygofauna were sampled from bores within the proposed open cut pit area.

Groundwater EC and pH data are summarised in **Table 3.10**. It is evident that the EC within alluvium aquifers appears generally lower than that within aquifers within the Mine Site (many bores here target coal measures) and outside the Mine Site. It is noted that BGW56 is located outside the Mine Site, through is in close proximity to Lawsons Creek. Differences in EC likely explain some of the observed differences in the composition and abundance of stygofauna, with greater EC generally less suitable. There was little evidence of any substantial difference in pH between these areas.

3.3 SUMMARY

3.3.1 Aquatic Habitat and Biota

The results of the field inspections are summarised as follows and in **Table 3.12**.

- Hawkins and Lawsons Creeks appear to be intermittent, with aquatic habitat consisting of a series of disconnected pools following extended periods of low rainfall. Many of the tributaries flowing through the Mine Site were not flowing despite recent rainfall and are probably highly ephemeral.
- Both creeks flow through disturbed habitat of relatively low ecological value.
- The limited water quality data collected suggested the water quality of Hawkins and Lawsons Creeks is moderate to poor, with low dissolved oxygen and elevated turbidity and electrical conductivity.
- Both creeks support a diverse macroinvertebrate fauna, suggesting relatively rich fauna, but assemblages were dominated by pollution tolerant species.
- Several anthropogenic barriers to fish passage were identified, but no natural barriers (e.g. waterfalls) were observed.
- The historical clearing of native riparian vegetation and surrounding agricultural land practices are contributing, if not primary, causes of localised environmental disturbance.
- Several native and introduced fish species were sampled in Hawkins and Lawsons Creeks. None of the native species are listed as threatened although one, river blackfish, appears to have experienced a reduction in abundance across its range due to anthropogenic disturbance to its habitat and these creeks could provide important habitat for this species.

- Springs adjacent to the Mine Site appear to support artificial impoundments which in turn support some relatively limited aquatic habitat. Price Creek also appears to support some limited aquatic habitat.
- The stygofauna assemblage present on and around the Mine Site appears to consist of relatively common and widespread taxa.

Table 3.12
Summary of Aquatic Habitat and Biota in the Study Area

Page 1 of 3

Component of Aquatic Ecology	**Description**	
Creeks:	**Lawsons Creek**	**Hawkins Creek**
Aquatic Habitat and Vegetation		
Riparian vegetation	Both creeks flow through disturbed habitat of relatively low ecological value. The historical clearing of native riparian vegetation and surrounding agricultural land practices are contributing, if not primary, causes of localised environmental disturbance. Riparian vegetation is minimal, few trees and large shrubs. Non-native species dominate.	
Aquatic vegetation (macrophytes)	Abundant and predominantly native species	
RCE score	20 to 23	24 to 26
	Consistent low scores in categories associated with the health of riparian vegetation and bank stability,	
Key Fish Habitat		
Key Fish Habitat (FM Act)	Yes (intermittent creek with disconnected pools)	Yes (intermittent creek with disconnected pools)
Fish habitat sensitivity type (NSW DPI (Fisheries) 2013a)	Type 1 (supports native aquatic plants and large wood debris)	Type 1 (supports native aquatic plants and large wood debris)
Fish habitat class (NSW DPI (Fisheries) 2013a)	Class 2 - Moderate fish habitat (Non-permanently flowing (intermittent) stream)	Class 2 - Moderate fish habitat (Non-permanently flowing (intermittent) stream)
Fish		
Fish habitat (general)	Perennial creek. Generally soft sediment, with some bedrock / boulders and coarse sediment in places. Some woody debris. Macrophytes abundant.	Perennial creek. Generally soft sediment, with some bedrock / boulders. Little or no woody debris. Macrophytes abundant.
Fish Species	Native and non-native species. None of these are listed as threatened, though one identified native species (river blackfish) appears to be experiencing a reduction in numbers and occurrence across its range due to anthropogenic disturbance to its habitat.	
Fish passage	Several anthropogenic barriers to fish passage were identified which would impede fish passage during low to moderate flows, but probably not during high flows / flood events. No natural barriers (e.g. waterfalls seen)	

Table 3.12 (Cont'd)
Summary of Aquatic Habitat and Biota in the Study Area

Page 2 of 3

Component of Aquatic Ecology	Description	
Creeks:	**Lawsons Creek**	**Hawkins Creek**
Macroinvertebrates		
Results of AUSRIVAS sampling	Both creeks support a diverse macroinvertebrate fauna, and, although this appears to be dominated by pollution tolerant taxa, these taxa were predicted to be present by the AUSRIVAS model. In any case, pollution tolerant taxa would likely also be present in undisturbed creeks. Some pollution sensitive taxa were also identified.	
Water Quality		
Water quality data compared against (ANZECC/ARMCANZ 2000) DTVs for upland watercourses in southeast Australia	The limited water quality data collected during the aquatic ecology surveys suggest that the water quality of Hawkins and Lawsons Creeks is moderate to poor, with low dissolved oxygen and elevated turbidity and EC.	
Walkers Creek, Blackmans Gully and Price Creek		
Aquatic Habitat and Biota	These ephemeral watercourses provide very limited aquatic ecology. A single pool was observed in Walkers Creek in March 2017. Price Creek supports some hydrophilic vegetation (sedges) though this is common and widespread and not of conservation significance. Blackmans Gully was dry during each of the site visits and would likely flow for a short period after rainfall only. These watercourses are unlikely to provide any substantial habitat for fish, but would provide some habitat for aquatic macroinvertebrates and potentially also refuge for amphibians.	
Key Fish Habitat		
Fish habitat sensitivity type (NSW DPI (Fisheries) 2013a)	Blackmans Gully and Walkers Creek: Type 3 (Ephemeral, no aquatic plants present) Price Creek: Type 2 (intermittent and supports native wetland vegetation, though not in-stream aquatic plants)	
Fish habitat class (NSW DPI (Fisheries) 2013a)	Class 3 (connected to Class 1 waterways)	
Battery Creek Spring, BSW25, BSW27 and BSW29 and Associated Farm Dams		
Aquatic Habitat and Vegetation	These springs provide aquatic habitat in the form of apparently permanent freshwater impoundments and support several aquatic macrophytes.	
Aquatic Fauna	These springs and associated impoundments likely also support aquatic macroinvertebrates and frogs, and possibly native species of fish. Eastern gambusia (a non-native fish) was observed in one impoundment.	

Table 3.12 (Cont'd)
Summary of Aquatic Habitat and Biota in the Study Area

Page 3 of 3

Component of Aquatic Ecology	Description	
Creeks:	**Lawsons Creek**	**Hawkins Creek**
Key Fish Habitat		
Fish habitat sensitivity type (NSW DPI (Fisheries) 2013a)	Not KFH, artificial waterbodies not included	
Fish habitat class (NSW DPI (Fisheries) 2013a)	Class 3 – all associated drainage lines	
Springs BSW18, BSW23 and BSW24 and Associated Pools and Drainage Lines		
Aquatic Habitat and Vegetation	Very limited, habitat consisted of isolated pools or waterlogged drainage lines with no aquatic plants. This habitat is likely to be highly ephemeral.	
Aquatic Fauna	None observed, though potential for some aquatic macroinvertebrates and frogs to be present.	
Key Fish Habitat		
Key Fish Habitat (FM Act)	No	
Fish habitat sensitivity type (NSW DPI (Fisheries) 2013a)	Not KFH, artificial waterbodies not included Type 3 (associated third order drainage lines)	
Fish habitat class (NSW DPI (Fisheries) 2013a)	Class 3 – all associated drainage lines	
Open Cut Pit and Adjacent Area (BGW18 and BGW20)		
Stygofauna	Stygofauna appear largely absent from the aquifers sampled in and around the open cut pits. Only two individuals of one taxon identified from two bores (BGW18 and BGW20) sampled in this area. These are located just outside of the open cut pits. This taxon was present also in bores adjacent to Hawkins Creek.	
Aquifers associated with Lawsons (BGW39 BGW56) and Hawkins Creek (BGW48, BGW49 and BGW54)		
Stygofauna	Four stygofauna taxa sampled from the groundwater bores adjacent to Hawkins and Lawsons Creeks, sometimes in relatively high abundance. Two unique to these bores.	
Springs to the West of the Open Cut Pit (BGW16 and BGW17)		
Stygofauna	Two taxa identified from the two bores associated with the springs to the west of the open cut pits. One unique to these bores	

3.3.2 Threatened Species, Populations and Communities

The aquatic threatened species and populations that could potentially occur and their likelihood of occurrence within the Study Area are summarised in **Table 3.13**. Likelihood of occurrence was determined by examining historical species records, published distributions and habitat preferences and the availability of appropriate habitat in the Study Area.

Table 3.13
Relevant Aquatic Species, Populations and Communities listed as Threatened under State and Federal Legislation and their Likelihood of Occurrence in the Study Area

Species or Population	BC Act status	FM Act status	EPBC Act status	Likelihood of occurrence
Species				
Australian grayling			Vulnerable	Unlikely
Flathead galaxias		Critically Endangered	Critically Endangered	Unlikely
Macquarie perch		Endangered	Endangered	Unlikely
Murray cod			Vulnerable	Possible
Silver perch		Vulnerable		Unlikely
Southern Purple Spotted Gudgeon		Endangered		Possible
Southern pygmy perch		Endangered		Unlikely
Trout cod		Endangered		Unlikely
Invertebrates				
Giant dragonfly	Endangered			Unlikely
Murray crayfish		Vulnerable		Unlikely
Darling River snail		Critically Endangered		Unlikely
Hanley's river snail		Critically Endangered		Unlikely
Populations				
Western population of olive perchlet		Endangered		Unlikely
Murray-Darling Basin population of eel tailed catfish		Endangered		Possible
Communities				
Lowland Darling Ecological Community		Endangered		Does not occur

The relatively recent occurrence of purple spotted gudgeon and eel tailed catfish in the Macquarie River catchment suggests that these species could also be present in the Study Area. Although habitat within sections of Hawkins and Lawsons Creeks is likely to provide at best sub-optimal habitat for Murray cod, there is a relatively recent record of this species just downstream in the Cudgegong River. For these reasons, Assessments of Significance have been undertaken for these species and the population of eel tailed catfish.

Although relatively recent records of silver perch exist from the Cudgegong River and it has been stocked in Lake Burrendong and Lake Windermere, its habitat requirements and its predicted distribution suggest it is unlikely to occur within the Study Area. Similarly the habitat requirements of trout cod and its predicted regional distribution suggests it is unlikely to occur within the Study Area. Although Murray crayfish have been recorded from the Cudgegong River any crayfish within the Study Area are likely to have been translocated outside of their natural distribution and the Study Area is not included in its predicted distribution. The current distribution ranges of Macquarie perch and Australian grayling indicate that they are very unlikely to occur in Study

Area. The current and predicted distribution of flathead galaxias, Murray hardyhead, olive perchlet, southern pygmy perch, Darling River snail and Hanley's river snail, and the habitat requirements of giant dragonfly, indicate that they are very unlikely to occur in the Study Area. For these reasons, the preparation of Assessments of Significance for these species and populations is considered unnecessary. Watercourses within and adjacent to the Study Area do not form part of the Lowland Darling Ecological Community, and this does not need to be considered further.

4. IMPACT ASSESSMENT

4.1 INTRODUCTION

In this Impact Assessment, the potential direct, indirect and cumulative impacts on aquatic habitats, quality of water, aquatic biota including GDEs and threatened aquatic species that may arise during the construction, operation, decommissioning and rehabilitation phases of the Project are described. The assessment of potential impacts on aquatic ecology arising from the Project is based on:

- The detailed description of the Project presented in RWC (2020);
- The description of the existing biophysical environment of surface aquatic ecology and GDEs presented in Section 3; and
- Assessment of potential impacts on surface water (WRM, 2020) and groundwater (Jacobs, 2020).

The potential impacts associated with construction, operation, and decommissioning stages relevant to aquatic ecology are described in Sections 4.2, 4.3 and 4.4, respectively.

4.2 SITE ESTABLISHMENT AND CONSTRUCTION ACTIVITIES

4.2.1 Potential Impacting Processes

Impacts to aquatic habitat and biota during the site establishment and construction stage of the Project have potential to arise from:

- Direct displacement of aquatic habitat, biota and any riparian vegetation beneath the footprint of open cut pits and various other mining-related facilities and storages;
- Changes in water quality (particularly elevated suspended sediments (SS)) and increased sedimentation in waterways due to potential mobilisation of sediments from areas disturbed following earthworks, soil stripping and vegetation clearance and from soils stockpiled during construction. Elevated SS and turbidity may be detrimental to aquatic habitat and biota via smothering and alteration of the substratum, although turbidity may be naturally elevated at certain times of year. SS also has potential to accumulate on and abrade fish and macroinvertebrate gill structures and the feeding apparatus of filter feeding macroinvertebrates (such as simuliids and chironomids caught in the AUSRIVAS samples) resulting in impaired fitness and potentially mortality.
- Accidental release of chemicals and fuels (e.g. oils, hydraulic fluids and fuel from construction equipment) and sewage could result in the input of hydrocarbon, metal contaminants and / or nutrients into watercourses. The accidental release into waterways of any pesticides, herbicides and/or sewage could also affect aquatic biota. Water soluble components of petroleum hydrocarbons include a variety of compounds that are potentially toxic to aquatic life. Pesticides and herbicides used for weed or pest control can also be particularly toxic to aquatic life. These could enter waterways following accidental release, if stored or used incorrectly.

- Proliferation and spread of aquatic pest species in waterbodies (e.g. raw water pond and pit dewatering pond associated with the processing plant) established during the site establishment and construction activities.
- Temporary full or partial barrier to fish passage in Lawsons Creek during construction of the relocated Maloneys Road. There would be no impacts to fish passage in perennial watercourses due to the construction of the water supply pipeline as it would be constructed using underbore techniques beneath perennial watercourses or ephemeral watercourses that contain significant water flows. There would be no change to watercourse profiles. In the event temporary diversions or coffer dams are required to manage minor flows, NSW DPI (Fisheries) would be consulted on appropriate methodology and no permanent barriers to fish passage would occur.
- Reductions in surface flow within Hawkins and Lawsons Creeks due to interception of surface water on site would be substantially less than during operation and would not be expected to result in significant impacts to aquatic ecology. Changes due to reductions in baseflow associated with groundwater drawdown would not occur as the open cut pits would not be excavated during the construction phase.

4.2.2 Mitigation Measures

Impacts associated with site establishment and construction works in the vicinity of watercourses could be minimised by:

- Limiting the area of all riparian zone and aquatic habitat disturbed where feasible and reasonable, particularly in the vicinity of Hawkins and Lawsons Creeks;
- Developing and implementing an Erosion and Sediment Control Plan with respect to protection of aquatic habitats and biota immediately downstream of the construction areas;
- Adhering to recommendations outlined in the surface water and groundwater assessments, including development of storage and transfer infrastructure in the most appropriate and feasible manner for the control and treatment of water on site;
- Maintaining a bunded area for storage of fuels, oils, refuelling and appropriate maintenance of vehicles and mechanical plant;
- Prohibiting refuelling, washing and maintenance of vehicles and plant within 30 m of all watercourses, where feasible and reasonable; and
- Reporting spillages to the appropriate officer and immediately deploying spill containment kits to restrict their spread into or within drainage lines.

The Erosion and Sediment Control Plan should be prepared in accordance with Managing Urban Stormwater: Soils and Construction, Volume 2E Mines and Quarries (DECC 2008) and should include a description of the erosion and sediment control structures that are to be used to minimise soil erosion and the potential for the transport of sediment to downstream waters. Temporary erosion and sediment control measures such as sediment fences, sandbag weirs, temporary drains, and temporary silt traps should be installed prior to all construction works. Maintenance of erosion and sediment controls and adaptive management should be undertaken throughout the Project life to ensure they continue to function effectively.

Construction works undertaken in the vicinity of watercourses should be undertaken in accordance with the NSW DPI Policy and Guidelines for Fish Habitat Conservation and Management (NSW DPI 2013a). These indicate that:

- Where feasible, riparian buffer zones should be established and maintained in or adjacent to Type 1 or 2 Habitat (i.e. those freshwater fish habitats considered to be highly or moderately sensitive) or Class 1-3 waterways (i.e. those containing major, moderate or minimal fish habitat). It is noted also that the condition of riparian vegetation in the Study Area is generally poor.
- Riparian buffer zones should be designed to maintain lateral connectivity between aquatic and riparian habitat;
- Where feasible, the width of the riparian buffer zone should be based on the habitat type and waterway class, with buffer zones of 100 m, 50 m and 10-50 m being applicable respectively to highly sensitive freshwater fish habitats (Type 1) or waterways containing major fish habitat (Class 1), moderately sensitive freshwater fish habitats (Type 2) or waterways containing moderate fish habitat (Class 2), and minimally sensitive fish habitats (Type 3) or waterways containing minimal fish habitat (Class 3/4), respectively; and
- Existing riparian vegetation should be retained in an undamaged state where possible and disturbed areas should be revegetated with local native species and monitored to ensure revegetation is successful.

4.2.3 Potential Impacts on Aquatic Habitat and Biota

4.2.3.1 Direct Displacement

Review of Lue + Botobolar 1:25000 NSW DPI stream order mapping (NSW DPI 2017) identifies that approximately 10 km of first and second order and 5 km of third order and greater watercourses would be displaced directly beneath the footprint of the various components of the Project (open cut pit, PP, TSF, WRE, low grade oxide ore) (**Table 4.1**). This includes 7 km beneath the TSF, 2 km within the open cut pit and 2 km beneath the WRE and Southern Barrier. There would be no displacement of Hawkins Creek, Lawsons Creek or Price Creek and activities have been set back from these watercourses to avoid any direct impacts. The one exception is the construction of an additional crossing on Lawsons Creek that would result in the modification of approximately 2.7 m by 2.4 m (6.5 m^2) of creek. The creek habitat in this section of watercourse was comparable to that observed elsewhere, i.e. disconnected pools with disturbed riparian vegetation.

Given the abundance of comparable watercourse habitat in the Study Area and beyond, the impact to aquatic habitat and associated biota as a result of the direct displacement of these sections of watercourse represents a relatively very minimal to negligible impact in the context of the local and regional area. The value of the aquatic habitat in the majority of these watercourses is also low, consisting of largely ephemeral habitat that would be available only for short periods following rainfall, and thus, would not provide permanent refuge for aquatic biota. Although some of the more permanent (potentially due to association with springs) farm dam and pool habitat may be displaced also, these would also remain abundant in the local and regional area, and, if displaced, their loss is not expected to result in any more than very minor impacts to the availability of such habitat in the Study Area and beyond. Aquatic biota such as plants (observed only in some of the farm dams), macroinvertebrates and any fish, associated with these ephemeral watercourse and disconnected pool habitat may also be lost, although given the abundance of these habitats in the Study Area and beyond, any loss is not expected to result in more than very minor impacts to population sizes at these extents. The aquatic biota present in these ephemeral and disconnected habitats would also be expected to have relatively great dispersal abilities and would be tolerant of disturbed environments. For example, many macroinvertebrate taxa that would utilise these habitats have flying adult stages and some plants, such as those in the genus *Potomogeton* may spread by seed (DiTomaso et al. 2013) and possibly fragment transfer via birds. Thus, they would have the ability to colonise new areas relatively easily. Any diversion channels created to replace these displaced ephemeral watercourses (primarily the sections of Walkers Creek and its tributaries within the footprint of the TSF and Blackmans Gully within the footprint of the open cut pit, as well as several other smaller ephemeral watercourses within the footprint of these and other facilities (**Figure3.2**)) would likely also provide similar habitat (assuming similar channel morphology) to that present. It is noted that Price Creek would not be displaced by the WRE. Several water supply dams would also be constructed to provide water supply during construction and operation and it is possible that these would provide habitat of comparable quality to that which may be lost. This would further limit the potential for reductions in population size at the scale of Study Area and beyond. The creation of a comparable amount of similar watercourse habitat as part of the re-alignment activities would be expected to offset loss due to Project activities. Where, feasible newly created watercourses would be designed and constructed to have the same geomorphology and length of displaced watercourses. These measures would ensure that impacts to watercourses are avoided and minimised to the greatest extent practicable in accordance with the NSW Biodiversity Offsets Policy for Major Project (OEH, 2014).

Table 4.1
Metres (m) of First, Second and Third Order Watercourses Located Directly Beneath the Footprints of Project components

Project Component	Stream Order			Total (Project Component)
	1	2	≥ 3	
Low Grade Ore Stockpile	138			138
Open Cut Pits	289	565	647	1,501
Processing Plant	471	143		614
Soil Stockpiles	379			379
Southern Barrier	220	117	821	1,158
Tailings Storage Facility	3,060	2,431	1,509	7,001
WRE	782		68	851
NAF Waste Rock Stockpile Area	109			109
TSF Embankment	671		77	748
Open Cut Pit/WRE/Southern Barrier*	489		2,073	2,562
Total (Stream Order)	**6,608**	**3,257**	**5,196**	**15,061**
* Includes watercourses that intersect more than one project component (largest three identified)				

The small abundance and quality of the riparian vegetation in the Study Area would mean that any potential further degradation due to localised disturbance would be minimal, especially as ancillary infrastructure is located well away from Hawkins and Lawsons Creeks. Limiting the area of all riparian zone and aquatic habitat disturbed where feasible and reasonable, and particularly in the vicinity of Hawkins and Lawsons Creek; would also minimise impacts to riparian vegetation and aquatic biota. Adherence with the NSW DPI Policy and Guidelines for Fish Habitat Conservation and Management (NSW DPI 2013a) with respect to riparian buffer zones (Section 4.2.2) would further minimise impacts to riparian vegetation and aquatic biota.

Residual impacts to riparian vegetation are expected to be minor if not negligible. The planting of native riparian vegetation along sections of realigned watercourses and along sections of Hawkins and Lawsons Creek would be expected to offset any minor loss due to project activities. Further assessment of riparian vegetation is provided in EnviroKey (2020).

4.2.3.2 Changes in Water Quality

The risk of unplanned release of sediments mobilised from disturbed sediments entering Hawkins and Lawsons Creeks would be effectively managed via standard sedimentation and erosion controls during the construction stage and through development and implementation of an Erosion and Sediment Control Plan. All water coming into contact with catchments disturbed by mining and waste management operations (e.g. TSF, WRE and open cut pits) would be captured and used as input to the process circuit (WRM, 2020). Water quality monitoring would also be implemented to test the effectiveness of these controls and inform additional management decisions if acceptable limits are exceeded. The Erosion and Sediment Control Plan would be prepared in accordance with Managing Urban Stormwater: Soils and Construction, Volume 2E Mines and Quarries (DECC 2008) (the ‘Blue Book’) and would include a description of the erosion and sediment control structures that are to be used to minimise soil erosion and the potential for the transport of sediment to downstream waters. Temporary erosion and sediment control measures such as sediment fences, sandbag weirs, temporary drains, and temporary silt traps would be installed prior to all construction works. Maintenance of erosion and sediment controls and adaptive management would be undertaken throughout the Project life to ensure they continue to function effectively.

Further controls have been identified within the site water management system developed to manage potential impacts on surface water in the receiving environment within and around the Mine Site (WRM, 2020). Based on the overburden geochemical characterisation investigations, water captured in the sediment dams are expected to be relatively good quality and, as such, suitable for release in accordance with the ‘Blue Book’ recommendations. Water would only be released in accordance with discharge water quality limits to be specified in the environmental protection licence (EPL). Draft EPL limits have been proposed based on the NSW Water Quality Objectives for the protection of aquatic ecosystems in upland rivers of the Manning River catchment as well as ANZECC (2000) trigger values for 95% protection of freshwater species. A site water quality monitoring plan will be implemented during operations to verify that the captured water quality is suitable for off-site release, and to monitor receiving water conditions. It is proposed to continue monitoring at existing background monitoring points, as well as in on-site sediment dams located at release points (WRM, 2020). Given these guidelines are achieved in the discharge, associated impacts to aquatic ecology would not be expected. Provided stringent water quality controls are implemented, the risk of potential indirect impacts to aquatic ecology from mobilised sediment and other potential contaminants would be very low.

Furthermore, the greatest risk of sediments entering the aquatic environment during unplanned releases would also be temporary and limited to the initial stage of the Project involving construction and earthworks. The risk of impacts to aquatic habitats and biota would be reduced following this initial work. Controls will be implemented to prevent the release of wastewater that is generated on site into watercourses. This includes appropriate infrastructure to store and control water on site and avoid accidental discharges to Hawkins and Lawsons Creeks and their tributaries. In particular, an earthen dam would be located downstream of the TSF embankment initially to operate as a sediment dam to manage suspended solids during the initial and subsequent construction of the TSF. It is noted also that suspended sediment loads in Hawkins and Lawsons Creek may be relatively high irrespective of the Project (indicated by levels of turbidity often exceeding guidelines during the aquatic ecology field surveys). This is likely associated with surrounding land use practices and the removal of riparian vegetation resulting in increased sediment mobilisation during rainfall events.

Measures have been outlined within the Surface Water Assessment (WRM, 2020) to minimise, manage and clean up spillages of fuels, oils and greases and appropriate storage and refuelling areas have been identified. During rainfall, it is possible that hydrocarbon residue and spillages from the roads and tracks within the Mine Site could enter waterways via surface runoff. However, taking into account the proposed management measures and safeguards (including maintaining a bunded area for storage of fuels, oils, refuelling and appropriate maintenance of vehicles and mechanical plant, prohibiting refuelling, washing and maintenance of vehicles and plant within 30 m of all watercourses, where feasible and reasonable, and reporting spillages to the appropriate officer and immediately deploying spill containment kits to restrict their spread into or within drainage lines.), the volumes of such in flows are likely to be very small.

Sewage would be appropriately treated to avoid such risks and there would be no discharge of any sewage to watercourses. Water soluble components of petroleum hydrocarbons include a variety of compounds that are potentially toxic to aquatic life (ANZECC/ARMCANZ 2000). Pesticides and herbicides used for weed or pest control can also be particularly toxic to aquatic life. These could enter waterways following accidental release if stored or used incorrectly.

4.2.3.3 Proliferation and spread of aquatic pest species

Three invasive species of fish (carp, wild goldfish and eastern gambusia) have been identified in the Study Area. All three are likely to be present in Hawkins and Lawsons Creeks and eastern gambusia were also identified in one farm dam and are likely to be present in several others. Blackberry and umbrella sedge was identified along sections of Hawkins and Lawsons Creeks. All these species prefer disturbed aquatic habitats with low-velocity, stable water flow. The key issues associated with invasive species include the need to report occurrence of some species (in this case, eastern gambusia), the need to ensure that activities associated with the Project do not lead to the introduction of invasive species and the need to ensure that activities do not facilitate the spread of invasive species within the region. As Project activities would not directly impact Hawkins and Lawsons Creeks, there is little potential for the Project to directly exacerbate the proliferation and spread of pest fish already present in these creeks. There is potential for eastern gambusia to proliferate in new water storages constructed as part of the Project and for blackberry to spread if disturbed during site establishment and construction activities. It is conceivable that these pests could be transported to Hawkins and Lawsons Creeks accidentally. However, these issues can be avoided or managed by effectively incorporating provisions for reporting on invasive species (e.g. targeted observations during monitoring) of water bodies and management of exchange of surface waters between the site and surrounding watercourses in terms of potential translocation of invasive species. There would also be no planned release of water potentially containing eastern gambusia to Hawkins and Lawsons Creeks that could lead to the proliferation of this species here.

4.2.3.4 Temporary full or partial barrier to fish passage

There is potential for temporary barriers to be constructed in Lawsons Creek associated with construction of the new crossing as part of the relocated Maloneys Road. If any temporary barrier is required, then NSW DPI (Fisheries) should be consulted. Nevertheless, the impact to fish passage associated with any temporary barrier to fish passage on Lawsons Creek is not expected to result in any more than minor associated impacts to fish populations in the creek. The creek is intermittent with aquatic habitat consisting of a series of disconnected pools. Thus, the temporary presence of a full or partial barrier to fish passage would be expected to have negligible additional influence on fish passage. Similarly, any temporary barriers to fish passage occurs as a result of diversions or coffer dams required to construct the water pipeline these would be located in intermittent or ephemeral watercourses and are not expected to result in any more than minor associated impacts to fish populations. NSW DPI (Fisheries) should be consulted if any disturbance to creek channels and banks would occur.

4.2.3.5 Changes in Surface Flow

Temporary and localised disruption of flows in Lawsons Creek would occur during the construction of the new Lawsons Creek crossing for the relocated Maloneys Road. Significant impacts to aquatic ecology are not expected given the localised and temporary nature of expected changes in flows.

Impacts to aquatic habitat and biota that could occur due to changes in the hydraulic regime during construction are considered together with those that could occur during operation in Sections 4.2.3 and 4.3.3.

4.2.4 Potential Impacts on Key Fish Habitat and Threatened Biota

The majority (10 km) of the watercourse habitat that would be displaced is first and second order and, thus, is not KFH. The artificial impoundments associated with springs and watercourses are also not KFH. The third order and higher watercourse habitat that would be displaced beneath the various Project component footprints is Type 3 – Minimally sensitive KFH (ephemeral habitat not supporting native aquatic or wetland vegetation). It is noted the 3rd order courses within the Mine Site are ephemeral and only experience discharge for short periods during and after a rainfall event. Due to the abundance of the habitat in the local and regional area, and that similar habitat may be provided by clean water diversions, the loss of this habitat represents a very minor to negligible impact to the availability of this KFH and any associated fish populations in the Study Area and beyond. None of the ephemeral and intermittent watercourse pool habitats are likely to provide habitat for threatened biota and associated impacts on threatened species and populations of fish are not expected to occur due to displacement or other modification of this habitat that may occur due to the Project. Given the realigned sections of watercourses containing Type 3 KFH watercourses provide a comparable amount (e.g. linear length) of similar habitat (e.g. similar channel width and similar, or improved condition, riparian vegetation) associated offsets would not be required. Price Creek, which provides Type 2 – Moderately sensitive KFH habitat, would not be displaced by the WRE and is outside the footprint of this facility.

Hawkins and Lawsons Creeks are KFH and contain Type 1 – Highly sensitive KFH (native aquatic plants and large wood debris). The construction of the new crossing over Lawsons Creek within the alignment of the relocated Maloneys Road will result in the modification of a small area of KFH and may result in the displacement of Type 1 – Highly sensitive KFH present here. The area of KFH that would be disturbed would, however, be negligible in the context of the creek and is not expected to result in any more than negligible associated impacts (such as reductions in population sizes) to any eel-tailed catfish, southern purple spotted gudgeon and Murray cod, i.e. those threatened species or populations considered to have a possibility of occurring in Lawsons Creek. Changes to water quality and rates of sedimentation in Hawkins and Lawsons Creeks are not expected to occur due to implementation of standard sediment and erosion controls that will prevent potentially contaminated water that may arise on site from entering these creeks. Thus, impacts to KFH due to smothering following sedimentation and to any threatened fish due to elevated suspended sediments are not expected to occur. The risk of any accidental release of chemicals into watercourses is also low due to the implementation of the proposed water quality controls, thus, associated impacts to threatened species of fish in Hawkins and Lawsons Creeks are not expected to occur.

Impacts to any threatened fish present in Hawkins and Lawsons Creeks due to potential proliferation of pest fish in waterbodies on site and any reduction in fish passage in Lawsons Creek due to construction of the crossing here are also not expected to occur. Each species of pest fish (including eastern gambusia) identified in the Study Area is present currently in each of these creeks. New water storages created on site would be monitoring visually for the presence eastern gambusia, in particular, which is easily observed around the water edge. If identified and if practical, these fish would be eradicated and / or the discharge screened (either using a mesh around the pump intake or at the outlet) prior to prevent release of these fish Hawkins and Lawsons creeks (if discharge were to occur here and water not be used on site). In any case, the Project would not be expected to contribute to the spread or proliferation of these species given they are already present in Hawkins and Lawsons Creeks, if present. The presence of any temporary partial or full barrier to fish passage is unlikely to have any noticeable impact on fish passage in a creek where aquatic habitat is likely to often consist of a series of disconnected pools. Furthermore, none of the threatened fish considered to have the potential to occur here require long distance migrations as part of reproduction that could be disrupted by such a barrier.

4.3 OPERATIONS

4.3.1 Potential Impacting Processes

Impacts to aquatic habitat and biota during the operations stage of the Project have potential to arise from:

- Reduced groundwater availability to subterranean GDEs due to groundwater drawdown following inflow of groundwater into the open cut pit voids;

- Reduced surface flow in Hawkins and Lawsons creeks due to interception of surface flows on-site and groundwater drawdown following excavation of the open cut pit and interception of surface water. Such impacts could also exacerbate the KTPs associated with changes to natural flow regimes in watercourses considered in Sections 4.5.1.3 and 4.5.2.1;

Changes in water quality in watercourses due to:

1. Release of sediment-laden water from disturbed areas and soil stockpiles from which sediments may be mobilised during wet weather and transported to waterways. This may result in elevated suspended sediments (SS) and sedimentation in Hawkins and Lawsons Creeks. There is a possibility some metals contained in dust settled on site may also enter waterways following mobilisation during rainfall events;
2. Accidental release of potentially toxic reagents and flocculants stored on site and used as part of processing of mined material;
3. Accidental release of chemicals and fuels (e.g. oils, hydraulic fluids and fuel from plant) and sewage resulting in the input of hydrocarbon, metal contaminants and / or nutrients into watercourses;
4. Accidental release of potentially toxic silver/lead concentrate and zinc concentrate from the processing plant;
5. Input of water with low pH that has leached or accidentally been released from PAF waste rock placed in the WRE or of water with low pH or toxicants that has leached or being accidentally released from the TSF, the low grade ore stockpile or the pipeline that transports tailings material from the processing plant to the TSF.
6. Changes in groundwater quality due to excavation of the open cut pit, possibly from exposure of unweathered PAF rock and material;
7. Proliferation and spread of aquatic pest species in waterbodies (e.g. raw water pond and pit dewatering pond associated with the processing plant) established to supply water during operation; and
8. Permanent full or partial barrier to fish passage in Lawsons Creek during construction of the relocated Maloneys Road.

4.3.2 Mitigation Measures

Impacts associated with operation would be minimised by:

- Minimising the area of the catchment that is disturbed, where feasible and reasonable;
- Diverting clean water around active disturbance areas;
- Capture and treatment of runoff;
- Adherence to the Erosion and Sediment Control Plan; and
- Where possible, euthanasia of aquatic pest in existing dams to ensure any aquatic pests, particularly, eastern gambusia, are not released into Hawkins and Lawsons Creeks.

4.3.3 Potential Impacts on Aquatic Habitat and Biota

4.3.3.1 Reduced Groundwater Availability

The excavation of the open cut pits has the potential to displace subterranean GDEs, such as stygofauna, from aquifers present in the open cut pit. Sampling of stygofauna within and around the open cut pit footprint and adjacent to Hawkins and Lawsons Creeks indicated only one stygofauna taxa was present in the open cut area (a total of two individuals from two bores). This taxon was also present in bores associated in Hawkins and Lawsons Creeks alluvium where it was also far more abundant (27 individuals from two bores). The results also suggest that aquifers within the open cut area support a relatively depauperate stygofauna assemblage. Thus, the potential direct loss of some individuals from the open cut area during excavation and mining represents a relatively minor impact to stygofauna populations within and surrounding the Study Area.

Open cut pit development would cause localised reversal of the prevailing groundwater flow regime resulting in the drawdown of the nearby water table potentially causing associated indirect impacts to stygofauna. Beyond the open cut pit, groundwater modelling predicts maximum drawdown beneath Hawkins Creek of 1 to 2 m, with some localised areas of 3 m to 4 m (Jacobs, 2020). Predicted maximum drawdown beneath Lawsons Creek is typically of the order of 1 m or less. It is unclear what impact such drawdown would have on the stygofauna populations present within the alluvium aquifers associated with these creeks. Among other factors, this would depend on the depth of the aquifer and the ability of stygofauna to migrate to deeper suitable aquifer habitat, if present. The thickness of Hawkins Creek alluvium is reported to be 4 m to 6 m (Jacobs, 2020) and that in Lawsons Creek is assumed to be of similar location and depth. This suggests that suitable habitat should remain for stygofauna following the predicted drawdown here, albeit with reduced availability. Any reduction in habitat availability would be expected to be associated with a reduction in the population size of stygofauna. However, based on predicted drawdown and the depth of the alluvium, a complete loss of stygofauna from Hawkins Creek alluvium should not occur. Given the magnitude of drawdown would be less in Lawsons Creek alluvium, impacts to stygofauna present here would be expected to be less severe than for Hawkins Creek. Drawdown would also be expected to occur within a limited extent of creek alluvium. For Hawkins Creek, such effects were considered from the confluence with Lawsons Creek to approximately 6 km to the northeast of the Mine Site in the upper catchment of Reedy Creek and Horse Gully tributaries. For Lawsons Creek, such effects were considered from approximately 3.5 km southeast of the Mine Site to 4 km west of the Mine Site (total of 7.5 km). It is noted that the areas considered extend beyond the predicted area of drawdown and, thus, any significant impacts to stygofauna are expected to be limited to within these areas. There are no known practical safeguard measures that could be implemented to mitigate potential impacts to stygofauna due to excavation of the open cut pit and associated reductions in the depth of the water table in associated nearby aquifers.

4.3.3.2 Reduced Surface Flows

The interruption of groundwater recharge and surface flows to Hawkins and Lawsons Creeks could reduce the flow rate in these creeks and could increase the number of zero flow days, especially during periods of low rainfall. Temporal flow patterns could also be affected and the magnitude, frequency and timing of peak flows could also be altered. Reduced surface flow can affect aquatic habitat and biota that may occur in the affected area; such as macrophytes and riparian vegetation, by reducing water availability. Reduced surface flows could occur due to interception of surface run-off and due to loss of baseflow due to interception of groundwater in the open cut pit.

Water impacted by the mining activities and captured in the water management system would be contained on site and reused, resulting in an associated reduction in surface flow to Hawkins and Lawsons creeks. The peak catchment area affected would be 550 ha or 2.0 % of the Lawsons Creek catchment (WRM, 2020). Once mining is complete, the affected catchment area would be 53 ha. This would be due to the loss of catchment and surface flow to Hawkins and Lawsons creeks via interception by the open cut pit footprint. Baseflow to both Hawkins Creek and Lawsons Creek would reduce due to interception of groundwater by the open cut pit (Jacobs, 2020). Groundwater drawdown associated with excavation of the open cut pit is predicted to peak 12 to 18 years post mining and to reduce baseline contributions to Lawsons Creek by 13 % (24 m^3/day / 184 m^3/day) and to Hawkins Creek by 42 % (30 m^3/day / 72 m^3/day).

During operations, the maximum impact of the Project on surface flows (WRM, 2020) would be to decrease flows in:

- Hawkins Creek for a distance of 3.5km within the area of predicted drawdown by 4.4%;
- Lawsons Creek downstream of Hawkins Creek and the Mine Site and upstream of Walkers Creek by up to 1.2%; and
- Lawsons Creek downstream of Walkers Creek by 2.2%.

Reductions would be well within the natural variability of flows, when the creeks are flowing. WRM (2020) has established that the Project's impacts in Lawsons Creek would be negligible when daily flows in Lawsons Creek exceed approximately 1ML/day.

Progressive rehabilitation of the Mine Site would see gradual reinstatement of catchments and once completion criteria have been met, runoff from these areas would again contribute to streamflow, primarily in Hawkins Creek catchment. After mining, the maximum impact of the Project on downstream flow (WRM, 2020) would be to decrease flows in:

- Hawkins Creek for a distance of 3.5km within the area of predicted drawdown by 1.4%;
- Lawsons Creek between the confluence of Hawkins and Walkers Creek by 0.4%; and
- Lawsons Creek downstream from its confluence with Walkers Creek by 0.4%.

Based on these relatively small amounts of predicted flow reductions, associated impacts to aquatic habitat and biota during average rainfall years would be expected to be minor. The relatively minor changes in stream flow predicted would be expected to result in associated minor changes in the availability of aquatic habitat in Hawkins and Lawsons Creeks. It is noted also that the greatest (albeit still relatively small) reduction in streamflow would be temporary and would occur during operation. After mining, reductions in streamflow would recover to a degree. During dry periods, notably between June 2013 to July 2016, baseflow comprised approximately 38% of mean daily discharge in Hawkins Creek. The predicted baseflow reduction to Hawkins Creek has potential to reduce dry period streamflow by approximately 16%. The potential streamflow reduction in Lawsons Creek is considerably less. It is expected that a baseflow reduction of this magnitude is only likely to be noticeable during periods of sustained drought. Such changes would be expected to reduce the number of flow days in Hawkins and Lawsons Creeks and result in an overall reduction in connectivity. However, these watercourses are naturally intermittent and would support aquatic biota adapted to such conditions. It would be expected, therefore, that such reductions in streamflow would not have major impacts to aquatic habitat and biota in these water courses. Nevertheless, some reduction in the availability of aquatic habitat (due to, for example, fewer days of flow and resulting reduction in pool water level) and associated reduction in the population size of aquatic biota (such as plants, macroinvertebrates, and fish) would be expected. However, such effects should be temporary, and occur during drought periods only.

Changes in downstream of the assessed areas, including in the Cudgegong River, are not expected. The loss of flow in Lawsons Creek from both surface water and groundwater impacts would be minimal at the confluence of Walkers Creek and Lawsons Creek where flows (when Lawsons Creek is flowing) would be reduced by approximately 2%. Runoff from a further 200 km^2 of the Lawsons Creek catchment downstream would result in the contributing loss attributable to the Project to be negligible downstream of Lawsons Creek.

4.3.3.3 Changes in Surface Water Quality

As would be the case during construction, the risk of sediments mobilised from disturbed sediments entering Hawkins and Lawsons Creeks would be effectively managed via standard sedimentation and erosion controls during operation through development and implementation of a Sediment and Erosion Control Plan and the Site Water Management Plan (Section 4.2.3.2). Mitigation measures included in these plans would incorporate the minimisation of area of disturbance, clean water diversions around active disturbance areas and the catchment and treatment of runoff, and active rehabilitation of disturbed areas. All groundwater entering the open cut pit would be returned to the process circuit for use and not discharged to watercourses. Planned release of sediment-laden water would occur only in accordance with the conditional requirements contained within an EPL and sediment-laden water management would be undertaken in accordance with Blue Book design guidance (WRM, 2020). The potential for hydrocarbons, other potentially toxic chemicals and/or nutrients in sewage to accidentally enter waterways is also very low given the control measures associated with consumables storage and waste management outlined in Section 1.2.3.5 that would be implemented. Flocculants would be added to sedimentation basins to enhance the removal of fine and dispersive sediments, if required. Should a flocculent be required, it would be selected to ensure it is not toxic to aquatic life (for example, HaloKlear flocculent). Water quality monitoring will also be undertaken to ensure the effectiveness of the control measures. Thus, the risk of potential indirect impacts to aquatic ecology from mobilised sediment and other potential contaminants would be very low.

The WRE and TSF would both contain water with low pH and may also contain various toxicants (such as metals including silver) leached either from rock material mined from the open cut pits (in the case of the WRE) and/or from the various chemicals (such as cyanide) used in the processing plant. The pipeline transporting tailings material from the processing plant to the TSF would also contain very poor quality water. If this water were to accidentally escape and enter waterways it could be detrimental to aquatic biota. The potential for this to occur, however, would be very low given the WRE and TSF would be designed according to industry best practice with several inherent features designed to prevent the release of water (Section 1.2.2). These include a decant system to enable the return of the top layer of water which is relatively free of particulates (“decant water”) from the TSF to the processing plant, a leachate drainage system to collect the low pH water in the WRE and several control measures associated with the storage of water in the TSF (Section 1.2.3.4). These latter control measures include an appropriate liner and seepage collection system and several measures to ensure structural integrity under potential extreme conditions (e.g. earthquake and flood events) and to collect and manage rainfall runoff from the embankment slopes. The TSF would also be designed to accommodate the peak upstream catchment discharge during the design and rainfall event that is determined by the failure consequence category of the TSF and in accordance with published design guideline (e.g. DSC, ANCOLD). In addition, there would be no planned discharge to watercourses. The pipeline to the TSF would include several inherent control measures to contain water and prevent it entering watercourses if it were to escape. These control measures include either placing the pipeline in a position where any escaped water would naturally gravitate towards the TSF or placing it in a bunded corridor to collect and contain spillages in scour sumps with capacity sufficient to prevent any release to waterways. Given these inherent design features and controls, and the comprehensive monitoring program outlined in Section 1.2.3.4 that would implemented to ensure the integrity and performance of the TSF, there would be a low potential of water with low pH and / or containing contaminants entering waterways. Poor quality water arising in the open cut pit void would also not enter surface water via groundwater as the direction of groundwater flow would be into the open cut pit void (Section 4.3.3.4). There would also be no discharge of water from the open cut pits to the surrounding environment. Rather, water pumped from the open cut pits would be re-used for processing. Thus, associated potential impacts to aquatic habitat and biota are not expected. Concerns regarding the potential for deposited dust containing heavy metals to impact on aquatic ecosystems has also been raised by some members of the community. Due to the number of factors (including rates of dust deposition, potential for mobilisation by rainfall, role of vegetation and soil type in influencing rates of mobilisation and the dissolvability of metals) associated with quantifying any changes in the concentrations of metals in watercourses due to input of dust during rainfall events informed assessment of impact to aquatic ecology could not be undertaken at this time. Ongoing monitoring will include the quantification of any elevation in metal concentrations in nearby watercourses and assessment of associated impacts to aquatic biota, if any.

4.3.3.4 Changes in Groundwater Quality

Excavation below the water table will expose potential acid forming material in the open cut pit walls. Oxidation of acid forming materials and subsequent mobilisation by groundwater inflows or rainfall runoff has potential to generate acid drainage within the open cut pit. During mining, any generated drainage will be captured by the dewatering system and pumped to the processing plant for use in processing (Jacobs, 2020). The final mine void is also predicted to remain a groundwater sink, with final equilibrium levels predicted to be approximately 40 m below the pre-mining groundwater level. The direction of groundwater flow will be towards the pit and the saline water that develops within the pit will not be able to escape or impact on local water quality. As such, no impacts stygofauna and other aquatic biota due to release of poor quality water from the open cut pit into surrounding groundwater are expected.

4.3.3.5 Proliferation and spread of aquatic pest species

As discussed **in** Section 4.2.3.3, there is potential for eastern gambusia to proliferate on-site via accidental spread to existing or newly created water storages. It is conceivable that these could then be transported accidentally to Hawkins and Lawsons Creek. However, there would be no planned release of water to these creeks and several control measures have been recommended for inclusion in an associated management plan (Section 4.2.3.3). Assuming their successful implementation there is unlikely to be any proliferation or spread of these or other pests on-site or in Hawkins and Lawsons Creek due to the Project.

4.3.3.6 Barriers to fish passage

The installation of a box culvert on Lawsons Creek as part of the proposed Maloneys Road relocation is expected to result in minimal impact on fish passage in the creek. Whilst there is potential for such a crossing to be a barrier to fish passage during low and moderate flows (if the step of the base creates a waterfall effect), Lawsons Creek currently has intermittent flow and naturally consists of a series of disconnected pools that would result in relatively minimal fish movement through the creek. A box culvert crossing would satisfy NSW DPI (Fisheries) guidelines for crossing requirements. Further, none of the native species of fish caught in the current surveys, nor the threatened species that have potential to occur in Lawsons Creek, undertake long distance migrations. Accordingly, these fish would be unlikely to be affected by the installation of the proposed box culvert crossing. Measures aimed at avoiding or minimisation the potential for a barrier to occur following installation of the crossing are provided in Section 5.

4.3.4 Potential Impacts on Key Fish Habitat and Threatened Species

There would be no direct impacts to Type 1 or Type 2 KFH during operation. The various measures that would be implemented to prevent the mobilisation of sediment onsite and its release to Hawkins and Lawsons Creeks (where Type 1 Highly Sensitive KFH is located) would effectively remove the potential for sedimentation and smothering to impact aquatic plants and large wood debris. Thus, impacts to KFH during operation of the Project are not expected. Similarly, planned releases of water to Hawkins and Lawsons Creeks that may arise as part of processing operations would adhere to EPL guidelines on water quality. The accidental release of such water or of potential contaminants (such as chemicals used in processing operations, hydrocarbons from vehicles and sewage) to watercourses is also low due to the several controls, including storage and containment measures described above. Thus, potential impacts to threatened species of fish that may occur in the watercourses are not expected to occur. Impacts to threatened species of fish due to the creation of a potential barrier fish passage due to the construction of the crossing over Lawsons Creek are also not expected as this is likely to result in negligible additional hindrance to fish passage in a naturally intermittent watercourses such as this (Section 4.3.3.6)

4.4 DECOMMISSIONING

4.4.1 Potential Impacting Processes

Impacts to aquatic habitat and biota during the operations stage of the Project have potential to arise from:

- Erosion of the final landform of the TSF and WRE and subsequent release of sediment-laden water to watercourses; and
- Runoff containing sediments and contaminants such as fertilisers and herbicides associated with the rehabilitation works entering watercourses during rainfall events.

The installation of the store and release capping layers to cover the TSF and WRE post-mining would prevent water from infiltrating into the material within the TSF and the PAF waste rock within the WRE (Section 1.2.4). This would minimise potential impacts to aquatic ecology associated with the potential leaching of poor quality water from these storages and its entry into nearby watercourses.

4.4.2 Mitigation Measures

The potential for erosion runoff during decommissioning would be minimised further by:

- Preparing and implementing the Rehabilitation Management and Erosion and Sediment Control Plans;
- Stabilisation of all earthworks, drainage lines and disturbed areas in the long term;
- Minimising the areas of exposed surfaces that would otherwise be potential sources of sediment; and
- Ultimately creating a stable and safe landform with minimal erosion.

4.4.3 Potential Impacts on Key Fish Habitat and Threatened Species

Activities undertaken during the decommissioning and rehabilitation phase are unlikely to cause significant impacts on aquatic habitats, aquatic flora or aquatic fauna, provided that appropriate measures to avoid, minimise and manage impacts are implemented.

4.5 KEY THREATENING PROCESSES

4.5.1 Fisheries Management Act 1994

4.5.1.1 Removal of Large Woody Debris from NSW Rivers and Watercourses

There would be no removal of large woody debris from Hawkins and Lawsons Creeks during the Project life. The removal of any woody debris in ephemeral watercourses as part of construction activities would result in negligible impacts to aquatic ecology.

4.5.1.2 Degradation of Native Riparian Vegetation along New South Wales Watercourses

The crossing over Lawsons Creek should be subject to a management plan to minimise harm to riparian vegetation. This would require detailed mapping of vegetation prior to construction (e.g. by a terrestrial ecologist or landscape expert), a detailed plan to avoid any unacceptable damage during construction and re-planting as required following the completion of construction activities.

4.5.1.3 Installation of instream Structures and Mechanisms that alter Natural Flow

The crossing over Lawsons Creek may result in an alteration to localised flow around the structure by creating disconnected pools immediately upstream and / or downstream. However, Lawsons Creek is intermittent and naturally consists of a series of disconnected pools. The installation of this crossing is expected to have negligible impact on flow in Lawsons Creek. The impacts of other mechanisms are considered in Section 4.5.2.1.

4.5.2 Biodiversity Conservation Act

4.5.2.1 Alteration to Natural Flow Regimes of Rivers and Watercourses and their Floodplains and Wetlands

Groundwater drawdown due to excavation of the open cut pit would result in a reduction in the creek water table and a reduction in baseflow to Hawkins and Lawsons Creeks. This would result in some minor (a few %) reductions in streamflow during average rainfall years. Based on these small reductions, no more than minor associated impacts to aquatic habitat and biota would be expected. Reductions in streamflow would be more noticeable during drought conditions. However, given that Hawkins and Lawsons creeks are naturally intermittent (and support assemblages of aquatic flora and fauna typical of disconnected pool habitat with periods of flow for some time after rainfall), and assuming flow would return along with rainfall, associated impacts to aquatic biota would not be expected to be significant.

4.5.2.2 Clearing of Native Vegetation

As described above, the crossing over Lawsons Creek should be subject to a management plan to minimise harm to riparian vegetation. This would require detailed mapping of vegetation prior to construction (e.g. by a terrestrial ecologist or landscape expert), a detailed plan to avoid any unacceptable damage during construction and re-planting as required following the completion of construction activities.

4.5.2.3 Predation by Mosquito Fish (Gambusia Holbrooki).

This species is already widespread throughout the Study Area, being present in watercourses and at least one dam on the Mine Site. The Project would, therefore, not cause the introduction of this species in the area. It may be possible, however, to limit its spread by managing dewatering of dams on site by treating the water to kill mosquito fish (also known as eastern gambusia). It is recommended that, as part of the site water management plan, all existing dams are inspected visually for the presence of eastern gambusia prior to dewatering activities. If these fish are observed, and if practical, they should be euthanized and / or the intake or offtake should be screened to help prevent release of these fish to Hawkins and Lawsons creeks.

4.5.3 Environment Protection and Biodiversity Conservation Act 1999

4.5.3.1 Loss and Degradation of Native Plant and Animal Habitat by invasion of escaped Garden Plants, including Aquatic Plants

No instream non-native aquatic plants were identified in the Study Area. Some non-native riparian and emergent aquatic plants were identified in Hawkins and Lawsons Creeks. However, these are currently widespread in the Study Area and the Project is unlikely to result in their further spread or proliferation.

4.5.3.2 Novel biota and their impact on biodiversity

As discussed in Section 4.2.3.3, there is potential for eastern gambusia to proliferate on-site via accidental spread to existing or newly created water storages. It is conceivable that these could then be transported accidentally to Hawkins and Lawsons Creeks. However, there would be no planned release of water to these creeks and several control measures have been incorporated into associated management plans Section 4.2.3.3). Assuming their successful implementation there is unlikely to be any proliferation or spread of these or other pests onsite or in Hawkins and Lawsons Creek due to the Project.

5. CONCLUSION AND RECOMMENDATIONS

The assessment of impacts to aquatic ecology did not identify any more than minor potential impacts to aquatic ecology due to the Project. In particular, no impacts to KFH and threatened species of fish (if they occur) in Hawkins and Lawsons Creeks are expected. The greatest potential risk to aquatic ecology is associated with the accidental release of poor quality (e.g. water with low pH as a result of mine activities and / or elevated SS) water to watercourses. These would be mitigated and / or minimised by the development and implementation of appropriate control measures, within documents such as an Environmental Management Plan, Erosion and Sediment Control Plan, and a Water Management Strategy.

There would be some disturbance of remaining riparian vegetation and the re-alignment of ephemeral watercourses (that provide limited aquatic habitat) as part of construction activities. New channels of realigned ephemeral watercourses would provide comparable aquatic habitat to that displaced beneath the footprint of the various mine facilities. Thus, there would be no residual loss of watercourse habitat and offsets associated with displacement of ephemeral watercourses and KFH would not be required. Although the current poor condition of riparian vegetation is due to historic land use practices, substantial potential impacts to aquatic ecology associated with the Project have not been identified, and there would be no further degradation of riparian vegetation along these creeks due to the Project. Given there would not be any residual loss of watercourse habitat, associated offsets would not be required.

Some localised impacts to stygofauna may occur due to drawdown of groundwater levels in alluvial aquifers near Hawkins and Lawsons Creeks, associated with groundwater drawdown due to excavation of the open cut pit. The results of the stygofauna monitoring program would help identify the magnitude and extent of any impacts to stygofauna that may occur.

Although no more than minor impacts to aquatic habitat and biota are expected, as a precautionary approach, it is recommended the monitoring of aquatic ecology in surface waters should be undertaken well before, then during and if necessary after the operation of the Project. A monitoring program should be developed for sections of Hawkins and Lawsons creeks that may be impacted and suitable reference sections upstream of these areas or in other comparable creeks within the vicinity of the Mine Site that would not be affected. The major components include geomorphology and flow, water quality and quantitative and semi-quantitative sampling of aquatic biota. Given that groundwater drawdown is predicted to occur in the vicinity of Hawkins and Lawsons creeks that could affect stygofauna present in associated alluvial aquifers, the monitoring program should also include stygofauna present in these aquifers. Suitable bores outside of the potential drawdown area should also be identified and sampled to provide reference data. Further details of the monitoring would be described in an Aquatic Ecology Management and Monitoring Plan or as a section within the Biodiversity Monitoring Plan for the Project. Where relevant, the monitoring would include the sites established as part of the existing environment studies.

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Annexures

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Annexure A

Fish Habitat Classification Criteria for A) Key Fish Habitat and B) Fish Passage

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a) Key fish habitat and associated sensitivity classification scheme criteria

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

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

b) Classification of waterways for fish passage criteria

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

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

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

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

Annexure B

Detailed Methods Description – Surface Aquatic Ecology

(Total No. of pages including blank pages = 4)

RCE Assessment Criteria

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

AUSRIVAS Macroinvertebrates

Field Methods

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

Laboratory Methods

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

AUSRIVAS Model

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

- OE50Taxa Score – The ratio of the number of macroinvertebrate families with a greater than 50% predicted probability of occurrence that were actually observed (i.e. collected) at a site to the number of macroinvertebrate families expected with a greater than 50% probability of occurrence. OE50 taxa scores provide a measure of the impairment of macroinvertebrate assemblages at each site, with values close to 0 indicating an impoverished assemblage and values close to 1 indicating that the condition of the assemblage is similar to that of the reference watercourses.
- Overall Bands derived from OE50Taxa scores that indicate the level of impairment of the assemblage. These bands are graded as described in **Table B-1**.

Table B-1 AUSRIVAS Bands and corresponding OE50 Taxa Scores for AUSRIVAS edge habitat sampled in spring

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

The SIGNAL2 biotic index (Stream Invertebrate Grade Number Average Level) developed by Chessman (2003) was also used to determine the environmental quality of sites on the basis of the presence or absence of families of macroinvertebrates. This method assigns grade numbers between 1 and 10 to each macroinvertebrate family, based largely on their responses to chemical pollutants. The sum of all grade numbers for that site was then divided by the total number of families recorded in each site to obtain an average SIGNAL2 index. The SIGNAL2 index therefore uses the average sensitivity of macroinvertebrate families to present a snapshot of biotic integrity at a site. SIGNAL2 values are as follows:

- SIGNAL > 6 = Healthy habitat;
- SIGNAL 5 – 6 = Mild pollution;
- SIGNAL 4 – 5 = Moderate pollution; and,
- SIGNAL < 4 = Severe pollution.

Annexure C

Results of Macrophyte Mapping

(Total No. of pages including blank pages = 10)

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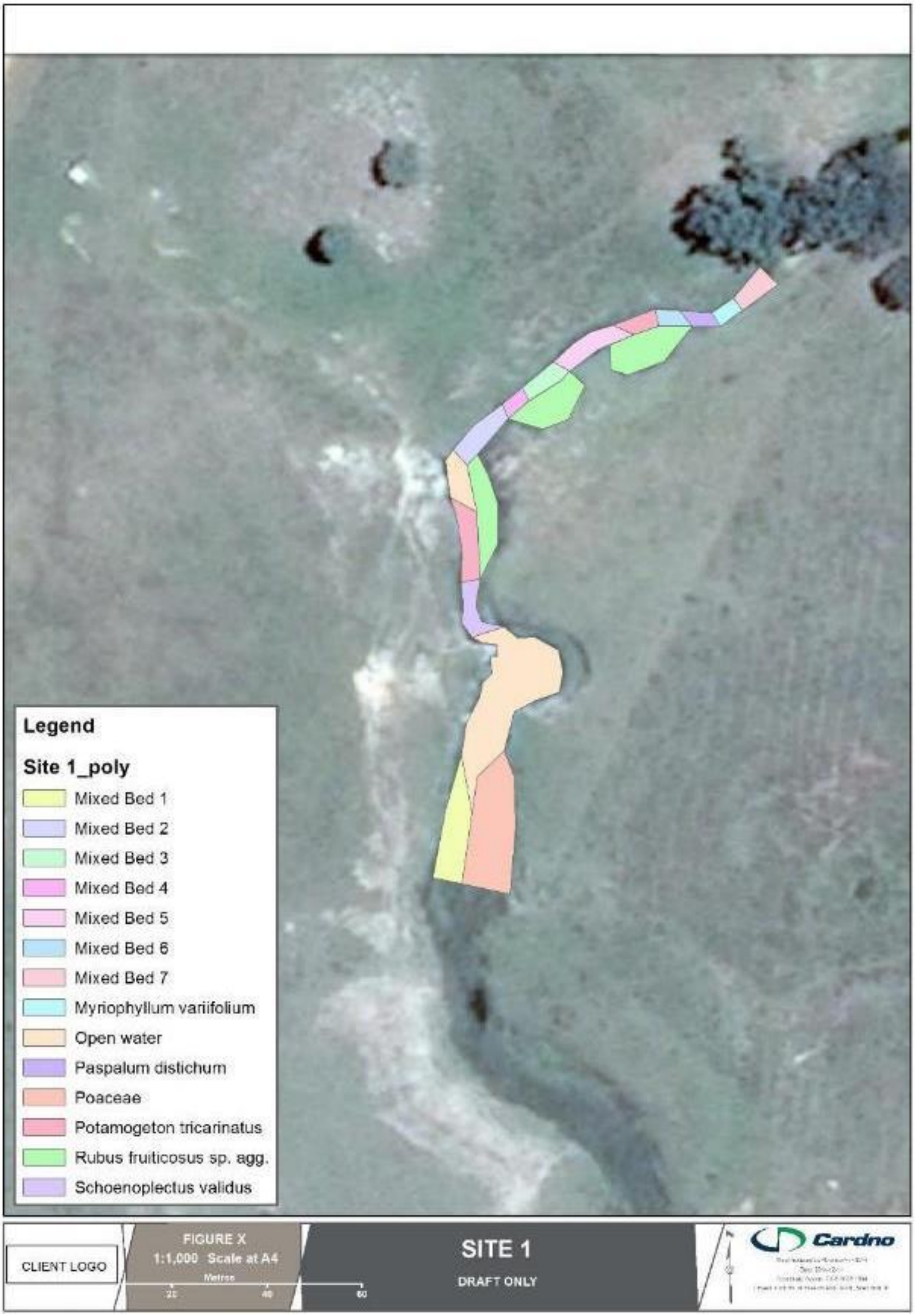
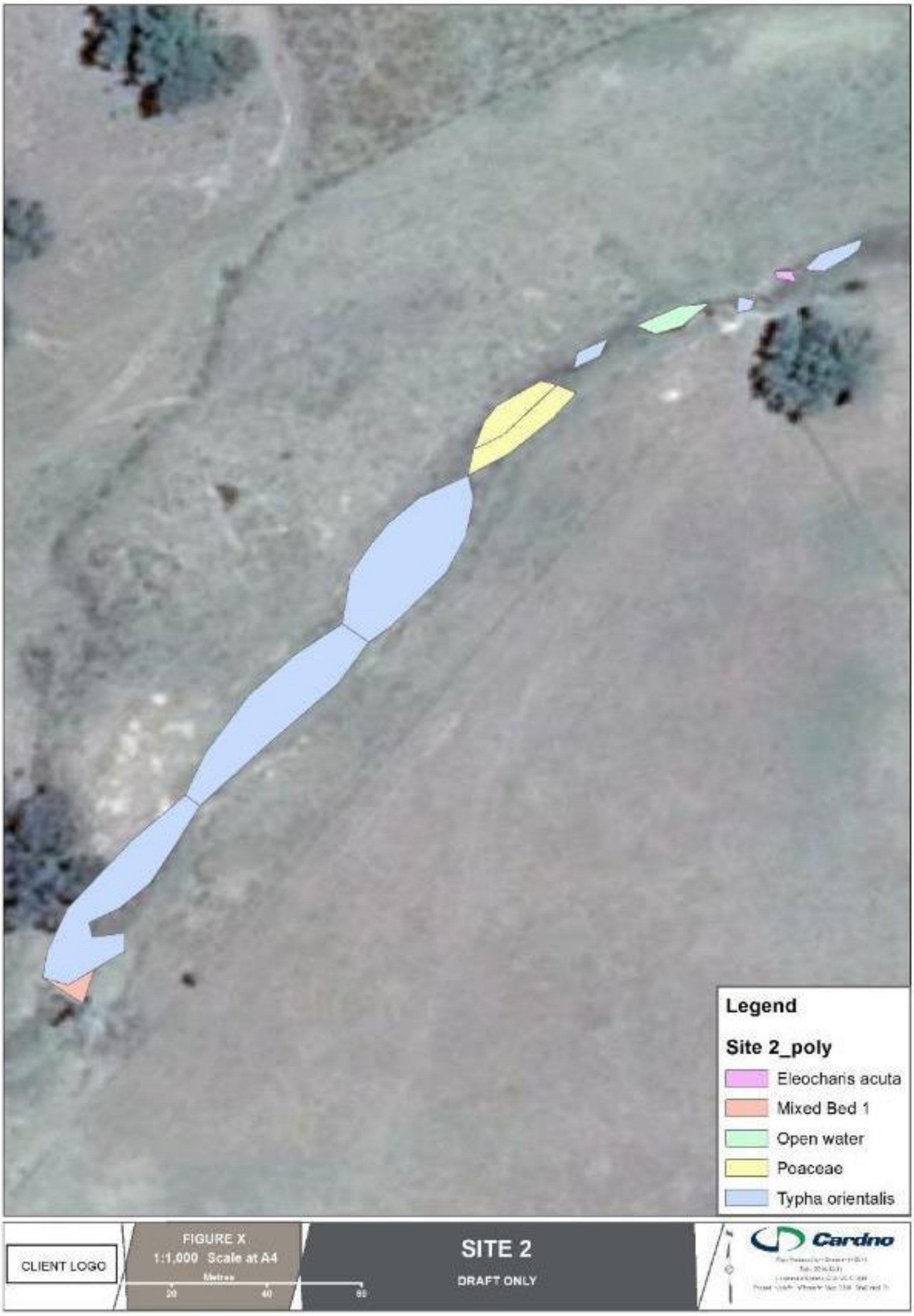
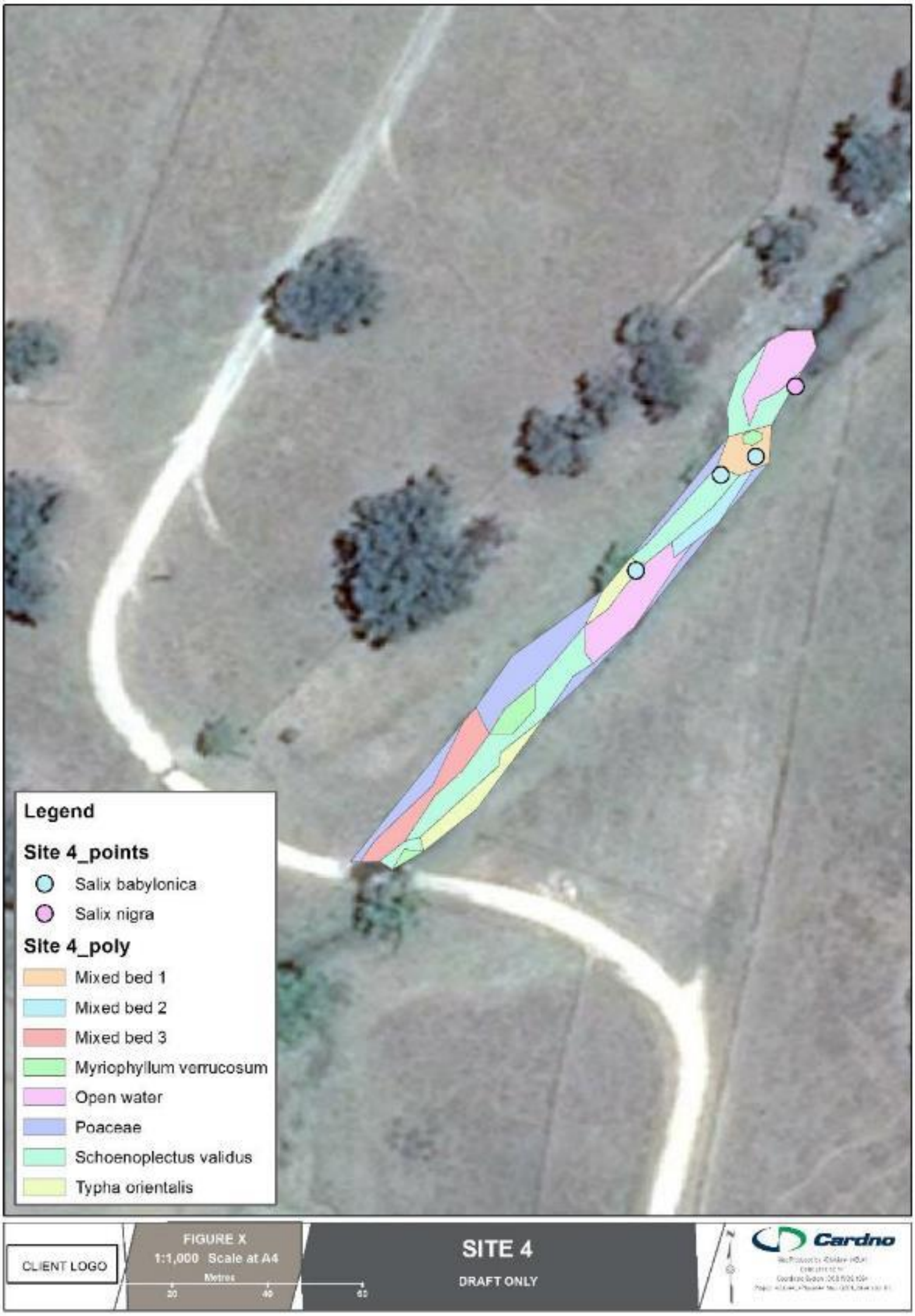
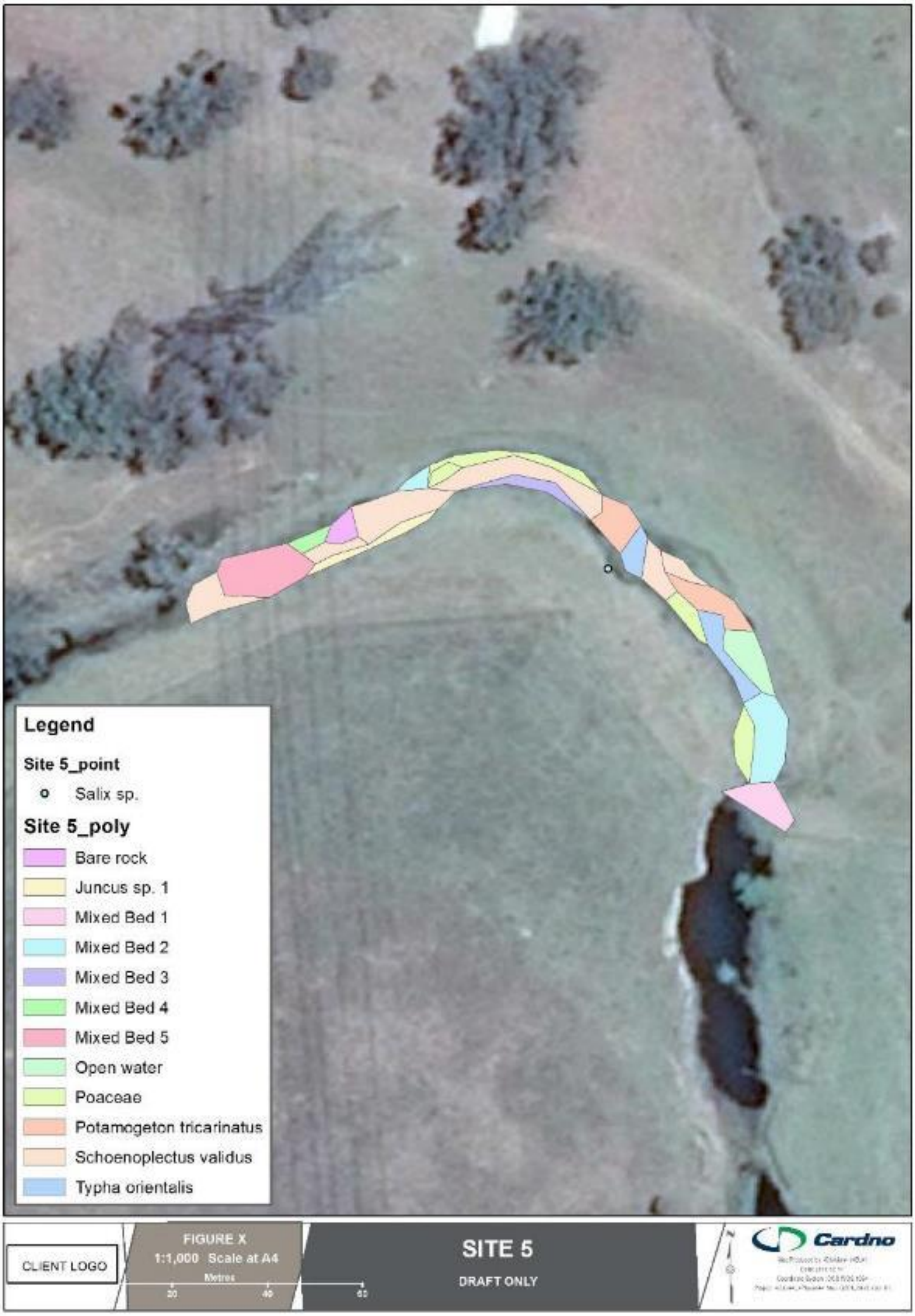
See **Figure 3.2** for the location of each site.

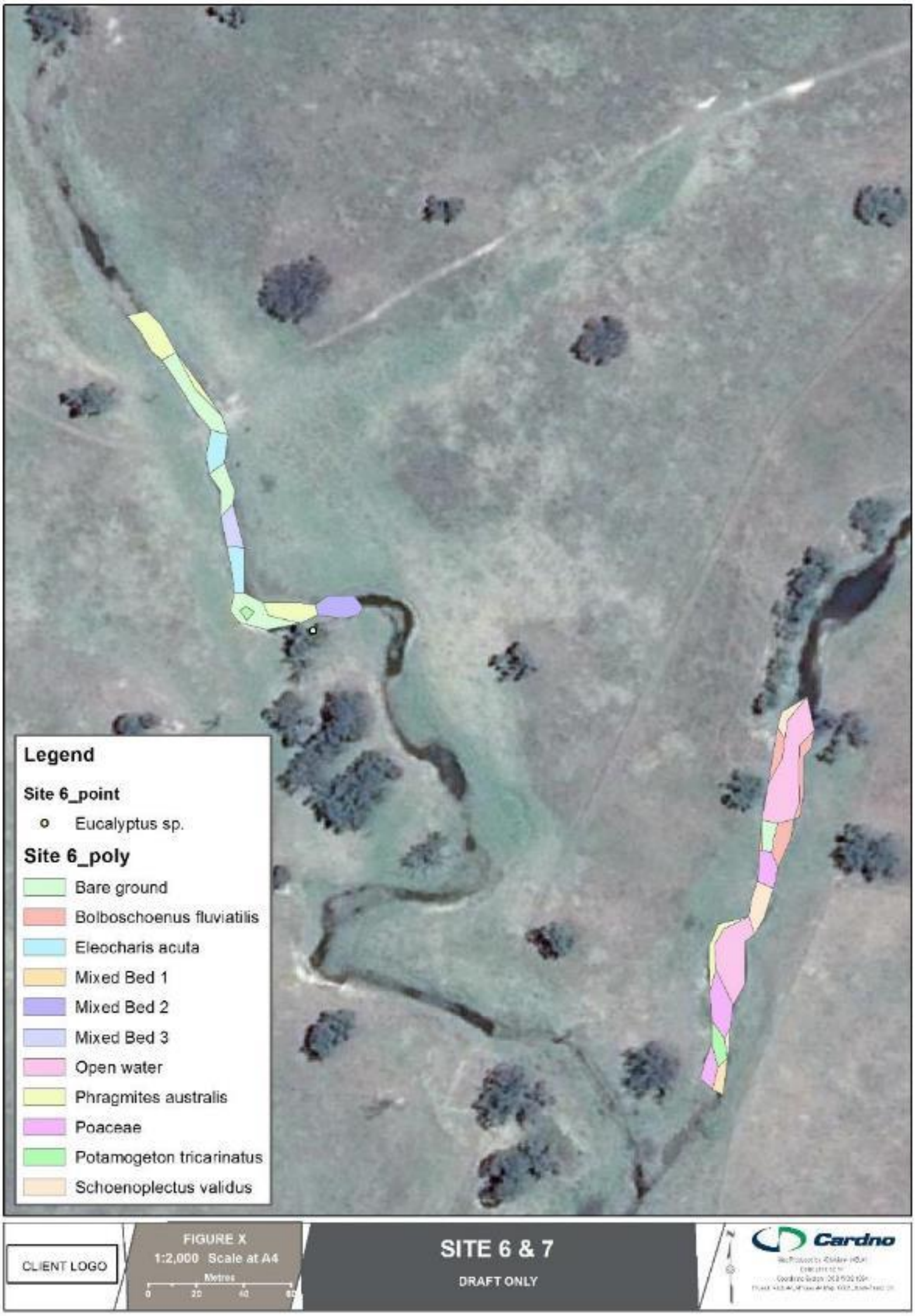



Legend
Site 2_poly
Eleocharis acuta
Mixed Bed 1
Open water
Poaceae
Typha orientalis
CLIENT LOGO
FIGURE X
1:1,000 Scale at A4
Metres
20
40
60
SITE 2
DRAFT ONLY
Cardno


Legend
Site 3_poly
Eleocharis acuta
Juncus sp. 1
Mixed Bed 1
Phragmites australis
CLIENT LOGO
FIGURE X
1:1,000 Scale at A4
Metres
20
40
60
SITE 3
DRAFT ONLY
Cardno


Legend
Site 4_points
Salix babylonica
Salix nigra
Site 4_poly
Mixed bed 1
Mixed bed 2
Mixed bed 3
Myriophyllum verrucosum
Open water
Poaceae
Schoenoplectus validus
Typha orientalis
CLIENT LOGO
FIGURE X
1:1,000 Scale at A4
Metres
20
40
60
SITE 4
DRAFT ONLY
Cardno


Legend
Site 5_point
Salix sp.
Site 5_poly
Bare rock
Juncus sp. 1
Mixed Bed 1
Mixed Bed 2
Mixed Bed 3
Mixed Bed 4
Mixed Bed 5
Open water
Poaceae
Potamogeton tricarinatus
Schoenoplectus validus
Typha orientalis
CLIENT LOGO
FIGURE X
1:1,000 Scale at A4
Metres
20
40
60
SITE 5
DRAFT ONLY
Cardno


Legend
Site 6_point
Eucalyptus sp.
Site 6_poly
Bare ground
Bolboschoenus fluviatilis
Eleocharis acuta
Mixed Bed 1
Mixed Bed 2
Mixed Bed 3
Open water
Phragmites australis
Poaceae
Potamogeton tricarinatus
Schoenoplectus validus
CLIENT LOGO
FIGURE X
1:2,000 Scale at A4
Metres
0
20
40
60
SITE 6 & 7
DRAFT ONLY
Cardno


Legend
Top_dam_poly
Open water
Potamogeton tricarinatus
Typha orientalis
CLIENT LOGO
FIGURE X
1:1,000 Scale at A4
Metres
20
40
60
TOP DAM
DRAFT ONLY
Cardno

Species of plant included in each of the mix beds identified at each site during mapping of macrophytes

Site #:	**1**							**2**	**3**	**4**			**5**					**6&7**		
Mixed Bed #:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**1**	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**
Bolboschoenus fluviatilis Myriophyllum variifolium																			X	
Eleocharis acuta Schoenoplectus validus																	X			
Eleocharis acuta Juncus sp. 1																				X
Eleocharis acuta Poaceae														X						
Juncus sp. 1 Eleocharis acuta																X				
Juncus sp. 1 Poaceae															X					
Juncus sp. 1, Verbena sp. Rumex crispus Poaceae												X								
Myriophyllum variifolium Eleocharis acuta Schoenoplectus validus				X																
Myriophyllum variifolium Typha orientalis Schoenoplectus validus					X															
Myriophyllum verrucosum Schoenoplectus validus Cyperus eragrostis Juncus sp. 1 Poaceae													X							
Paspalum distichum Eleocharis acuta									X											
Poaceae Verbena sp. Typha orientalis											X									
Schoenoplectus validus Eleocharis acuta														X						
Schoenoplectus validus Eleocharis acuta Paspalum distichum																		X		
Schoenoplectus validus						X														
Schoenoplectus validus Paspalum distichum Poaceae										X										
Schoenoplectus validus Eleocharis acuta Paspalum distichum							X													
Typha orientalis Eleocharis acuta								X												
Typha orientalis Myriophyllum variifolium			X																	
Typha orientalis Schoenoplectus validus	X	X																		

Annexure D

in situ Water Quality Data for Sites Sampled on Hawkins and Lawsons Creeks

(Total No. of pages including blank pages = 2)

See **Figure 3.2** for the location of each site.

			1		2		3		4		5		6		7
Measure	**DTV**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
13 to 14 December 2011															
Temperature (°C)		22.8	0.0	18.2	0.1	19.1	0.0	22.4	0.0	22.8	0.0	21.6	0.1	22.7	0.6
Conductivity (µS/cm)	30-350	497	0	1085	3	1517	2	782	14	758	6	774	3	347	0
pH	6.5-8.0	6.9	0.0	7.4	0.0	7.0	0.0	7.1	0.0	7.2	0.0	7.2	0.0	7.2	0.0
ORP (mV)		239	9	237	2	242	0	196	2	223	2	211	4	220	7
Dissolved Oxygen (%Sat)	90-110	90.6	0.3	93.1	0.7	64.8	0.7	92.4	0.1	88.8	1.1	80.5	0.6	105.5	0.0
Turbidity (ntu)	2-25	30.4	1.9	32.3	0.9	31.2	1.2	29.3	1.7	31.5	1.1	33.7	1.5	34.3	1.3
3 to 5 April 2013															
Temperature (°C)		15.7	0.0	18.0	0.1	14.0	0.1	15.9	0.0	16.8	0.0	18.0	0.2	16.0	0.1
Conductivity (µS/cm)	30-350	494	0	2541	7	996	76	879	1	863	19	946	6	428	2
pH	6.5-8.0	7.4	0.1	8.1	0.0	7.4	0.2	7.8	0.0	7.9	0.0	7.8	0.0	7.7	0.2
ORP (mV)		125	1	104	1	157	5	117	1	97	1	110	1	94	1
Dissolved Oxygen (%Sat)	90-110	64.5	1.1	101.6	2.2	63.0	13.7	76.4	0.1	89.3	0.8	80.5	0.0	61.5	0.8
Turbidity (ntu)	2-25	8.4	3.8	0.0	0.0	12.7	2.0	0.0	0.0	0.0	0.0	1.3	0.2	0.0	0.0
21 to 24 March 2017															
Temperature (°C)		21.8	0	23.6	0	23.3	0	24.7	0	21.7	0	21.8	0		
Conductivity (µS/cm)	30-350	448	0	1190	0	1361	0	686	0	851	0	1013	0		
pH	6.5-8.0	7.5	0	7.2	0	7.2	0	7.4	0	7.4	0	7.6	0		
Dissolved Oxygen (%Sat)	90-110	63.5	1.1	87.6	2.2	65.0	13.7	87.3	0.8	81.5	0.0	60.5	0.8		
Turbidity (ntu)	2-25	17.1	0	22.4		39.7	0	17.5	0	17.1		15.1	0		
December 2018															
Temperature (°C)		23.2	0												
Conductivity (µS/cm)	30-350	1259	0												
pH	6.5-8.0	7.5	0												
Dissolved Oxygen (%Sat)	90-110	55.2	0												
Turbidity (ntu)	2-25	22.2	0												

Grey shading indicates measure outside of the Default Trigger Values (DTV) taken from ANZECC/ARMCANZ (2000) guidelines for slightly disturbed upland rivers in southeast Australia. N = 2, except for turbidity where n = 6, SE = Standard Error

Annexure E

Macroinvertebrate Taxa Identified from AUSRIVAS Edge Samples

(Total No. of pages including blank pages = 6)

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December 2011

Taxon	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7*
Nematoda			•				
Corbiculidae / Sphaeriidae	•				•		
Lymnaeidae					•		
Planorbidae			•				
Physidae	•	•	•	•	•	•	
Hirudinidae					•		
Oligochaeta			•				
Cladocera	•	•		•		•	
Copepoda	•			•		•	
Ostracoda			•	•	•	•	
Atyidae	•	•	•	•	•	•	
Parastacidae		•	•	•	•		
Araneae					•		
Hydracarina	•	•	•	•	•		
Hypogastruridae	•						
Entomobryidae					•	•	
Caenidae	•	•	•	•	•	•	
Baetidae	•		•	•	•	•	
Leptophlebiidae	•	•	•	•	•		
Coenagrionidae	•	•	•		•	•	
Protoneuridae				•	•		
Gomphidae		•					
Aeshnidae	•	•	•	•			
Telephlebiidae				•			
Hemicorduliidae	•	•	•				
Aphididae						•	
Mesoveliidae			•				
Hydrometridae	•						
Veliidae	•			•			
Nepidae						•	
Corixidae	•	•	•	•	•	•	
Notonectidae	•	•	•	•	•		
Dytiscidae	•	•	•	•	•	•	
Hydrochidae			•		•	•	
Hydrophilidae	•	•	•				
Hydraenidae			•	•			
Scirtidae		•		•	•		
Brentidae						•	
Curculionidae	•						
Chironomidae/Chironominae	•	•	•	•	•	•	
Chironomidae/Orthocladiinae	•				•		
Chironomidae/Tanypodinae	•	•	•		•	•	
Ceratopogonidae	•	•	•	•	•		
Simuliidae	•				•		
Psychodidae					•		
Tipulidae	•		•		•		
Stratiomyidae	•						
Hydroptilidae	•						
Hydropsychidae	•			•	•	•	
Ecnomidae	•			•	•	•	
Leptoceridae	•	•	•	•	•	•	

*Site 7 not sampled using AUSRIVAS in December 2011

April 2013

Taxon	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Temnocephalidae	•				•		
Corbiculidae/ Sphaeriidae				•			•
Ancylidae						•	•
Planorbidae		•	•				
Physidae	•	•	•		•	•	•
Oligochaeta	•						
Cladocera	•	•	•				
Copepoda	•	•	•				
Ostracoda		•	•			•	
Atyidae	•	•	•	•	•		•
Parastacidae	•		•	•	•	•	•
Araneae	•			•			
Hydracarina	•	•	•				
Hypogastruridae		•					
Caenidae		•	•	•	•	•	
Baetidae	•		•	•		•	
Leptophlebiidae	•	•	•	•		•	•
Coenagrionidae	•	•	•	•	•	•	•
Gomphidae							•
Aeshnidae		•	•		•		
Hemicorduliidae	•	•	•				
Gelastocoridae			•				
Corixidae	•	•	•	•	•	•	•
Notonectidae	•		•		•	•	
Dytiscidae	•	•	•	•	•	•	
Gyrinidae	•			•	•		•
Hydrophilidae		•	•	•		•	
Hydraenidae		•	•			•	
Chironomidae/Chironominae	•	•	•	•	•	•	•
Chironomidae/Orthocladiinae							•
Chironomidae/Tanypodinae	•	•	•	•	•	•	•
Ceratopogonidae	•	•	•	•		•	
Simuliidae				•			
Hydroptilidae	•	•		•			
Hydropsychidae				•	•		
Ecnomidae	•				•	•	
Leptoceridae	•	•	•	•	•	•	•

March 2017

Taxon	Site 1	Site 8	Site 9	Site 5	Site 6	Site 10
Corbiculidae/ Sphaeriidae	•					
Physidae	•	•	•			•
Hirudinea		•				
Oligochaeta	•	•		•		
Cladocera	•		•			
Copepoda	•	•	•	•	•	
Ostracoda	•	•	•	•		
Atyidae			•	•	•	•
Parastacidae	•		•	•	•	
Araneae			•			
Hydracarina	•	•				
Hypogastruridae	•					
Caenidae	•	•		•	•	•
Baetidae	•		•	•		
Leptophlebiidae	•		•	•		
Coenagrionidae	•	•	•	•	•	•
Isostictidae		•				
Protoneuridae		•	•			
Gomphidae					•	
Hemicorduliidae	•	•				
Synthemistidae	•		•			
Veliidae					•	
Corixidae	•	•	•	•		
Notonectidae			•			•
Carabidae				•		•
Haliplidae	•				•	•
Dytiscidae	•	•	•	•	•	•
Gyrinidae	•				•	
Hydrochidae			•		•	•
Hydrophilidae		•	•	•	•	•
Chironomidae/Chironominae	•	•		•	•	•
Chironomidae/Tanypodinae	•	•	•	•	•	
Ceratopogonidae	•	•				
Stratiomyidae				•		•
Leptoceridae	•	•		•	•	•

December 2018

Taxon	Site 11a	Site 11b
Oligochaeta		•
Copepoda	•	•
Ostracoda	•	•
Atyidae	•	•
Caenidae	•	•
Baetidae	•	•
Leptophlebiidae	•	•
Chorismagrionidae		•
Gomphidae		•
Veliidae	•	•
Haliplidae	•	•
Dytiscidae	•	•
Hydrophilidae		•
Chironomidae/Chironominae	•	•
Chironomidae/Tanypodinae	•	•
Ceratopogonidae	•	•
Leptoceridae	•	•

Annexure F

Detailed Methods Description – Stygofauna

(Total No. of pages including blank pages = 2)

Field Methods

The stygofauna sampling method for this assessment was designed with consideration of the recommendations contained in the Western Australia Environmental Protection Authority – Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia (WAEPA 2007) and The Cooperative Research Centre for Contamination Assessment and Remediation of the Environment – Sampling Strategies for Biological Assessment of Groundwater Ecosystems (Hose and Lategan 2012). In this case, modified plankton nets were used to sample stygofauna. The procedure for sampling stygofauna in each bore was as follows:

- Three hauls using a 150 µm mesh net were undertaken. The weighted net was lowered to the bottom of the bore and the bottom agitated (via up and down movements) to suspend biota in the sediment or water/sediment interface. The net was then slowly pulled to the surface.
- After each haul the contents of the net were rinsed into a sample container. Care was taken to ensure all material was washed from the net in to the container. The sample was then preserved with 100% ethanol and labelled (bore code, job reference, date) on the inside and outside of the container.
- Three net hauls using a 50 µm mesh net were undertaken and the contents of each transferred to the same container as per the above procedure. The use of the 150 µm mesh net before the 50 µm net helps remove coarser particles from the water within the bore which may otherwise clog the finer mesh net.

Groundwater bore water quality data (electrical conductivity, pH and ORP) and the depth to water was collected just prior to, or within a few days following, sampling for stygofauna. These water quality data complemented the longer term data collected including metal and nutrient sampling, as part of the ongoing groundwater quality data collection.

Laboratory Methods

Stygofauna samples were sorted under a binocular microscope (at 40 X magnification) and the sediment checked by a second experienced taxonomist. Biota were identified to the lowest practical taxonomic level (where published keys are available) and a selection of specimens delivered to Dr Peter Hancock (Ecological Pty. Ltd.) to confirm identifications.

Annexure G

Location of the Groundwater Bores Selected for Sampling of Stygofauna

(Total No. of pages including blank pages = 2)

Bore	Easting	Northing	Further Detail
BGW12	769243	6387654	Just to the north and outside of the Mine Site
BGW16	766055	6386705	Associated with a spring to the west of the TSF
BGW17	766292	6386508	Associated with a spring to the west of the TSF
BGW18	768881	6384866	Approximately 200 m south of open cut pit area
BGW20	769369	6385130	Approximately 100 m south of open cut pit area
BGW25	768466	6384374	Between open cut pit and Lawsons Creek
BGW27A	769534	6385285	Within WRE
BGW29	768155	6385098	Southwest of the open cut pit
BGW39	768776	6383440	Adjacent to Lawsons Creek
BGW44	769491	6386931	Adjacent to Price's Creek north of WRE
BGW46	768671	6385286	Approximately 100 m west of open cut pit
BGW48	769665	6384192	Adjacent to Hawkins Creek
BGW49	769677	6384300	Adjacent to Hawkins Creek
BGW50	769756	6384843	Adjacent to Hawkins Creek
BGW51	769756	6384847	Adjacent to Hawkins Creek
BGW53	770249	6385024	Adjacent to Hawkins Creek
BGW54	770139	6385175	Adjacent to Hawkins Creek / Price Creek
BGW55	766412	6383571	Adjacent to Lawsons Creek
BGW56	766777	6383407	Lue Township Well Adjacent to Lawsons Creek
BGW102	768972	6385816	Within open cut pit area
BGW106	769287	6385731	Within open cut pit area
BGW107	769171	6385848	Within open cut pit area

Annexure H

Raw Stygofauna Sampling Data

(Total No. of pages including blank pages = 4)

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Order	Family	Species	Bore Number																	
			16	**17**	**18**	**20**	**25**	**27**	**29**	**39**	**46**	**48**	**49**	**50**	**51**	**53**	**54**	**102**	**106**	**107**
3 to 5 April 2013																				
Stygofauna																				
Anaspidacea	Psammaspididae	*Psammaspides* sp.			1	1						6								
Cyclopoida	Cyclopidae		1	>100								22								
Ostracoda	Candonidae									2										
Ostracoda	Cyprididae		1	>100																
Non-Stygofauna																				
Acarina (Mesostigmata)										4										
Collembola										6	3				1					
Cladocera				>100																
Diptera	Chironomidae									2										
Hymenoptera	Formicidae									1		1								
Thysanoptera	Phlaeothripidae						*ns*	*nt*	*ns*	1	*nt*		*ns*	*nt*		*ns*	*ns*	*nt*	*nt*	*ns*
19 to 21 June 2013																				
Stygofauna																				
Amphipoda	Paramelitidae											1								
Anaspidacea	Psammaspididae	*Psammaspides* sp.										7					1			
Cyclopoida	Cyclopidae											>50								
Ostracoda	Cyprididae			>50																
Non-Stygofauna																				
Phylum: Nematoda			*nt*		*ns*	*nt*	*ns*	*nt*	*ns*	*ns*	*ns*		*nt*	*ns*	*nt*	*Nt*		*ns*	*ns*	*nt*
5 to 6 November, 10 to 12 December 2013																				
Stygofauna																				
Amphipoda	Paramelitidae												1							
Anaspidacea	Psammaspididae	*Psammaspides* sp.											12							
Cyclopoida	Cyclopidae		5									6	1							
Ostracoda	Cyprididae			30													2			
Non-Stygofauna																				
Coleoptera	Hydrochidae																			1
Hemiptera													1							
Thysanoptera					*ns*	*nt*	*nt*	*ns*	*nt*	*nt*	*ns*			*ns*	*nt*	*ns*		*ns*	*ns*	

NS = Not sampled, NT = Sampled, but no taxa caught.

Order	Family	Species	Bore Number															
			12	**16**	**17**	**18**	**20**	**27A**	**39**	**44**	**46**	**48**	**49**	**50**	**55**	**56**	**106**	**Well**
March 2017																		
Stygofauna																		
Anaspidacea	Psammaspididae	*Psammaspides* sp.											2					
Cyclopoida	Cyclopidae											45	77					
Copepoda																15		
Ostracoda	Candonidae																	
Ostracoda	Cyprididae																	
Non-Stygofauna																		
Acarina (Halacaroidea)												33	10			1		
Collembola			2									60						
Cladocera																		
Diptera	Chironomidae																	
Hymenoptera	Formicidae																	
Thysanoptera	Phlaeothripidae																	
	Hydrophilidae			1														
Oligocheatae												7	1					

Annexure I

Assessments of Significance / Consideration under Significant Impact Criteria for the Listed Threatened Species of Fish

(Total No. of pages including blank pages = 8)

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Southern Purple Spotted Gudgeon – Assessment of Significance (FM Act)

Page 1 of 2

Assessment Criteria	Response
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	Southern purple spotted gudgeon lay small numbers of adhesive eggs in a single batch a rock, log or aquatic plants. They may produce several batches of eggs each spawning season (spring to summer). The males guard and fan the eggs (Lintermans 2009). Newly hatched larvae are approximately 4 mm long. The causes of the decline in southern purple spotted gudgeon include predation by introduced fish such as gambusia and redfin perch; habitat loss; rapid fluctuations in water levels (due to water regulation) that have deleterious effects on successful reproduction and recruitment. Sedimentation in waterways may also smother eggs or egg laying surfaces thereby affected the reproduction of this species. Several water quality control measures are inherent in the Project design and are outlined in this assessment. These would prevent the release of sediment laden water to Hawkins and Lawsons creeks. The Project is also not expected to exacerbate the spread or proliferation of pest fish already present in these creeks. Predicted reductions in surface flow in Hawkins and Lawsons Creeks, which are intermittent creeks that consist of disconnected pools naturally, are also minor. Thus, the Project is not expected to exacerbate existing threating processes present in Hawkins and Lawsons Creeks so that this species would 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* *(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

Southern Purple Spotted Gudgeon – Assessment of Significance (FM Act) (Cont'd)

Page 2 of 2

Assessment Criteria	**Response**
d) In relation to the habitat of a threatened species, population or ecological community: *(i) the extent to which habitat is likely to be removed or modified as a result of the action proposed, and* *(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* *(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality*	Southern purple spotted gudgeon are slow-moving ambush predators. They are benthic species and usually found in areas with good cover such as cobble and rocks or aquatic vegetation. This species occurs in slow moving or still waters of creeks, rivers, wetlands and billabongs, but appears to prefer slower flowing, deeper habitats. Approximately 6.5 m^2 of Lawsons Creek would be modified by construction of the box culvert. This may also create barrier to passage under normal flow conditions. The amount of habitat that would be modified would be negligible relative the amount of undisturbed creek bed present elsewhere. Lawsons Creek is also naturally intermittent and consists of a series of disconnected pools. The section of creek adjacent to the crossing is currently also heavily degraded with poor water quality, riparian vegetation in poor condition and abundant species of pest fish. Thus, impacts to southern purple spotted gudgeon associated with the construction and operation of the crossing are not expected. The rehabilitation of riparian vegetation in the vicinity of Lawsons Creek and the proposed box culvert offers the opportunity to improve the habitat of this species.
(e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly)	There are no critical habitats for purple spotted gudgeon listed under the FM Act.
(f) whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan	No recovery plan or threat abatement plan for purple spotted gudgeon currently exist. Recovery actions relevant to the Project contained in the priorities action statement for this species include: Habitat rehabilitation; and Pest eradication and control The controls and impact minimisation measures described here would prevent impacts to this species occurring. The placement of instream woody debris and restoration of riparian vegetation as part of the Project would provide the opportunity to enhance purple spotted gudgeon habitat.
(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 Project would not result in the net removal of any woody debris or further degradation of riparian vegetation associated with and Lawsons Creeks and would not exacerbate associated KTPs. The very minor potential changes to the local hydrological regime adjacent to the proposed crossing on Lawsons Creek would not significantly exacerbate the associated KTP.

Murray River Basin Population of the Freshwater Catfish (*Tandanus tandanus*)

Assessment Criteria	**Response**
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	Not applicable
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	The Freshwater Catfish is a benthic species that lives, feeds and breeds near the bottom. It does not migrate. It spawns in spring and summer when water temperatures are 20-24° C. The eggs are deposited in a nest constructed of pebbles and gravel within a circular to oval depression. The eggs are large and non-adhesive and settle into the interstices of the substratum. The nest is guarded and fanned by male fish. Probably threatening processes relevant to this species include loss of habitat through flow regulation, loss of habitat and spawning sites through sedimentation, chemical pollution through pesticides and interactions with pest species such as carp. Several water quality control measures are inherent in the Project design and are outlined in this assessment. These would prevent the release of sediment laden water to Hawkins and Lawsons Creeks. The Project is also not expected to exacerbate the spread or proliferation of pest fish already present in these creeks. Predicted reductions in surface flow in Hawkins and Lawsons creeks, which are intermittent creeks that consist of disconnected pools naturally, are also minor. Thus, the Project is not expected to exacerbate existing threating processes present in Hawkins and Lawsons Creeks so that this species would be placed at risk of extinction.
(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* *(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

Murray River Basin Population of the Freshwater Catfish (*Tandanus tandanus*) (Cont'd)

Page 2 of 2

Assessment Criteria	Response
d) In relation to the habitat of a threatened species, population or ecological community: *(i) the extent to which habitat is likely to be removed or modified as a result of the action proposed, and* *(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* *(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality*	Freshwater catfish occur in a variety of habitats, including rivers, creeks, lakes, billabongs and lagoons, in clear to turbid waters and over a variety of substrata, including mud, gravel and rock. They may be found in flowing watercourses, but appear to prefer sluggish or still waters. Approximately 6.5 m^2 of Lawsons Creek would be modified by construction of the box culvert. This may also create barrier to passage under normal flow conditions. The amount of habitat that would be modified would be negligible relative the amount of undisturbed creek bed present elsewhere. Lawsons Creek is also intermittent and appears to consist of series of disconnected pools naturally. The section of creek adjacent to the crossing is also heavily degraded with poor water quality, riparian vegetation in poor condition and abundant species of pest fish. Thus, impacts to eel tailed catfish associated with the construction and operation of the crossing are not expected.
(e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly)	No critical habitats for Murray River Basin population of eel tailed catfish are listed under the FM Act.
(f) whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan	No recovery plan or threat abatement plan for Murray River Basin population of eel tailed catfish currently exist. Recovery actions relevant to the Project contained in the priorities action statement for this species include: • Habitat rehabilitation; and • Pest eradication and control The controls and impact minimisation measures described here would prevent impacts to this species occurring. The placement of instream woody debris and restoration of riparian vegetation as part of the Project would provide the opportunity to enhance purple spotted gudgeon habitat.
(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 Project would not result in the net removal of any woody debris or further degradation of riparian vegetation associated with Hawkins and Lawsons Creeks and would not exacerbate associated KTPs. The very minor potential changes to the local hydrological regime adjacent to the proposed crossing on Lawsons Creek would not significantly exacerbate the associated KTP.

Murray Cod (*Maccullochella peeliil*) – EPBC Act Significant Impact Criteria

Assessment Criteria	**Response**
Long-term decrease in the size of local and regional populations	Murray cod are endemic to the Murray-Darling River system and historically were present throughout most of this system, except for the upper reaches of tributaries. This species is still present throughout most of its historic range. The Project does not include elements that would result in the direct modification of any more than negligible (approx. 10 m^2 beneath the Lawsons Creek crossing) potential Murray cod habitat. The habitat within this section of creek is also natural substantially fragmented due to the intermittent flow of the creek. There would also be no snag removal as part of the Project. Several water quality control measures are inherent in the Project design and are outlined in this assessment. These would prevent the release of sediment laden water to Hawkins and Lawsons creeks. The Project is also not expected to exacerbate the spread or proliferation of pest fish already present in these creeks. Predicted reductions in surface flow in Hawkins and Lawsons creeks, which are intermittent creeks that consist of disconnected pools naturally, are also minor. Given these, the Project is not expected to result in a reduction of the population size of Murray cod.
Reduced area of occupancy	Murray Cod have been found in a variety of habitats, including clear rocky watercourses, slow flowing, turbid rivers, and billabongs. This fish is usually found in sheltered areas, where there is extensive cover in the form of large rocks, snags, overhanging vegetation or other woody structures. Juveniles have been found in the main river channel. Murray Cod are thought to be sedentary species, remaining in a specific hole, snag or area of the river until spring-summer, when they undertake extensive upstream spawning migrations. After spawning, the adults return to their territory downstream. As described above, the Project does not include elements that would result in the direct modification of any more than negligible (approx. 10 m2 beneath the Lawsons Creek crossing) potential Murray cod habitat. The habitat within this section of creek is also natural substantially fragmented due to the intermittent flow of the creek. There would also be no snag removal as part of the Project. Together with successful implementation of the control measures inherent in the Project design and described in this assessment, the Project is not expected to result in a reduction in the potential area of occupancy of Murray cod.
Fragmentation of an existing population into two or more populations.	Given the currently natural highly fragmented disconnected pool habitat in Lawsons Creek, the potential partial barrier to fish passage represented by installation of the crossing here is not expected to result in any more than minor further reduction in habitat connectivity in Lawsons Creek

Murray Cod (*Maccullochella peeliil*) – EPBC Act Significant Impact Criteria (Cont'd)

Page 2 of 2

Assessment Criteria	**Response**
Adverse effects on habitat that is critical to the survival of the species	The habitat provided by Hawkins and Lawsons Creeks is relatively degraded, with evidence of existing sedimentation, poor water quality, minimal riparian vegetation and abundant pest species. Thus, it would be very unlikely to provide critical habitat.
Disrupt the breeding cycle of a population	Murray Cod spawn in late spring and early summer. Spawning has been reported to occur in the vicinity of submerged rocks and in depressions excavated in clay banks. The eggs are adhesive and are deposited as a large mat on the spawning surface. Removal of snags and potential sedimentation in waterways could disrupt the breeding cycle by removing or smothering important breeding substratum. However, these are not expected to occur as a result of the Project and disruptions of breeding cycles are not expected.
Modify, destroy, remove, isolate or decrease the availability and or quality of habitat to the extent that the species is likely to decline.	As described above, the Project does not include elements that would result in the direct modification of any more than negligible (approximately 6.5 m^2 beneath the Lawsons Creek crossing) potential Murray cod habitat. The habitat within this section of creek is also natural substantially fragmented due to the intermittent flow of the creek. There would also be no snag removal as part of the Project. Together with successful implementation of the control measures inherent in the Project design and described in this assessment, the Project is not expected to result in a reduction in the potential area of occupancy of Murray cod.
Result in invasive species that are harmful becoming established in the threatened species habitat	Hawkins and Lawsons Creeks currently support several species of pest fish. A potential increase in numbers of eastern gambusia could occur in isolated waterbodies on-site. However, there would be no planned release of water to Hawkins and Lawsons Creeks. Measures to limit and control the number of pest species that proliferate in water storages have also been included in the Project design. Based on this, the Project would not result in the establishment of species of pest fish in Hawkins and Lawsons Creeks.
Introduce disease that may cause the species to decline	The construction and operation of the Project does not include any mechanisms that would introduce disease.
Interfere with the recovery of the species	The overall objective of the National Recovery Plan for Murray Cod National Murray Cod Recovery Team (2010b) is to have self-sustaining populations managed for conservation, fishing and culture. Extraction of water. The potential threats posed by the Project activities would be unlikely to interfere with the recovery of the species. This is due the very localised nature of the impact (in the case of the proposed crossing) or the very low likelihood of the impact occurring (in the case of accidental releases of poor quality water)