Central Queensland Coal Project

Chapter 15 – Aquatic Ecology

Supplementary Environmental Impact Statement

CDM Smith

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Central Queensland Coal Project

Chapter 15 – Aquatic Ecology

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CDM Smith Australia Pty Ltd
ABN 88 152 082 936
Level 4, 51 Alfred Street
Fortitude Valley
Qld 4006
Tel: +61 7 3828 6900
Fax: +61 7 3828 6999

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15 Aquatic Ecology

This chapter describes the existing aquatic flora and fauna values within and surrounding the Central Queensland Coal Project, as defined by the boundary of the Central Queensland Coal Mine Lease 80187 (mine ML) and the adjacent ML 700022 on which the train loadout facility (TLF) is located. The assessment is based on desktop literature reviews of existing background information and site-specific field assessments.

The investigation focuses on habitats within the Project area and wider surrounds, and targets threatened species where necessary. Survey sites were selected in representative locations across the wider area and encompassed the variety of aquatic habitat types present. The Project area together with additional sites visited surrounding the Project area represent the ecological Study area, as referred to in this chapter.

The chapter assesses the likely impacts of the Project on terrestrial and aquatic flora and fauna Environmental Values (EVs). This chapter collates the results of several ecological technical reports (refer Appendix A9e – Aquatic Ecology Results and A9f – Stygofauna Results) and provides the results of an updated desktop review and an additional site survey. Note that Appendix A9f – Stygofauna Results references the original proponent; Styx Coal Pty Ltd, and the original Project name, Styx Coal Mine Project; however, the Central Queensland Coal Pty Ltd is the new Proponent for the Project and the Project has been renamed as Central Queensland Coal Project to better reflect the change of Proponent. This proponent and title change does not affect the technical studies.

Specific objectives of the aquatic ecology assessment were to:

- Review the relevant background information including databases, mapping and literature;
- Confirm the likely presence / absence of aquatic flora and fauna (and associated habitats) listed under Queensland's *Nature Conservation Act 1992* (NC Act) and the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act);
- Characterise the main flow channels associated with the Project area and allow the identification of priority monitoring areas;
- Assess the potential for stygofauna (aquatic groundwater invertebrates) to occur within the Study area;
- Discuss potential direct and indirect impacts to terrestrial and aquatic ecological values as a result of the Project; and
- Propose mitigation measures to protect or enhance aquatic ecological values within the Project area.

The Project's impacts on Matters of National Environmental Significance (MNES) as listed under the EPBC Act are addressed in detail in Chapter 16 - MNES.

Matters raised in submission to the Environmental Impact Statement (EIS) relating to Chapter 15 – Aquatic Ecology were predominantly focused on:

- Provide further description of mapped wetlands (as described under the Queensland *Vegetation Management Act 1999* (VM Act) located within the Project boundary;
- Further consideration of impacts to waterways providing for fish passage as a Matter of State Environmental Significance (MSES); and

- The extent of potential impacts to wetlands and Groundwater Dependent Ecosystems (GDE) as a result of groundwater drawdown resulting from the Project's activities.

The following provides updated information to that provided in the EIS, in response to the submissions relating to EIS Chapter 15 - Aquatic Ecology. Appendix A13 includes the full details of all submissions received for the Project.

15.1 Project Overview

Central Queensland Coal Proprietary Limited (Central Queensland Coal) and Fairway Coal Proprietary Limited (Fairway Coal) (the joint Proponents), propose to develop the Central Queensland Coal Mine Project. As Central Queensland Coal is the senior proponent, Central Queensland Coal is referred to throughout this Supplementary Environmental Impact Statement (SEIS). The Project comprises the Central Queensland Coal Mine where coal mining and processing activities will occur along with a TLF.

The Project is located 130 km northwest of Rockhampton in the Styx Coal Basin in Central Queensland. The Project is located within the Livingstone Shire Council Local Government Area. The Project is generally located on the "Mamelon" property, described as real property Lot 11 on MC23, Lot 10 on MC493 and Lot 9 on MC496. The TLF is located on the "Strathmuir" property, described as real property Lot 9 on MC230. A small section of the haul road to the TLF is located on the "Brussels" property described as real property Lot 85 on SP164785.

The Project will involve mining a maximum combined tonnage of up to 10 million tonnes per annum (Mtpa) of semi-soft coking coal (SSCC) and high grade thermal coal (HGTC). The Project will be located within ML 80187 and ML 700022, which are adjacent to Mineral Development Licence (MDL) 468 and Exploration Permit for Coal (EPC) 1029, both of which are held by the Proponent. It is intended that all aspects of the Project will be authorised by a site specific environmental authority (EA).

Development of the Project is expected to commence in 2019 with initial early construction works and extend operationally for approximately 19 years until the depletion of the current reserve, and rehabilitation and mine closure activities are successfully completed.

The Project consists of two open cut operations that will be mined using a truck and shovel methodology. The run-of-mine (ROM) coal will ramp up to approximately 2 Mtpa during Stage 1 (2019 - 2022), where coal will be crushed, screened and washed to SSCC grade with an estimate 80% yield. Stage 2 of the Project (2023 - 2038) will include further processing of up to an additional 4 Mtpa ROM coal within another coal handling and preparation plant (CHPP) to SSCC and up to 4 Mtpa of HGTC with an estimated 95% yield. At full production two CHPPs, one servicing Open Cut 1 and the other servicing Open Cut 2, will be in operation. Rehabilitation works will occur progressively through mine operation, with final rehabilitation and mine closure activities occurring between 2036 to 2038.

A new TLF will be developed to connect into the existing Queensland Rail North Coast Rail Line. This connection will allow the product coal to be transported to the established coal loading infrastructure at the Dalrymple Bay Coal Terminal (DBCT).

Access to the Project will be via the Bruce Highway. The Project will employ a peak workforce of approximately 275 people during construction and between 100 (2019) to 500 (2030) during operation, with the workforce reducing to approximately 20 during decommissioning. Central Queensland Coal will manage the Project construction and ongoing operations with the assistance of contractors.

This SEIS supports the EIS by responding to the submissions that were made during the public notification period regarding the original EIS and identifies the material changes to the Project.

15.2 Relevant Legislation and Policies

Environmental protection of existing terrestrial wildlife and habitats is governed by several legislative Acts, policies and guidelines which are described in Chapter 1 - Introduction. Those with relevance to terrestrial and aquatic values are outlined below.

15.2.1 Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act regulates activities that may have an impact upon MNES. The Project has the potential to impact upon MNES including listed threatened species, communities and migratory birds and, therefore has been designated as a Controlled Action under the Act. This chapter does not assess the potential impacts on MNES as prescribed under the EPBC Act. As per the Project ToR impacts to MNES are described separately within Chapter 16 – MNES.

15.2.2 Nature Conservation Act 1992

The NC Act provides for the protection and management of native wildlife and habitat that supports native species with particular regard to:

- The clearing of plants protected under the NC Act;
- Activities that may cause disturbance (that is tamper, damage, destroy, mark, move or dig up) to animal breeding places; and
- The taking of fauna.

Subordinate legislation lists protected species and areas to which the regulatory provisions of the NC Act apply including:

- *Nature Conservation (Wildlife) Regulation 2006*: this Regulation lists terrestrial and aquatic plant and animal species presumed extinct, endangered, vulnerable, rare, common, international or prohibited. It recommends management objectives for the protection and maintenance of these species in Queensland, as appropriate; and
- *Nature Conservation (Protected Plants) Conservation Plan 2000*: this Plan provides protection and management of native flora.

15.2.3 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (EP Act) and subordinate legislation provide regulatory provisions for the protection and management of EVs in relation to mining activities.

15.2.3.1 Environmental Protection (Water) Policy 2009

The EP Act also regulates wetlands in wetland management areas under the subordinate environmental protection policy (EPPs) including the *Environmental Protection (Water) Policy 2009* (EPP (Water)). The EPP (Water) establishes a process for identifying EVs to be protected and states standards for water quality in support of those values. The EPP (Water) provides a framework for:

- Identifying EVs and management goals for Queensland waters;

- Stating water quality guidelines and objectives (WQOs) to protect or enhance the EVs;
- Providing a framework for making consistent, equitable and informed decisions about Queensland waters; and
- Monitoring and reporting on the condition of Queensland waters.

Section 7 of the EPP (Water) specifies the hierarchy of guidelines that are used, to identify water quality objectives in aquatic habitats. The hierarchy (in the order of use) of water quality guidelines for the Project are:

- Queensland Water Quality Guidelines (QWQG) (EHP 2013); and
- Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resources Management Council of Australia and New Zealand (ARMCANZ) Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (herein referred to as the ANZECC and ARMCANZ 2000).

The Project is located within the Styx River Basin and EVs / WQOs for the area are detailed in the Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values and Water Quality Objectives (EHP 2014).

15.2.4 Environmental Offsets Act 2014

The *Environmental Offsets Act 2014* (EO Act), Environmental Offsets Regulation 2014 and the Queensland Government Environmental Offsets Policy provides a streamlined framework for environmental offset requirements. Offsets are required where there is an unavoidable impact on significant EVs. In addition, an environmental offset can only be required if impacts from a prescribed activity constitute a significant residual impact as identified through the following guidelines:

- The State guideline that provides guidance on what constitutes a significant residual impact for MSES;
- The Commonwealth Significant Impact Guidelines for what constitutes a significant residual impact on MNES; and
- Any relevant local government significant impact guideline for Matters of Local Environmental Significance (MLES).

To avoid duplication with offsets required under the EPBC Act, the policy provides that the administering agency must consider other relevant offset conditions which for the same or substantially the same prescribed impact. If duplicating conditions are imposed, it allows the proponent to remove the duplication.

15.2.5 Fisheries Act 1994

The *Fisheries Act 1994* (Fisheries Act) provides for the management, protection and conservation of fisheries and fish habitat. Mine developments are required to comply with the Act and minimise impacts to areas of fish habitat which are defined under the Act as: ‘Areas of water, land and plants that are associated with the lifecycle of a fish, including those not presently occupied by fish’. Declared fish habitat areas provide long term protection for fish habitats which are deemed essential for sustaining fisheries. Fish habitat areas are protected from physical disturbance under the Act.

15.2.6 Coastal Management Act 1995

The *Coastal Protection and Management Act 1995* seeks to provide for the protection and management of the 'coastal zone' including its 'resources and biological diversity,' and ensure development decisions are aligned with the potential threat from 'coastal hazards.' The Act defines the 'coastal zone' under which the Act applies, and specifies areas for controlling development and management practises including 'coastal management districts' and 'erosion prone areas.' The Coastal Management Plan (EHP 2013) has been prepared under the Act to describe how the coastal zone of Queensland is to be managed.

15.2.7 Biosecurity Act 2014

The *Biosecurity Act 2014* (Biosecurity Act) provides legislative measures to manage pests and weeds, diseases and environmental contaminants, to address the impacts they have on the economy, environment, agriculture, tourism and society. The Act commenced on 1 July 2016 and supersedes a range of separate legislative implements previously used to manage biosecurity. This includes the *Land Protection (Pest and Stock Route Management) Act 2002* which previously provided legislative measures to manage damaging pests and weed species.

The purpose of the Biosecurity Act is to:

- Provide a framework for an effective biosecurity system for Queensland that helps to minimise biosecurity risks and facilitates responding to impacts on a biosecurity consideration, including responding to biosecurity events, in a timely and effective way;
- Ensure the safety and quality of animal feed, fertilisers and other agricultural inputs;
- Help align responses to biosecurity risks in the State with national and international obligations and requirements for accessing markets for animal and plant produce, including live animal and plants; and
- Manage risks associated with emerging, endemic and exotic pests and diseases that impact on plant and animal industries, the build environment, companion or leisure animals, biodiversity and the natural environment, tourism, lifestyle and pleasure industries or infrastructure and service industries, the transfer of diseases from animals to humans and from humans to animals, biological, chemical and physical contaminants in carriers.

The Biosecurity Act provides a consistent regulatory approach for the management of invasive biosecurity matter across Queensland. The Biosecurity Act specifically requires the local governments to have a biosecurity plan for invasive biosecurity matter for its local government area and to pay an amount each financial year to the Land Protection Fund when requested.

Under the Biosecurity Act everyone has a 'general biosecurity obligation'. This means everyone is responsible for managing biosecurity risks that are under their control and that they know about or should reasonably be expected to know about.

Under the general biosecurity obligation, individuals and organisations whose activities pose a biosecurity risk must:

- Take all reasonable and practical steps to prevent or minimise each biosecurity risk;
- Minimise the likelihood of causing a 'biosecurity event' and limit the consequences if such an event is caused; and

- Prevent or minimise the harmful effects a risk could have, and not do anything that might make any harmful effects worse.

15.2.8 Planning Act 2016

The *Planning Act 2016* (Planning Act) establishes a new planning system for the state and replaces the *Sustainable Planning Act 2009* (SP Act). The Act provides a planning framework and development assessment system for Queensland. The *Planning Regulation 2017* (Planning Regulation) commenced on the 3 July 2017. Similar to the *Sustainable Planning Regulation 2009,* the Planning Regulation gives effect to a suite of supporting instruments such as the *State Planning Policy 2017.*

The SPP is a statutory instrument prepared under the Planning Act that relates to matters of Queensland interest. The SPP applies to a range of circumstances under the Planning Act, including for development assessment and when proposed new planning schemes are made or amended. The SPP is applicable to assessable development within Queensland.

The provisions of the SPP may also be considered under the standard criteria of the EP Act which includes ecological matters of State interest including:

- Biodiversity - MSES - Regulated vegetation and MSES - Regulated vegetation (intersecting a watercourse) and waterway barriers; and
- Water Quality - Climatic regions - stormwater management design objectives.

The Act also provides direction for the management of wetlands. The SP Regulation identifies areas designated as 'wetland protection areas' (WPA) to be protected during operational works development.

In relation to additional ecologically related approvals, Section 4A of the *Mineral Resources Act 1989* precludes the application of the Planning Act to activities undertaken for purposes of the mining tenure where those activities occur within the mining lease.

15.3 Environmental Objectives and Performance Outcomes

In accordance with the EP Act (Section 125), generally there are three key areas to be identified and addressed through the Environmentally Relevant Activity (ERA) application process regarding land and the associated ecological values:

- Identify the EVs of the site, including any significant flora and fauna associated with the land;
- Identify the possible impacts due to the proposed activity and all associated risks to the EVs; and
- Identify the strategies to mitigate the identified risks to the EVs.

Performance outcomes for the related aquatic EVs identified within the Project area include:

- Activities that disturb land, soils, subsoils, landforms and associated flora and fauna will be managed in a way that prevents or minimises adverse effects on the aquatic EVs of the area including downstream;

- Areas disturbed by Project activities will be rehabilitated to achieve sites that are stable, safe to wildlife and able to sustain an appropriate land use for EVs;
- The activity will be managed to prevent or minimise adverse effects on the environmental values of land and water due to unplanned releases or discharges; and
- The activity will be managed to prevent or minimise adverse effects on the EVs of land and water due to groundwater drawdown.

Any EA applications that have the potential to impact land must describe how environmental objective and performance outcomes for the ERA will be achieved.

The EPP (Water) provides a framework for:

- Identifying EVs and management goals for Queensland waters;
- Stating WQOs to protect or enhance the EVs;
- Providing a framework for making consistent, equitable and informed decisions about Queensland waters; and
- Monitoring and reporting on the condition of Queensland waters.

15.4 Nomenclature

Flora nomenclature within this chapter follows taxonomy accepted by the Queensland Herbarium and Queensland Museum. Fauna nomenclature follows the Birdlife Australia Rarities Committee checklist (for birds), *The field guide to the freshwater fishes of Australia* (Allen et al. 2003) (for fish) and the Department of Environment and Science's (DES) (formerly the Department of Environment and Heritage) WildNet database taxonomy (for all other fauna), unless otherwise noted. All flora and fauna in this chapter will be referred to initially by both their common and scientific names and then for ease of reading only by the common name.

15.5 Study Methodology

The methodology for the terrestrial and aquatic ecology assessment and stygofauna assessment involved a combination of desktop and field based assessment methods, including:

- A desktop review of relevant literature, published ecological studies and Commonwealth and State databases. The desktop review specifically identified suitable vegetation communities to support aquatic fauna and flora species which may exist within the Project area, and the potential presence of stygofauna within the Project area. Stygofauna were targeted as these species live underground in aquifers which have the potential to be impacted by mining operations;
- Two field surveys to assess and confirm the presence of aquatic species and habitat values present in the Project area and surrounds; and
- Groundwater sampling to confirm the presence, or potential presence, of stygofauna within impacted aquifers.

15.5.1 Desktop Review

15.5.1.1 Aquatic Ecology Desktop Review

Desktop studies were undertaken prior to field assessments. The desktop review was used to obtain background information relating to the potential presence and distribution of species and ecological communities (including connectivity across the regional landscape), particularly those listed under the VM Act or NC Act. Desktop studies involved database searches and review of:

- Current RE mapping V10.0 – (Queensland Herbarium 2017);
- Commonwealth EPBC Act Protected Matters Search Tool [Department of the Environment and Energy (DotEE)] (to confirm current legislative status of listed species);
- DES's WildNet (Wildlife Online) database results;
- Mapping for MSES and Aquatic Conservation Assessment (DES);
- Wetland and watercourse GIS data (DES);
- Styx River Catchment Aquatic Baseline Monitoring Program, Waratah Coal Mine Project (ALS Water Resources Group 2011); and
- Draft Stygofauna Survey. Report for Styx Coal South Project EM Plan (GHD Water Sciences July 2012).

Database searches were undertaken over a 50 km radius for State databases and 25 km radius for Commonwealth databases using the central portion of the Project area as a reference point. The EPBC protected matters search tool, whilst based on some species records, primarily relies on modelling of suitable habitats (with mapped boundary constraints accounted for) and is largely a predictive tool. As such, given the site's location (close to the coast) a smaller search radius was used for the search tool in order to avoid the inclusion of marine / coastal species not applicable to the Project area.

Wildlife Online database records are based on records of species from a wide variety of observers and although the records are generally accurate in terms of spatial location, not all records have been verified. Records from DES's Species Profile Search are generally restricted to sightings from Queensland Government department activities and are considered spatially accurate. Atlas of Living Australia records are largely verified and include specimen records from museum collections across Australia. The database search results for fauna and flora species are provided in Appendix A9c – Ecological Desktop Search Results.

15.5.1.2 Matters of State Environmental Significance

DES maintains a mapping database of MSES as a guide to assist the planning and development decision-making process. Queensland's SPP includes a biodiversity interest that states 'Significant impacts on matters of national or state environmental significance are avoided, or where this cannot be reasonably achieved; impacts are minimised and residual impacts offset'. MSES are defined under the SPP as including:

- Lands designated as part of protected areas and marine parks;
- Category B and C remnant vegetation;
- REs that intersect with wetlands and watercourses;

- Landscape connectivity areas;
- Habitat for threatened flora and fauna (as listed under the NC Act);
- Strategic Environmental Areas under the *Regional Planning Interests Act 2014*;
- WPAs as shown on the Map of referable wetlands;
- Wetlands as mapped under the VM Act;
- Waterways as mapped under Waterway Barrier Works and Fish Passage mapping;
- Selected wetlands and watercourses in high ecological value waters defined in the EPP (Water); and
- Legally secured offsets.

15.5.1.3 Aquatic Conservation Assessment

Aquatic Conservation Assessments have been carried out in a number of areas within Queensland including that in which the Project area occurs (Inglis and Howell, 2009). Aquatic Conservation Assessments have been developed using the Aquatic Biodiversity Mapping Method with the intent of identifying conservation values of wetland areas. It provides a robust and objective conservation assessment using criteria, indicators and measures that are founded upon a large body of national and international literature.

The criteria, each of which may have variable numbers of indicators and measures, are naturalness (aquatic), naturalness (catchment), diversity and richness, threatened species and ecosystems, priority species and ecosystems, special features, connectivity and representativeness. The results are used to aid decision-making processes for a range of applications such as: prioritising land protection and rehabilitation, local and regional water resource planning, and development impact assessments.

15.5.1.4 Stygofauna Desktop Review

A desktop assessment using published technical reports was undertaken to assess the potential for stygofauna to occur within the Project area and to assess potential impacts on these communities as a result of the Project. The desktop assessment reviewed a number of reports from published EIS documents and scientific literature. The review focussed on literature from within the region surrounding the Project area and the Bowen Basin.

15.5.2 Field Surveys

A detailed aquatic ecology survey was undertaken for the former incarnation of the Central Queensland Coal Project which encompassed a much larger area (EPC 1029). The survey was carried out by ALS Water Sciences over six days from 1 to 6 June 2011 (refer Appendix A9e - Aquatic Ecology Results for technical report).

A number of other surveys associated with aquatic values of the Project area have been carried out including:

- Two seasonal surveys of local and Project associated groundwater bores for the presence of stygofauna were carried out by GHD Water Sciences from 21 to 24 November 2011 and 15 to 18 March 2012 (refer Appendix A9f - Stygofauna Results for technical report);
- A second less intensive aquatic ecology survey was carried out by CDM Smith in February 2017. The survey focused on freshwater sites previously surveyed in 2011;

- Additional opportunistic surveys for freshwater turtle species at Deep Creek and Tooloombah Creek waterholes in June and September 2017;
- A targeted vegetation assessment of the wetland flora values of two mapped wetlands located within the ML in January 2018;
- A general assessment of GDE values associated with the Project area carried out in February 2018;
- Analysis of water samples collected by CDM Smith personnel in Deep Creek and Tooloombah Creek in July 2018 for radon isotopes and the stable isotopes of water to better understand the relationship between surface water and groundwater; and
- Targeted GDE investigations in August–September 2018 (by David Stanton, 3D Environmental) of tree water use comparing: a) soil and leaf water potentials; and b) stable isotopic compositions of soil and xylem water.

15.5.2.1 Aquatic Ecology - Survey Site Locations

Field assessments were undertaken at nine sites in the wider catchment surrounding the Project during June 2011 (refer Appendix A9e - Aquatic Ecology Results). Survey locations were selected to be representative of the overall aquatic stream environment within the Study area and to provide baseline aquatic ecosystem parameter values.

The local area had experienced wet conditions in the months preceding the surveys including over 500 mm in December 2010 (long-term December average 124 mm) and nearly 300 mm in March 2011 (long-term December average 133 mm). As a result, sampling conditions were considered highly suitable with abundant flowing water available in creeks in the area.

Conditions during the February 2017 survey were very hot and dry. Excepting a single day in January on which 212 mm was recorded at St Lawrence (located 74 km north of the Project area), mean rainfall in the area was below average in the months preceding the survey and across the entirety of February. How the January rain event affected the Project site is uncertain as no rain was recorded in Rockhampton on the same day. Nevertheless, although no flow was recorded at the time sizeable waterholes remained which were suitable for sampling.

Water quality samples were collected at each site. The QWQG and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality were used to assess the water quality parameters (ANZECC and ARMCANZ 2000; and EHP 2013).

Aquatic organisms were assessed at nine locations within or surrounding the mine area:

- Three sites on Deep Creek (De1, De2 and De3) sampled in 2011. A fourth site (De4) located upstream of De3 was sampled in 2017 due to lack of site access to De3;
- Two sites on Tooloombah Creek sampled in 2011 and 2017 (To1 and To2);
- Three sites downstream of the Project on Styx River sampled in 2011 (St1, St1b and St2); and
- One site on Granite Creek located 13 km northwest of the Project sampled in 2011 (Gr1).

In addition, a tributary of Deep Creek potentially impacted by the Project (Barrack Creek) was inspected in both 2011 and 2017. Very little water was present on both occasions and no sampling was able to be carried out.

Table 15-1 provides descriptions of the aquatic ecology survey sites which are depicted in Figure 15-1.

Table 15-1 Aquatic ecology survey site descriptions.

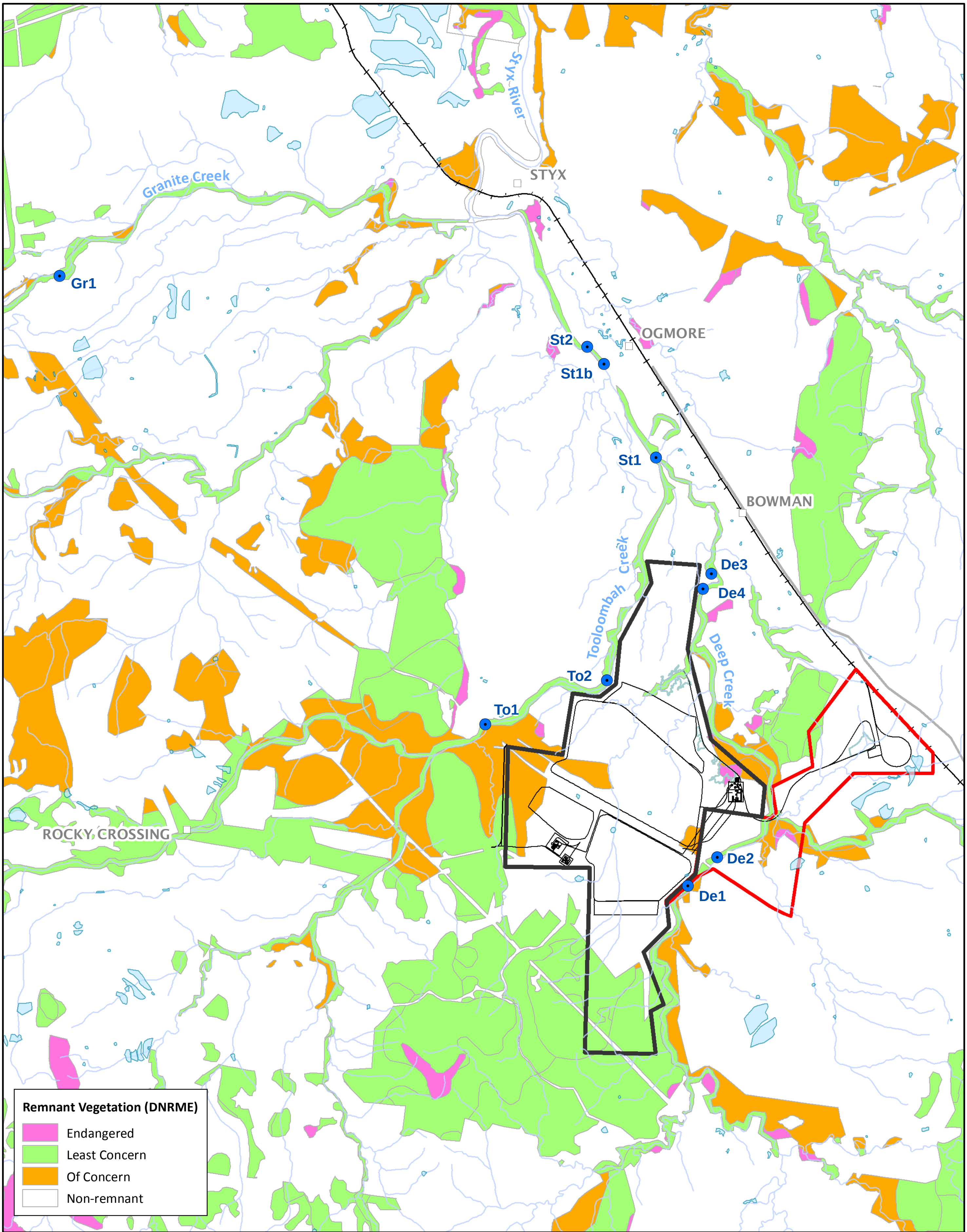
De1 – Upper Deep Creek	
Site coordinates	-22.71803, 149.67018
Description	Adjacent to eastern boundary of MLs. Low flow at time of 2011 survey. Evidence of recent flooding – debris noted approx. 7 m above channel. Steep incised banks 7 m above water level. Substrate comprised small cobbles, gravel and sand. Well vegetated riparian zone at all levels with Lantana (*Lantana camara*) dominant in shrub layer. Channel well shaded. Some cattle access evident but likely minor due to steep banks. Pool dries out after prolonged dry weather.
Macroinvertebrate Signal score	Riffle – 4.76
Approx. channel size	3 m (riffle) to 6 m (pool)
Mean depth	0.2 m (riffle) to >0.5 m (pool)
De1 pool section – June 2011	**De1 pool section – February 2017**
	
De2 – Deep Creek (below highway)	
Site coordinates	-22.71272, 149.67582
Description	Located north of highway. Substantial pool present. Low flow at time of survey in 2011. Substrate comprised small cobbles, gravel and sand. Bank height approx. 2.5 m above channel. Thin riparian zone with moderate shade cover. Vehicle / cattle crossing point evident. Cattle access evident. Pool dries out after prolonged dry weather.
Macroinvertebrate Signal score	Riffle – 5.25
Approx. channel size	7 m (riffle) to 14 m (pool)
Mean depth	0.2 m (riffle), uncertain depth of pool – likely to retain water for extended periods
De1 pool – February 2017	
	
De3 – Lower Deep Creek	
Site coordinates	-22.66108, 149.67363

Description	Adjacent to north-east corner of MLs. Low flow at time of survey. Evidence of recent flooding – debris noted approx. 6-8 m above channel. Steep incised banks 8 m above water level. Substrate comprised largely gravel and sand. Well vegetated riparian zone at all levels. Rubber Vine (*Cryptostegia grandiflora*) dominant in some areas. Channel well shaded. Abundant woody debris observed in channel. Cattle access evident despite presence of exclusion fencing. Pool dries out after prolonged dry weather.
Macroinvertebrate Signal score	Riffle – 5.71
Approx. channel size	1.8 m (riffle) to 10 m (pool)
Mean depth	0.3 m (riffle), uncertain depth of pool at time of sampling
De3 riffle site – June 2011	
	
De4 – Lower Deep Creek	
Site coordinates	-22.664023, 149.672344
Description	Located approximately 700 m upstream of De3. No flow observed. Steep incised banks, 8 m above water level on west side. Substrate comprised largely gravel and sand. Well vegetated riparian zone at all levels (Rubber Vine dominant on lower east bank). Channel well shaded. Woody debris observed in channel. No obvious cattle access evident but evidence of pig presence observed.
Macroinvertebrate Signal score	
Approx. channel size	8 m (pool)
Mean depth	Uncertain depth of pool – likely to retain water for extended periods
De4 pool – February 2017	
	
St1 – Upper Styx River	
Site coordinates	-22.64, 149.6624
Description	Just downstream of merge of Deep Creek and Tooloombah Creek. Low flow at time of survey. Evidence of recent flooding – debris noted approx. 6 m above channel. Shallow banks 5-7 m above water level. Substrate comprised largely gravel and sand. Very disturbed riparian zone with few tall trees and weed species common (Rubber Vine dominant in some areas). Poor channel shading. Aquatic vegetation present.

Macroinvertebrate Signal score	Riffle – 3.65
Approx. channel size	5 m (run) to 40 m (pool)
Mean depth	0.3 m (riffle area in Tooloombah Creek), main channel uncertain – 0.6 m at edge
St1 pool site – June 2011	
	
St1b – Styx River	
Site coordinates	-22.6232, 149.65187
Description	Located upstream of bridge on Ogmore Connection Road. Substrate dominated by silt / clay. Riparian zone shows evident of infrequent tidal inundation (marine couch present close to channel). Clearing evident with few tall trees present and weed species common. No channel shading. Aquatic vegetation present. Cattle access evident.
Macroinvertebrate Signal score	Riffle – 3.5
Approx. channel size	6 m to 12 m (pool)
Mean depth	Up to 2.5 m in main channel
St2 – Lower Styx River	
Site coordinates	-22.62018, 149.64848
Description	Located downstream of bridge on Ogmore Connection Road. Right bank heavily incised (6 m above channel), left bank floodplain less than 3 m above channel. Substrate dominated by silt / clay. Regular tidal inundation of site and few tall trees present as a result. Weed species common (heavy cover of Noogoora Burr (*Xanthium occidentale*)). No channel shading. Aquatic vegetation present.
Macroinvertebrate Signal score	Riffle – 3.52
Approx. channel size	4 m to 10 m (pool)
Mean depth	Up to 1.2 m in main channel
St2 pool site – June 2011	
	
To1 – Tooloombah Creek	
Site coordinates	-22.68923, 149.62985
Description	Located adjacent to bridge over highway (downstream). Moderate flow at time of survey. Evidence of recent flooding – debris noted approx. 6 m above channel. North bank steep (>15 m above channel), gentle slope on south bank. Rocky creek with areas of substrate dominated by bedrock, as well as cobbles / gravel / sand. Well vegetated riparian zone. Channel moderately shaded. Evidence of cattle activity recorded at site. Pool extends well upstream of sample site and maintains water through extended dry weather.

Macroinvertebrate Signal score	Riffle – 5.77
Approx. channel size	5 m (riffle) to 17 m (pool)
Mean depth	0.3 m (riffle) to >1.5 m (pool)
To1 pool site (upstream of bridge) – June 2011	**To1 pool site (at bridge) – February 2017**
	
To2 – Tooloombah Creek downstream	
Site coordinates	-22.68083, 149.6535
Description	Located adjacent to western boundary of MLs. Moderate flow at time of 2011 survey. North bank relatively steep (7 m above channel), gentle slope on south bank. Substrate dominated cobbles / gravel / sand with large rocks sometimes present. Well vegetated riparian zone in good condition although occurrences of Rubber Vine present. Evidence of cattle activity recorded at site. Channel moderately shaded.
Macroinvertebrate Signal score	Riffle – 5.37
Approx. pool size	2.5 m (riffle) to 35 m (pool)
Mean pool depth	0.3 m (riffle), uncertain depth of pool – likely to retain water for extended periods, creek may be permanent some years
To2 riffle site – June 2011	**To2 pool site – February 2017**
	

Gr1 - Granite Creek	
Site coordinates	-22.60893, 149.54475
Description	Located downstream of highway and 13 km north-west of MLs. Moderate flow at time of survey. Series of large pools joined by riffle areas. Evidence of recent flooding – debris noted approx. 3 m above channel. Banks gently sloped, north bank approx. 5 m above channel. Substrate dominated by cobbles / gravel / sand. Riparian zone disturbed and substantially narrowed in sections. Weeds common. Channel poorly shaded. Aquatic vegetation present.
Macroinvertebrate Signal score	Riffle – 6.06
Approx. pool size	3 m (riffle) to 25 - 45 m (pool)
Mean pool depth	0.3 m (riffle), 3.8 m in deep section of pool – likely to retain water for extended periods
Gr1 riffle site – 5 June 2011	**Gr1 pool site – 5 June 2011**
	



N

0 1 2 km

Scale @ A4 1:100,000
Date: 01/11/18
Drawn: J Parnwell

Legend

- Aquatic ecology survey location
- ML 80187
- ML 700022
- Mine infrastructure
- Main Road
- North Coast Rail Line
- Watercourse
- Reservoir
- Dam

Figure 15-1
Aquatic ecology – survey locations (2011 and 2017)

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018
QLD Department of Environment and Heritage Protection, 2016;

CDM Smith

Aquatic Habitat Assessment and Water Quality

Aquatic habitat assessment was required at freshwater sites in accordance with the AusRivAS protocols. These field sheets covered Site Description, Site Access, Water Quality, Habitat Data, Substrate data, Reach profile, and Reference Condition data.

In-situ water quality measurements were recorded in June 2011 and February 2017 at the time of the aquatic ecology assessments using a multi-parameter water quality meter and measurements included water temperature (°C), pH, conductivity (mS/cm), and dissolved oxygen (% saturation and mg/L). Water quality meters were calibrated in the laboratory and in the field prior to use. Turbidity was measured separately using a hand-held turbidity meter. Subsequent monthly water quality sampling assessments were carried out at these sites and additional sites from May 2017 to April 2018.

Water samples were collected for laboratory analysis according to procedures outlined in the Department of Environment and Heritage Protection (EHP 2013) guidelines. Samples were kept chilled in an esky and sent to the ALS laboratory in Brisbane within 24 hr of collection to ensure that they were received within sample holding times. Water samples were tested for the presence of a range of metals (refer to Chapter 9 - Surface Water (and also Chapter 10 – Groundwater) for a more detailed description).

Flow velocities were assessed to assist with the interpretation of water quality and provided an indication of the relative nature of flow conditions experienced at the time of sampling. Flow measurements were taken where macroinvertebrates or fish were collected. Nonetheless, this process provided some indication of the relative nature of flow conditions experienced at the time of sampling.

Aquatic Macroinvertebrates

Macroinvertebrate sampling methodology followed protocols identified in the 'QLD Australian River Assessment System (AusRivAS) Sampling and Processing Manual (DNRW 2001).' At each site, habitat sampled was dependent on habitat availability. Two different habitats were sampled during the 2011 survey, if available, including edge habitat and riffle habitat (with a total of three replicates per site where sufficient habitat was available). For each sample, the collected material was placed into a sorting tray and macroinvertebrates picked *in situ*.

The sample stored in 80% ethanol for later identification. Identification of taxa was performed to Family level except lower Phyla (Porifera, Nematoda and Nemertea), Oligochaetes, Acarina and Microcrustacea (Ostracoda, Copepoda, Cladocera). Chironomids were identified to sub-family.

For the 2017 survey, only edge habitat was sampled as no riffle habitat was available. All collected sample material (including sediment / debris) was stored in ethanol for sorting and identification off-site.

Survey sites were compared to each other using analyses based on the diversity and abundance of indicator fauna present at each site. This included the use of Signal-2 analyses of the macroinvertebrate fauna, taxa richness, and PET richness (Plecoptera, Ephemeroptera and Trichoptera). This methodology follows the National River Health Program (Chessman 2003a, Chessman 2003b, Chessman et al. 2006 and EHP 2013).

The appropriate Queensland AusRivAS models and resulting scores and bandings were utilised to detect any changes in observed and expected macroinvertebrate communities within the study sites (DNRW 2001). AusRivAS generates site-specific predictions of the macroinvertebrate fauna expected to be present in the absence of environmental stress. The expected fauna from sites with a similar set of physical and chemical characteristics are then compared to the observed fauna, and the ratio derived is used to indicate the extent of impact.

In addition, a number of multivariate analyses were undertaken to identify spatial and temporal trends between sites. The results are presented in detail in the Aquatic Ecology technical report (see Appendix A9e - Aquatic Ecology Results).

Aquatic Vertebrates

During the 2011 survey, fish were sampled at each site using a combination of baited traps and electrofishing (from a boat or backpack dependent on site conditions). The Deep Creek sites were sampled using a back-pack electrofishing unit which was more suited to the relatively narrow and shallow creek habitat. Deep pools that were present on Deep Creek were not sampled for fish as boat access could not be gained and there was evidence of the presence of Estuarine Crocodiles (*Crocodylus porosus*). The Granite Creek site was sampled with the electrofishing boat as the creek had very wide pools up to 45 m across. For the 2017 survey only baited traps were deployed at each site.

Captured fish were identified to species level on site after which they were released at the point of capture. An analysis of fish species diversity and abundance, community composition and community age structure was carried out at freshwater and estuarine sites in accordance with the Queensland Fish Monitoring Standard (Freshwater) and estuarine methods proposed by ALS (2010a). Freshwater fish species were identified using Allen et al. (2003) and estuarine specimens identified using Kuiter (1996).

Freshwater turtles and other aquatic fauna (such as Platypus (*ornithorhynchus anatinus*)) were recorded via visual observations and accidental capture during the 2011 survey.

Baited opera house traps were deployed for capturing turtles during the 2017 survey. Traps were left partially submerged in shallow waters for a minimum of two hours before checking.

Aquatic Habitat Assessment

Aquatic habitat assessments were carried out during the 2011 survey as required at freshwater sites and in accordance with the AusRivAS protocols. The field sheets covered site description, site access, water quality, habitat data, substrate data, reach profile, and reference condition data.

15.5.2.2 Stygofauna Assessment

Protocols for sampling stygofauna were designed based on the Western Australia (WA) Guidelines (Guidance for the Assessment of Environmental Factors, Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Impact Assessment in Western Australia Statement No. 54 and Statement Number 54a, WA EPA 2003; and WA EPA 2007). The more recent Queensland *Guideline for the Environmental Assessment of Subterranean Aquatic Fauna* (DSITIA, 2014) is not specific to Queensland and recommends field sampling regimes as applied under the WA guidelines. The guidelines allow for a pilot study to be conducted where there is considered to be a low likelihood of stygofauna occurrence (based on a desktop review of available information).

The desktop review indicated that stygofauna may have some potential to occur within the shallow aquifers that occur in the mine area. Two seasonal surveys were conducted by GHD Water Sciences in November 2011 and March 2012 which involved collecting groundwater samples to be examined for the presence of stygofauna. A total of 21 groundwater bore locations were sampled in 2011. In 2012, 19 groundwater bores were sampled including nine bores that were not sampled in 2011.

Overall a total of 30 bores within the Project area and surrounds were assessed for stygofauna presence (see Table 15-2 and Figure 15-2). This includes 20 bores established specifically for the Project and 10 landholder bores.

The full water column within each bore was sampled using six hauls of a weighted phreatobiological net (mesh size 50 µm). Samples were preserved in 100 per cent (%) ethanol. A small amount of Rose Bengal, which stains animal tissue pink, was added to each sample to aid sample processing. Samples were transported to the consultant's laboratory where stygofaunal specimens were identified to Order or Family using available taxonomic keys, and then identified to morpho-species within each higher taxon.

Groundwater samples were collected using a bailer lowered to approximately 3 m below the water surface prior to stygofauna sampling. Water was measured for temperature (°C), pH, electrical conductivity (µs/cm) and dissolved oxygen (mg/L and % saturation) using a YSI 556 multi-parameter water quality meter. Groundwater sampling preceded biological sampling to ensure the groundwater contained within the bore was undisturbed.

Table 15-2 Details of groundwater bores sampled for stygofauna

Bore ID	Date sampled	Latitude	Longitude	Standing water level (m)	Bore depth (m)	Bore type/ Lithology
STX 20c	23/11/2011	-22.685598	149.650101	15.5	75.6	Exploration Hole
STX 21	23/11/2011	-22.683998	149.654604	10.3	25.0	Exploration Hole
STX 081	22/11/2011 16/03/2012	-22.71201	149.650172	9.2 9.2	107.5	Exploration Hole
STX 090	21/11/2011 15/03/2012	-22.716497	149.670195	10.7 10.9	40.0 (estimated)	Exploration Hole
STX 091	22/11/2011 15/03/2012	-22.723915	149.663314	10.8 10.7	75.1	Exploration Hole
STX 093	22/11/2011 15/03/2012	-22.719469	149.667898	12.0 11.9	75.0	Exploration Hole
STX 096	21/11/2011 16/03/2012	-22.709395	149.669503	12.4 12.4	74.6	Exploration Hole
STX 097	23/11/2011	-22.704403	149.659803	11.9	74.9	Exploration Hole
STX 105	21/11/2011	-22.698701	149.665599	14.2	74.6	Exploration Hole
STX 112	22/11/2011 16/03/2012	-22.71266	149.650184	9.9 9.4	95.0	Exploration Hole
STX 130	23/11/2011	-22.695503	149.650496	15.6	30.0	Exploration Hole
STX 136c	23/11/2011	-22.6869	149.660302	14.3	74.6	Exploration Hole
Granite vale steel pipe	22/11/2011	-22.558917	149.596782	6.5	8.0 (estimated)	Windmill / Quaternary alluvium
Granite vale pvc pipe	22/11/2011	-22.558926	149.596783	6.6	8.0 (estimated)	Windmill / Quaternary alluvium
Plainvue 1	17/03/2012	-22.448836	149.602438	7.5	17.0 (estimated)	Production with pump attached
Neerim 1	23/11/2011	-22.787002	149.681701	2.1	12.0 (estimated)	Exploration Hole / Quaternary alluvium
Neerim 2	23/11/2011	-22.808396	149.670903	4.4	50.0	Exploration Hole
Neerim 3	23/11/2011	-22.849701	149.674203	4.4	30.0 (estimated)	Exploration Hole
Riverside Well	24/11/2011 17/03/2012	-22.591299	149.629996	7.8 7.1	10.0 (estimated)	Well / Quaternary alluvium

Bore ID	Date sampled	Latitude	Longitude	Standing water level (m)	Bore depth (m)	Bore type/ Lithology
Riverside 1	24/11/2011 17/03/2012	-22.591696	149.631102	7.6 7.3	10.0 (estimated)	Production no pump attached / Quaternary alluvium
Riverside 2	24/11/2011 17/03/2012	-22.589401	149.635103	6.8 6.9	11.0 (estimated)	Exploration Hole
Riverside 3	24/11/2011 17/03/2012	-22.586804	149.632701	5.9 5.3	11.0	Monitoring piezo / Quaternary alluvium
STX 038	16/03/2012	-22.586588	149.647035	9.3	75.1	Exploration Hole
STX 077	16/03/2012	-22.707893	149.667577	13.8	35.0 (estimated)	Exploration Hole
STX 095	16/03/2012	-22.708684	149.672622	13.4	75.7	Exploration Hole
STX 100	16/03/2012	-22.705805	149.648213	6.8	77.7	Exploration Hole
STX 113	16/03/2012	-22.7096	149.663737	11.0	110.0 (estimated)	Exploration Hole
STX 114	16/03/2012	-22.710936	149.657254	9.9	25.0	Exploration Hole
STX 126b	16/03/2012	-22.701281	149.647231	16.6	74.6	Exploration Hole
STX 127	16/03/2012	-22.699613	149.642159	16.1	81.0	Exploration Hole

15.5.2.3 Targeted GDE Sampling

A number of targeted onsite measurements and sampling methods were carried out on vegetation communities potentially impacted by drawdown of groundwater in order to ascertain their potential use of groundwater. These included leaf water potential (LWP) measurements, stable isotope analysis and soil coring to root depth. This was carried out as part of wider investigations of the occurrence of groundwater dependent ecosystems in the area. The sampling protocols for these methods are summarised below. Further information on the targeted GDE sampling methods is provided in Section 15.6.4.2.

Leaf Water Potential Measurement

For plants to transpire they must maintain a LWP that is more negative than the soil water potential (SWP). A dry soil will have a highly negative SWP and a plant must be able to regulate their stomatal conductance and lower their LWP to be more negative than the SWP to extract water. By contrast, a moist soil or one that is maintained in moist state by shallow groundwater will not require plants to lower their LWP excessively to extract water. Thus, measuring LWP and SWP concurrently provides an indication of where in the soil profile plants are drawing their water from and it also provides an indication as to whether plants have access to groundwater (at the water table, SWP approaches zero).

LWP measurements were carried out in August 2018 during dry conditions with only 28 mm of rainfall recorded at St Lawrence (38 km north of the Project) from May onwards (BoM 2018). This was considered suitable for conducting measurements of LWP as trees would be most likely to access groundwater (if necessary) at this time given the dry ground conditions. Signs of leaf stress at this time would indicate that species are potentially not tapped into groundwater.

Leaf water potential was measured pre-dawn using a Plant Water Potential Gauge. Leaves were collected from the highest accessible part of the tree using an extension pole and attached lopper head. A suitable leaf is selected and the petiole (leaf stem) is cut and placed in the pressure chamber with the cut stem protruding from the chamber at atmospheric pressure. The vessel is sealed around the petiole and pressure applied via an external gas cylinder. The protruding stem is observed and pressure readings recorded at the first point that water is noted to be exuded by the leaf. The positive pressure applied to the leaf at this point is measured as the 'LWP'.

Soil samples were collected for measuring soil water potential during the same soil coring sample process described for the soil pore water stable isotope analysis below. Soil moisture potential was measured onsite using a portable Dew Point PotentiaMeter. A 7 ml soil sample collected from each core is inserted in the potentiometer and analysed for between 10 – 15 minutes.

Stable Isotope Analysis – Soil Water

The overarching aim of stable isotope analysis in this context is to determine the degree to which trees utilise groundwater on either a permanent or seasonal basis. It will be applied only at those sites which are specifically located to investigate the interactions between tree roots and groundwater (refer Figure 15-2). Trees may utilise water from a range of sources including the phreatic zone, the vadose zone and surface water and the stable isotopes of water, oxygen 18 (18O) and deuterium (2H) may be a useful tool to help define the predominant source of water used by terrestrial vegetation. The method relies on a comparison between the stable isotope ratios of water contained in plant xylem (from a twig or xylem core) with concentrations in the various sources of water including potential artesian water sources, and shallow soil moisture. Knowing the isotopic composition of these sources and plant water can assist in conceptualising plant water uptake.

Soil sampling for soil pore water was undertaken at regular intervals along a retrieved soil core at each site to capture signatures for possible isotopic end points (ground water and surface water) and a range of potential plant moisture sources within from the upper soil surface to the top of the phreatic (aquifer) zone. Soil was sampled at the following intervals:

- Initial soil sample taken within the top 10 cm of soil profile;
- Subsequent soil samples taken at 0.5 m intervals down borehole to the top of the phreatic zone; and
- Additional soil samples taken where a noted change in soil texture is observed within soil core (e.g. change from clay to sandy clay / loam soil).

A minimum 200 ml equivalent of soil was collected for each sample to be analysed. Samples were immediately sealed, labelled for identification and kept on ice / frozen until despatched for laboratory analysis.

Xylem water for stable isotopes was sampled by collecting twigs from the outer branches of mature trees that were the subject of the assessment at each site. Up to four twig samples were collected from the outer branches of four of the subject trees at each site. Collected branches contained some stem diameters of at least 10 mm. Stems were cut into maximum 5 cm lengths and the bark stripped. Stems were sealed in wide mouth sample containers with leakproof polypropylene closure labelled for identification and kept on ice /frozen until despatched for laboratory analysis.

All stable isotope analyses were carried out by the Australian National University Stable Isotope Laboratory.

Stable Isotope Analysis – Surface/Groundwater Interactions

To better understand the relationship between the surface water and groundwater, the stable isotopes of water (2H and 18O) and radon isotope (222Rn) were analysed from water samples collected from the site. The stable isotopes of water can be used to discriminate between different sources of water. The method relies on the distinct isotopic compositions which can arise as a result of isotopic fractionation caused mainly by transportation processes (i.e. mixing) and phase transitions (i.e. evaporation) through the atmosphere, lithosphere and biosphere (Barnes and Allison, 1988).

Six grab water samples were collected from Tooloombah Creek in-stream pools (two sampling points each from three pools within the creek) and another three from Deep Creek in-stream pools (a sampling point from three pools within the creek) between 16th and 18th July 2018. Groundwater samples were collected from six monitoring wells that are close to the surface water sampling points, using a low-flow groundwater sampling pump.

Water samples were analysed by Environmental Isotopes (contracted via Australian Laboratory Services, ALS). The hydrogen and oxygen isotope ratios were measured using a Wavelength Scanned-Cavity Ring-down Spectrometer (Picarro L2120) based on Munksgaard *et al*. (2011).

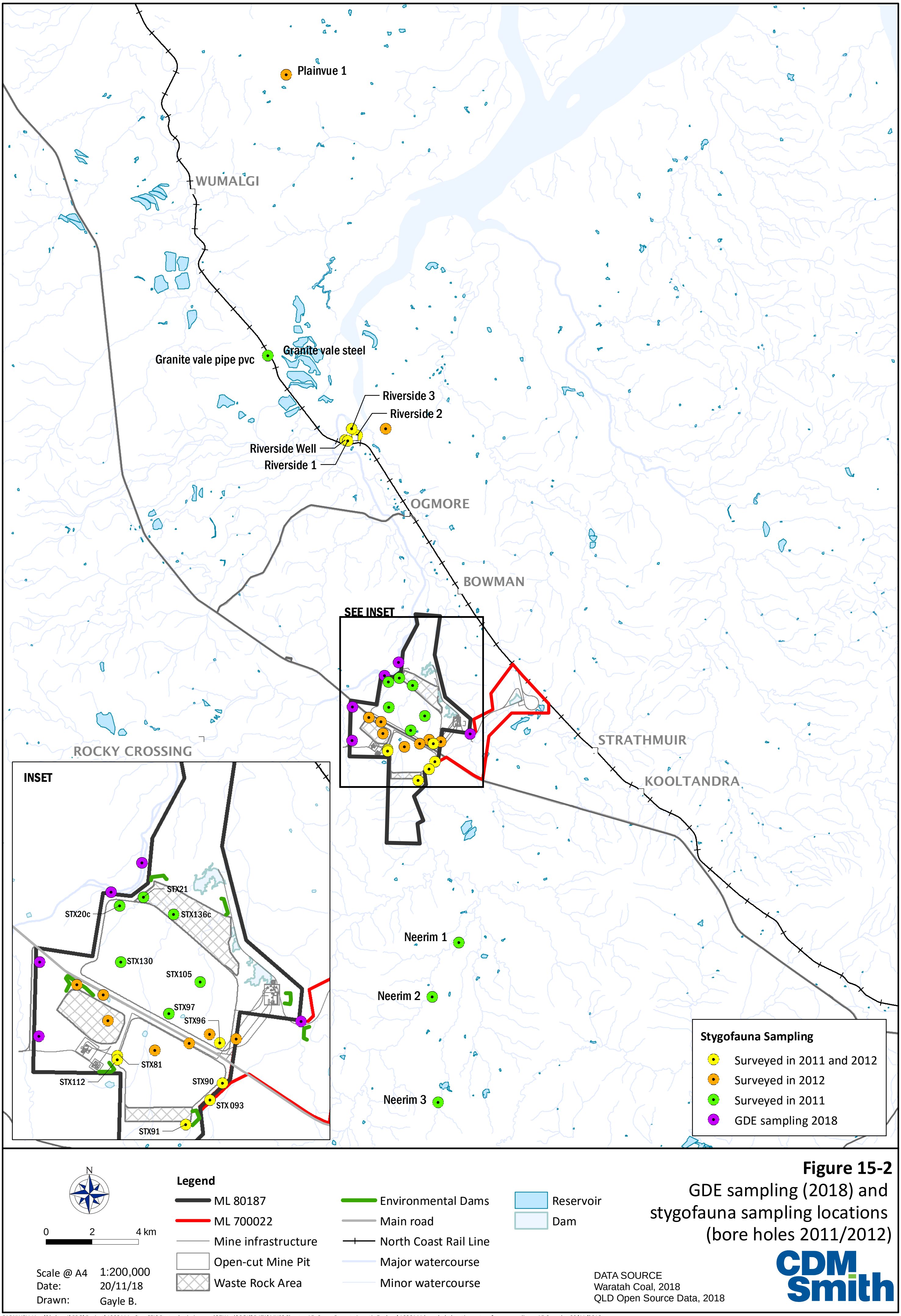


Figure 15-2
GDE sampling (2018) and stygofauna sampling locations (bore holes 2011/2012)

PARNWELLJA \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 15_Supp_Report_Aquatic Ecology\1000111 bore hole location - stygofauna sampling__15-2.mxd 20/11/2018

15.6 The Styx River Catchment - Existing Environment

The Styx River catchment is located on the coast in Central Queensland, approximately 180 km south from Mackay and 150 km north of Rockhampton. The catchment is bordered by the Connors Ranges in the northwest, the Broadsound Ranges to the southwest and empties into Broad Sound near Rosewood Island, south of Saint Lawrence. The Styx catchment represents a transitional zone between the slow-flowing streams of the adjacent and much larger Fitzroy Basin and steep, fast-flowing streams located to the north.

The Styx River Catchment covers approximately 301,300 ha, and the main tributaries include: Deep, Granite, Montrose, Stoodleigh, Tooloombah, Waverly and Wellington Creeks. Many of the creeks are poorly documented and observations from the current survey indicate that many of the smaller waterways are intermittent or ephemeral from the late dry season onward.

The main land use is agriculture which occupies 78% of the catchment, and cattle grazing is the predominant form of agriculture carried out in the region. Many cleared areas are badly eroded from sheet and gully erosion, particularly in the centre of the catchment and this occurs in association with particular soil types (Melzer et al 2008).

The water quality of rivers and streams within the study area is classified as high and the catchment is classified as being only slightly modified from the natural condition (ALS 2011). Many of the creeks of the region record high turbidity during periods of high flow due to the erodible and dispersive soils present in the catchment (Melzer et al. 2008). Water quality is discussed in detail at Chapter 9 – Surface Water and Chapter 10 – Groundwater.

The mine area and TLF is situated within the lower catchments of Tooloombah Creek and Deep Creek. Both creeks feed directly into the Styx River (2 km north of the Project area) which discharges into the Broad Sound area approximately 33 km northeast of the Project. Deep Creek has a total catchment area of 29,801 ha and Tooloombah Creek has a catchment area of 36,968 ha. The haul road to the TLF crosses Deep Creek and Barrack Creek (which lies within the Deep Creek catchment). Tooloombah Creek and Deep Creek are non-perennial or ephemeral, and largely flow only following heavy rainfall events.

Both Tooloombah Creek and Deep Creek are currently subject to degrading impacts from current land use on the Mamelon property and from adjacent and surrounding properties. Cattle access impacts occur on both creeks. Cattle access visibly impacts ecological values on the creeks including damaging streambank and streambed stability, denuding of stream bank vegetation, degrading water quality (through deposition of cattle faeces) and decreasing the natural level of water in waterholes. Several of these factors substantially increase stream turbidity as well as through direct cattle movements in waterholes. These impacts appear more marked in Deep Creek due to the finer soils associated with that creek.

Feral pigs are present and have been regularly observed including along the creek lines themselves and in or near mapped wetlands on the property. They can have similar impacts to cattle such as degradation of water quality and impacting streambank vegetation. Their habit of digging to reach plant tubers and underground fungi can lead to plant death and areas of exposed soil increasing water turbidity and generally degrading wetland health. Pigs are opportunistic omnivores that can directly impact wetland / creek fauna including feeding on crayfish and frogs. The introduced Chital (Axis axis) is a deer native to India and also occurs on the property and has been observed at waterholes on Tooloombah Creek. The impact of this species is uncertain at this stage although it is an opportunistic browsing species that may degrade streambank vegetation and is likely to have other similar effects on stream health as cattle.

There are several surface water entitlements in Tooloombah and Deep Creek for irrigation, stock and domestic supply. These entitlements are summarised in Table 15-3. The entitlements are:

- 119/CP900367 - Irrigation entitlement located on parcel of land adjacent to the Mamelon property, separated by Deep Creek, and approximately 3 km downstream of mine infrastructure and environmental dam release point locations on Deep Creek;
- 1/RP616700 - Domestic / stock supply entitlement located on parcel of land adjacent to the Mamelon property and straddling Tooloombah Creek. The extraction point appears to supply a small off-stream storage on the western overbank of Tooloombah Creek, on the Bar-H property; and
- 45/MPH26062 - Irrigation entitlement on parcel of land directly bordering the Project to the north and extracting approximately 6 km downstream of the Bruce Highway on Tooloombah Creek.

Table 15-3 Environmental values for waters associated with the Project

Water Source	Location	Authorised Use	Entitlement Per Water Year	Maximum Extraction Rate	Water Name / Type
Tooloombah Creek	1/RP616700	Domestic Supply; Stock	18.0 ML	-	Tooloombah Creek / Watercourse (Surface Water)
Deep Creek	119/CP900367	Irrigation	20.0 Ha	-	Deep Creek / Watercourse (Surface Water)
Tooloombah Creek	45/MPH26062	Irrigation	8.0 Ha	-	Tooloombah Creek / Watercourse (Surface Water)

As no maximum extraction rates are defined it is expected that abstraction under these surface water entitlements impact on the environmental values of the creeks. Other impacts associated with local development includes the upstream take of gravel from the banks of Tooloombah Creek. This material is quarried approximately 7 km upstream of the property close to the creeks intersection with Mount Bison Road and is used for road construction and maintenance purposes. The degradation of the bank in this section of Tooloombah Creek is very likely to result in loose material entering the creek during flow events thereby increasing turbidity in downstream waterholes.

15.6.1 Climate

The Styx region is located about 140 km north of the Tropic of Capricorn and is subject to a seasonally dry tropical climate. Most rainfall occurs between October and April with the driest months being August-September. Mean monthly temperatures are highest in January and February, and the lowest in June-July.

Air temperatures in the study region vary cyclically on a seasonal basis with the lowest mean minimums of around 11 degrees Celsius in winter (July) and the highest mean maximums of around 32 degrees Celsius in summer (December-January period).

The year prior to the June 2011 field survey extending from June 2010 through to May 2011 had extremely high rainfall (refer Figure 2-2 in Appendix A9e - Aquatic Ecology Results). Rainfall from August 2010 through to May 2011 was above mean rainfall in all months except February 2011.

15.6.2 Desktop Results

15.6.2.1 Queensland Wetland and Watercourse Mapping

The majority of mapped drainage lines intersecting the Project are associated with Deep Creek. Existing wetland mapping describes the following drainage system located within the MLs boundary:

- Two 2nd order drainage lines, one each feeding both Tooloombah and Deep Creeks; and
- Eleven 1st order drainage lines associated with Deep Creek and two 1st order drainage lines feeding Tooloombah Creek.

The haul road associated with the TLF crosses:

- Deep Creek as a 4th order drainage line in this area;
- Barrack Creek as a 4th order drainage line; and
- Two un-named tributaries of Barrack Creek as a 3rd order drainage line and a single 1st order drainage line.

The TLF and associated infrastructure intersect two further 1st order drainage line and a single 2nd order drainage line.

Queensland government wetland mapping (DES) indicates two palustrine wetlands (non-riverine vegetated wetlands) and five lacustrine wetlands (wetlands in topographic depressions / dammed areas with little vegetation) are located within the Project boundary. Onsite observations indicate the lacustrine wetlands are farm dams.

Under the VM Act wetland mapping layer there are two wetlands located within the boundary of the mine ML. Both are located close or on the western boundary of the ML.

15.6.2.2 Wetland Protection Areas

Development in the vicinity of wetlands located in the Great Barrier Reef catchment are subject to assessment under *State code 9: Great Barrier Reef wetland protection areas* within the State Development Assessment Provisions. The provisions impose limitations to development associated with 'high impact earthworks' in areas mapped as WPA which also include a 500 m buffer, or trigger area around the wetland itself. WPA are also considered as MSES.

There is a single WPA located within the western extent of the Project area boundary (see Figure 15-3). There are also several WPAs located downstream of the Project area adjacent to the Styx River and associated tributaries. These wetland areas are mapped as RE 11.1.3a – hypo-saline wetlands with *Melaleuca* species and / or Forest Red Gum (*Eucalyptus tereticornis*) with mangroves, saltmarsh species and Marine Couch (*Sporobolus virginicus*) potentially present. The nearest WPAs outside of the Project area include:

- A single WPA mapped as occurring 10 km to the west of the Project boundary located adjacent to Tooloombah Creek (upstream of the Project area);
- Three WPAs located 14 km north of the Project associated with the floodplain between the Styx River and Stoodleigh Creek; and
- Two WPAs located 12 km and 16 km north-west of the Project area on the floodplain west of the Styx River (Figure 15-3).

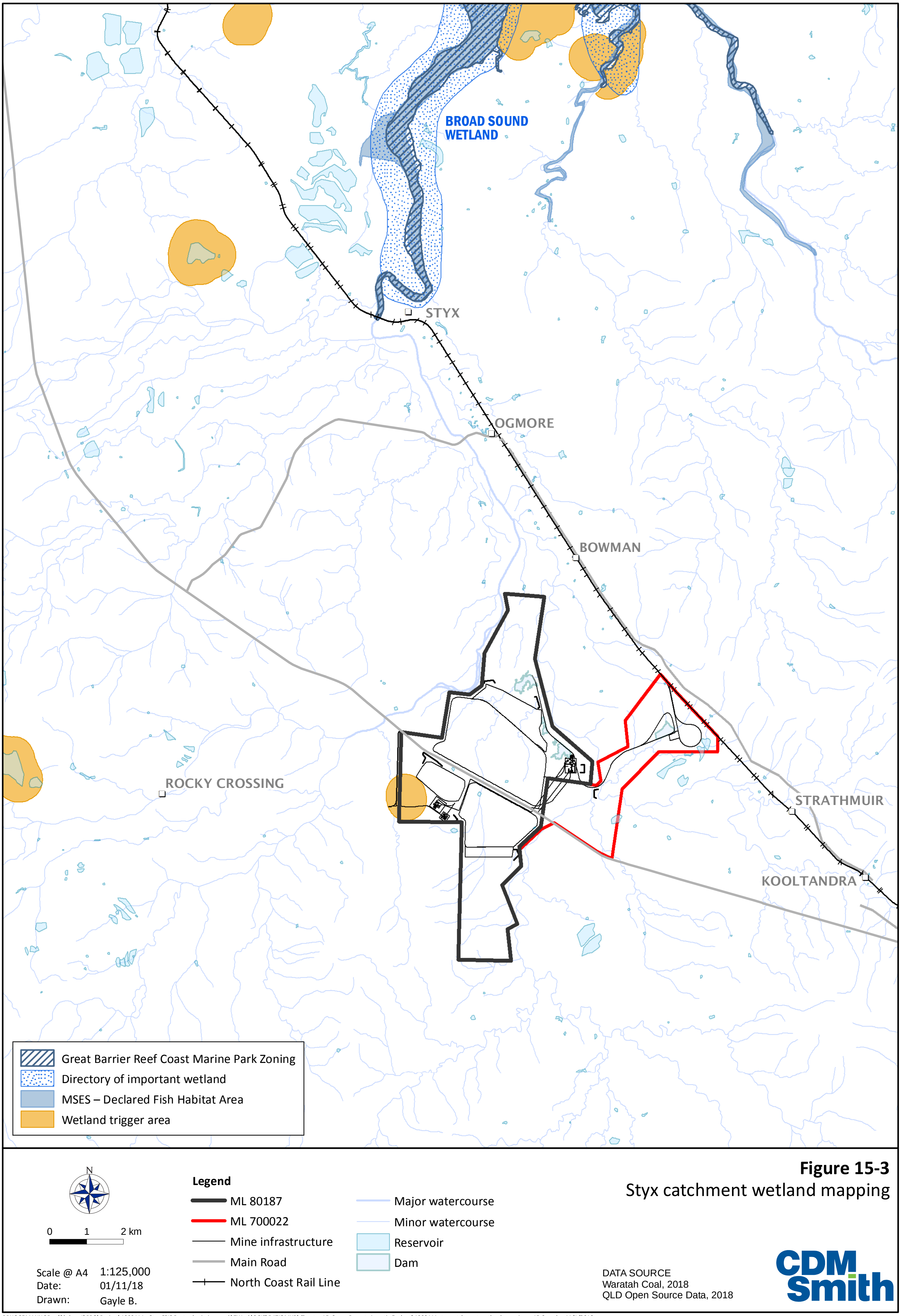


Figure 15-3
Styx catchment wetland mapping

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 15_Supp_Report_Aquatic Ecology\1000111 styx catchment wetland mapping__15-3.mxd 11/1/2018

15.6.2.3 High Environmental Value Waters – EPP Water

The estuarine section of the Styx River north of the Styx rail crossing is classed as High Ecological Value (HEV) waters under the Environmental Protection (water) Policy 2009. This area is located 8 km directly north, or 9.7 km downstream of the Project area (see Figure 15-4) and coincides with the boundary of Broad Sound Fish Habitat Area (FHA) and Great Barrier Reef Coastal Marine Park (GBRCMP). HEV waters are considered as a MSES under the Environmental Offsets Regulation 2014.

15.6.2.4 Fish Habitat Area

Broad Sound is Queensland's largest declared FHA at over 170,000 ha (see Figure 15-4). The FHA boundary is located 8 km directly north, or 9.7 km downstream of the Project area. All habitats within the FHA, including terrestrial areas such as rocky headlands, sand bars and estuarine vegetation, are protected from coastal development and other physical disturbance. The Broad Sound FHA is declared a 'management A area.' Management A areas are afforded a higher level of protection and management as they are considered as key fish habitats. The management of the Broad Sound FHA balances conservation of fisheries for commercial, recreational and indigenous fishing, all of which occur in the area. Fisheries species that occur in the FHA include: Barramundi; blue salmon; bream; estuary cod; flathead; grey mackerel; grunter; mangrove jack; queenfish; sea mullet; school mackerel; whiting; banana prawns; mud crabs (DNPSR 2014).

All FHAs are considered as a MSES under the Environmental Offsets Regulation 2014.

15.6.2.5 Directory of Important Wetlands

Broad Sound is listed in the Directory of Important Wetlands of Australia (DIWA). The southern boundary of the designated wetland is located 8 km directly north, or 9.7 km downstream of the Project area. The lower Styx River forms part of the catchment of the wetland. It is noted as "A good example of a marine and estuarine wetland complex within a large sheltered embayment adjacent to a broad coastal plain" (DotEE 2017). The Broad Sound wetland encompasses an area of approximately 2,100 km^2 comprising a complex aggregation of tidal marine and estuarine wetlands. These have been formed in a sheltered embayment and have a very large tidal range of approximately 9 m. Broad Sound is the largest shallow, macro-tidal bay on Australia's east coast.

The Broad Sound wetland area includes the Torilla Plain, a large marine plain to the east of the Project area formed on the southern side of the Torilla Peninsula. In this area wetlands occur as numerous interconnected pools and channels which may merge into much larger waterbodies in the wet season.

Broad Sound comprises wetland habitats including seagrass beds, lower intertidal and supratidal mudflats, and mangroves. Brackish and freshwater swamps and lagoons occur in adjacent upland areas. The wetland is noted as providing significant habitat for waterbirds including substantial aggregations of a range of migratory shorebirds listed under the EPBC Act (DotEE 2017).

The seagrass beds in the northwest of the Broad Sound area support populations of Dugong (*Dugong dugon*). There is a Dugong Protection Area (DPA) (administered under the Great Barrier Reef Marine Park Regulations 1983) extending from Carmilla Creek south to Clairview Bluff approximately 55 km north of the Project).

15.6.2.6 Great Barrier Reef Coast Marine Park

The tidal waters of Broad Sound are also incorporated within the boundary of the GBRCMP. These waters extend outwards to encompass islands in the wider area including the Peak islands to the east and Prudhoe Island to the north. The GBRCMP is administered under the Marine Parks Act 2004. The offshore waters are located within the Great Barrier Reef Marine Park (GBRMP) which is regulated under the *Great Barrier Reef Marine Park Act 1975*. The GBRCMP boundary is located 8 km directly north, or 9.7 km downstream of the Project area.

The Styx River portion of Broad Sound is mapped as a 'general purpose use zone' (see Figure 15-4) which provides opportunities for reasonable use, whilst still maintaining conservation values and reflecting the relevant criteria for listing. This zone extends approximately 41 km downstream of the Project area where the Styx River becomes a broad shallow estuary bordered to the west by Rosewood Island. At this point the waters of much of Broad Sound are mapped as a 'Marine National Park Zone.' These areas are classed as a 'no-take' area and extractive activities like fishing or collecting are not allowed without a permit.

The GBRCMP is considered as a MSES where designated as a 'highly protected area' as defined in Schedule 2 of the Environmental Offsets Regulation 2014. The downstream section of the park closest to the Project is identified as a 'general use zone' and is therefore not identified as a 'highly protected area.' The Marine National Park zone is located approximately 33 km northeast of the Project (or 40 km downstream) by which time the Styx River opens into a broad shallow estuary.

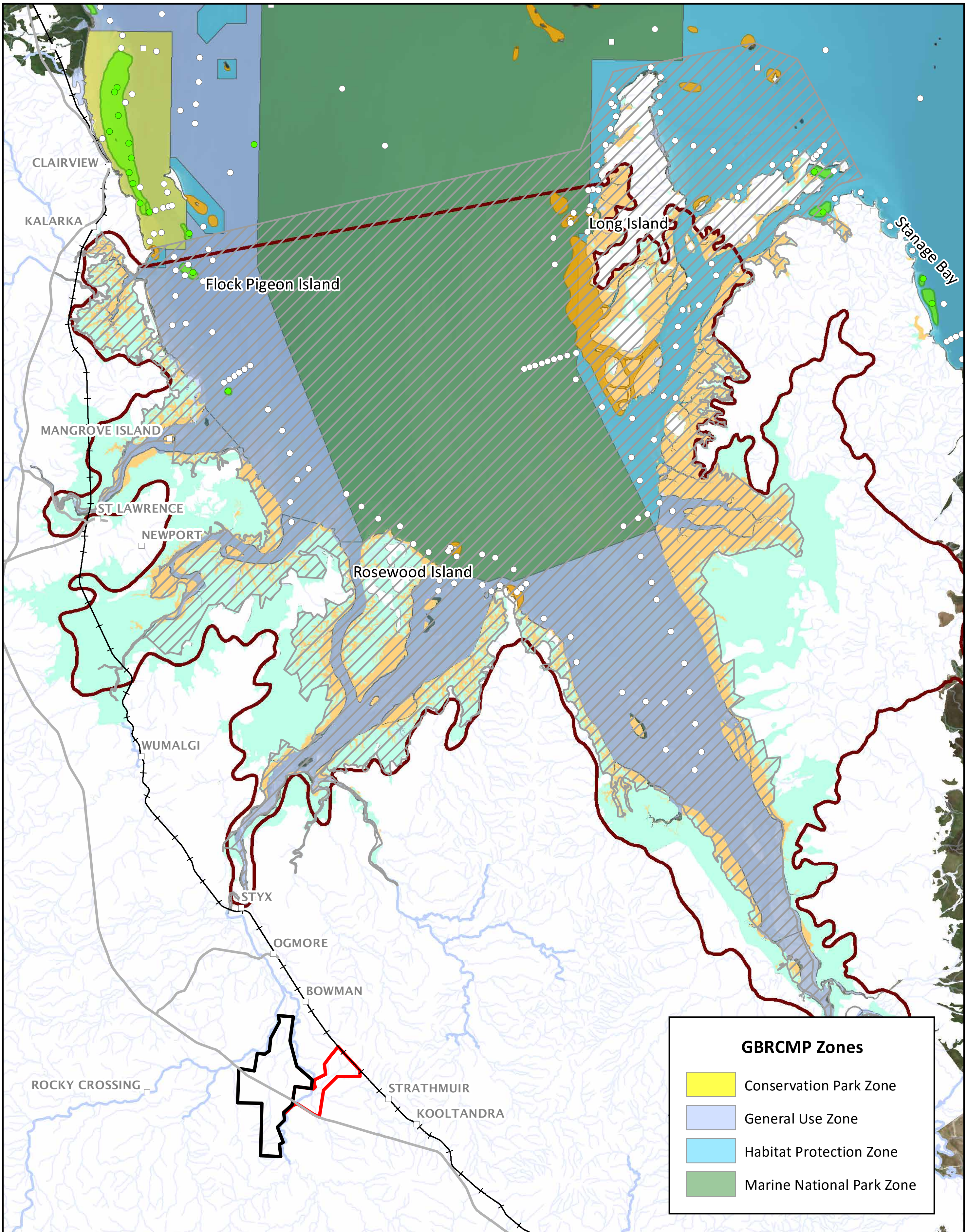
15.6.2.7 Great Barrier Reef World Heritage Area

Broad Sound is also incorporated within the boundary of the Great Barrier Reef World Heritage Area (GBRWHA) which is considered a MNES under the EPBC Act (refer Chapter 16 – MNES). The GBRWHA extends from the low water mark on the coast of Queensland past the continental shelf outside the outer reef. The GBRWHA boundary aligns with the boundary of the GBRCMP and FHA being located 8 km directly north, or 9.7 km downstream of the Project area.

The Great Barrier Reef was inscribed as a World Heritage property in 1981, as it was deemed to meet all the natural heritage criteria for listing. The relevant criteria for the listing were:

- Criterion 7: contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance;
- Criterion 8: be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features;
- Criterion 9: be outstanding examples representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals; and
- Criterion 10: contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of Outstanding Universal Value from the point of view of science or conservation.

The GBRWHA extends from the low water mark on the coast of Queensland past the continental shelf outside the outer reef. The GBRWHA boundary aligns with the boundary of the GBRMP and FHA being located 8 km directly north, or 9.7 km downstream of the Project area. The GBRMP is considered as a MSES where designated as a 'highly protected area.' The downstream section of the park closest to the Project is identified as a 'general use zone' and therefore not identified as a 'highly protected area.' The Marine National Park zone is located approximately 33 km north-north east of the Project (or 40 km downstream) by which time the Styx River opens into a broad shallow estuary.



Legend

N

0 2.5 5 km

Scale @ A4 1:350,000
Date: 09/05/18
Drawn: Parnwell, J

- ML 700022
- ML 80187
- Broad Sound DIWA Wetland
- Mapped reef areas
- Broad Sound FHA

Remnant Vegetation (DNRME)

- Saltmarsh
- Mangroves

Seagrass presence/absence (Aims, 2016)

- Survey point - absent
- Survey point - present
- Seagrass meadow composite

Figure 15-4
Wider Broad Sound - MSES values

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017

CDM Smith

PARNWELLJA \\brbsvr1\PRO\Project\BES150160.03-Styx Coal Project 5 mtpa EIS Preparation\CADD GIS\GIS\DATA\MXD\Chapter 16\BES150160.03-003 R5 GBR Marine Park.mxd 9/05/2018

15.6.2.8 Downstream Marine Values – Broad Sound

Several ephemeral drainage lines empty into Broad Sound including Herbert Creek (associated with the Torilla Plain), Saint Lawrence and Waverley Creeks, and the Styx River (associated with the Project area). Flooding within the Styx basin is seasonal and is often associated with a cyclonic event. The Styx River is a relatively small, ungauged catchment and there are no gauges on any of the waterways associated with Broad Sound. As a result, there is no history of flood heights or frequency and no local tidal data from which storm surge data can be inferred.

Broad Sound is in a remote location and there is limited ecological survey and monitoring data available from the area. Data which is relevant to the area downstream of the Project including marine communities and species is presented in the following sections. For the purpose of clarity, where Broad Sound is referred to in the following text, this refers to the area encompassed by the Broad Sound DIWA boundary as depicted in Figure 15-4.

Broad Sound as a geographical entity refers to the large triangular estuary on the western side of the Torilla Peninsula (directly east of the mouth of the Styx River). The extreme tidal range and generally shallow depth in the wider Broad Sound area has a natural impact on water quality in the area. Constant high turbidity is caused by tidal resuspension of sediments largely due to the currents caused by the ingoing and outgoing tides. Nutrient and chlorophyll concentrations are generally low in this area (De'ath and Fabricius 2008). The turbidity plume extends outwards from Broad Sound to local islands in the Capricorn area of the Great Barrier Reef (such as the Percy Islands group) (Kleypas 1996).

An assessment of baseline water quality observed from the tributaries discharging to Broad Sound was not undertaken. It is difficult to make this assessment without a suitable baseline data set for Broad Sound which does not appear to exist. Broad Sound likely experiences a complex and broad range of water quality influences reflecting varying inputs from fresh and marine waters. Widespread clearing of vegetation in low-lying areas for agriculture / cattle grazing will increase erosion, mobilisation of sediments and nutrients entering Broad Sound from within the contributing catchments within the Styx River Basin. Extensive construction of low embankments to create ponded pasture throughout the Broad Sound area have altered freshwater inputs from the catchment (Holmes et al. 2013).

Water borne pollutant inputs to the Great Barrier Reef (GBR) lagoon (and hence Broad Sound) from land uses in the Styx Basin have been modelled as part of reporting for the wider Fitzroy Basin on the reduction of pollutant loads in the GBR catchment through improved land management practices (Dougall et al. 2014). The modelling for the Styx Basin is based on generalised data from across the catchment coupled with land use cover estimates, as there are no stream gauges in the Styx catchment to provide flow or water quality data.

A summary of results pertinent to the Styx Basin compared to the much larger Fitzroy Basin as reported in the 2013 assessment is provided at Table 15-4. It's important to note the modelled area includes minor drainages to the north which do not feed into the Styx River catchment. The modelling indicated the Styx Basin exhibits pollutant loads per basin area slightly above that exhibited by the Fitzroy Basin.

Table 15-4 Landuse and pollutant run-off data for the Styx and Fitzroy Basins (Dougall et al. 2014)

Basin statistics	Styx Basin			Fitzroy Basin		
Total area	3,013 km^2			142,552 km^2		
Agricultural lands (includes grazing)	2,352 km^2			109,482 km^2		
	Estimated pollutant loads					
	Pre development	**Post development**	**Anthropogenic sourced**	**Pre development**	**Post development**	**Anthropogenic sourced**
Suspended solids (total) (kt/year)	28	68	40	440	1,740	1,300
Total Nitrogen (t/year)	119	154	35	2,768	3,688	921
Total Phosphorus (t/year)	21	38	17	414	983	569
Herbicides (kg/year)	N/A	22	22	N/A	521	521

Mangroves and Saltmarsh Communities

Saltpans and saltmarsh communities occupy 372 km^2 of the Broad Sound wetland area. Current vegetation mapping indicates large areas of saltpans and mudflats with saltbush species along the Styx River beginning approximately 15 km downstream of the Project boundary (refer Figure 15-4). These become extensive further downstream extending 5 km to 6 km inland on the northern bank of the river as the channel splits around Rosewood Island. Mangrove communities occur along the banks of the river beginning 21 km downstream of the Project boundary. Mangroves occupy 216 km^2 within the DIWA wetland boundary, becoming more extensive near Rosewood Island. There are no specific references to the mangrove species occurring in Broad Sound. Based on vegetation mapping dominant species are expected to be Grey Mangrove (*Avicennia marina*), *Rhizophora* and *Bruguiera* species, Spurred Mangrove (*Ceriops tagal*) and Black Mangrove (*Aegiceras conrniculatum*). The extent of mangroves and saltmarsh within the wetland area did not decline between 2001 and 2013 (EHP 2017). Marine plants including saltmarsh and mangroves are considered as MSES.

Broad Sound (with Shoalwater Bay) is considered one of the five main centres within the GBR for mangrove and saltmarsh communities. These are critical habitats for important juvenile marine species such as Barramundi (*Lates calcarifer*), mullet and peneid prawns. In the past, there has been extensive construction of ponded pastures in the Broad Sound area. Bund walls have been constructed to convert saltmarsh into pasture, restricting movements of juvenile fish into these areas (Goudkamp and Chin 2006), but creating additional temporary and brackish wetlands.

Coral Reefs

Mapping for the GBRMP area indicates small fringing reefs occur within Broad Sound on Turtle Island and Charon Point approximately 35 km north-northeast of the Project boundary. A larger reef area occurs on the southwest edge of Long Island (52 km northeast), a continental island adjacent to the west of the Torilla Peninsula (refer Figure 15-4). Several small reefs also occur in the Clairview area to the north of Broad Sound (approximately 55 km north).

The structure of coral reefs in the area surrounding Broad Sound (including offshore islands such as Peak Island) has been surveyed in the past in order to examine the impact of the naturally turbid conditions and tidal range on reef development. Coral richness in the area is lower than in adjacent regions (De'ath and Fabricius 2008). High turbidity inhibits photosynthesis in symbiotic algae (Thompson et al. 2014) and low tides that allow for extended exposure at low tides are not suitable for most coral species (Kleypas 1996). Kleypas (1996) examined reef systems surrounding the Broad Sound area, including the Percy Islands and Duke Island (90 km and 120 km north-east of the

Project respectively). The study found that reefs within or close to Broad Sound were thinner, in shallower waters and comprised species associated with deeper waters. The effects of elevated turbidity in and surrounding Broad Sound included:

- Decreasing hard coral colony size associated with distance to Broad Sound;
- Decreasing diversity of both soft and hard corals;
- Shifting coral morphology; and
- Lack of reef building (or framework) species (Kleypas 1996).

Seagrass

Seagrass mapping data from the past 30 years has been collated across the GBR area (Carter et al. 2016). The only mapped seagrass beds known in the Broad Sound DIWA area are small patches located in the north-east corner of the wetland. There are no seagrass beds mapped in the vicinity of the Styx River estuary or surrounds. Extensive seagrass beds occur to the northwest in the Clairview area and in Shoalwater Bay, including small patches near the islands off Stanage Bay (refer Figure 15-4). Seagrasses require suitable light conditions and appropriate nutrient levels. It is likely the extreme tidal range in Broad Sound influences the lack of seagrass likely due to high turbidity levels and prolonged exposure of tidal flats during low tides. Marine plants including seagrass are considered as MSES.

Large Marine Fauna

The seagrass beds to the northwest of Broad Sound (around the township of Clairview) support populations of Dugong. Dugong is listed as Vulnerable under the NC Act. There is a DPA (administered under the Great Barrier Reef Marine Park Regulations 1983) extending from Carmilla Creek south to Clairview Bluff approximately 55 km north of the Project). A second DPA occurs in the Shoalwater Bay area to the north-west of the Project. Shoalwater Bay DPA is considered the most important Dugong site in the southern area of the GBRMP. Sightings of Dugong are rare in the majority of Broad Sound. In a review of Dugong sighting data by Marsh and Penrose (2001) there are no reported sightings in the Broad Sound area. More recently extensive aerial transect surveys for Dugong and marine turtles which included Broad Sound recorded no individuals in the sound itself. The nearest reported sightings were individuals in the Clairview and Stanage Bay areas (Sobtzick et al. 2017) which are 60 km north and 70 km north-east of the Project area respectively. Given the lack of seagrass in the majority of Broad Sound it is unlikely the area downstream of the Project provides suitable habitat value for the species.

Humpback Whale (*Megaptera novaehollandiae*) is listed as Vulnerable under the NC Act and EPBC Act. The species is well known to occur in the waters off Shoalwater Bay (although not in the bay itself). There is no indication the species uses the waters of Broad Sound for resting or feeding and it is likely the tidal regime and associated turbid waters are unsuitable for the species.

Other protected marine species recorded from the region include inshore dolphin species including Australian Hump-back Dolphin (*Sousa sahulensis*) and Australian Snubfin Dolphin (*Orcaella brevirostris*), both of which are listed as Vulnerable under the NC Act. Past surveys indicate that both species occur in the Shoalwater Bay area although Australian Snubfin Dolphin occurs in low numbers compared to further south in the Fitzroy River estuary (Cagnazzi 2010; Cagnazzi et al. 2013). During boat-based surveys of Broad Sound carried out over two weeks in 2013 low numbers of both species were detected (seven separate pods detected including two pods of Australian Snubfin Dolphins). All records were located north of the Styx River. Both species were detected in the channel on the western side of Rosewood Island (CCP 2013). There are several ALA database records of Australian Snubfin Dolphin (only) in the wider area to the north of Broad Sound. Given the shallow nature of the Styx River, particularly at low tides, suitable habitat for these species in the river is not expected to extend upstream much further than Rosewood Island.

Marine turtles occur in the Broad Sound area and surrounds. There are large nesting aggregations of Flatback Turtles (*Natator depressus*) (Vulnerable under the NC Act) at Wild Duck Island (74 km north north-east of the Project) and Avoid Island (75 km north of the Project). The species nests at lower levels on many of the islands in the local region and selected mainland beaches (Limpus et al. 2002). Targeted nesting surveys in the region indicate the nearest nest sites for this species were the Clairview area (55 km north including mainland beach sites and nearby Flock Pigeon Island), north-east side of Long Island (67 km north north-east), and in the Stanage Bay area (70 km north-east including mainland sites and Quail Island) (Limpus et al. 2002). There are many ALA database records in the wider area and islands but no records within the Broad Sound area itself.

Green Turtle (*Chelonia mydas*) (Vulnerable under the NC Act) has been recorded nesting on several offshore islands in the region including the Percy Islands group (120 km north-east), Curlew Island (116 km north) and islands and mainland beaches in Shoalwater Bay (68 km north-east). Records from the ALA database show several records of Green Turtle in Broad Sound including the Styx River estuary, however these are all attributable to a single radio-tracked individual released by the Cairns turtle rehabilitation and reef HQ facility in 2010. The Shoalwater Bay sites are the nearest known nesting sites to the Project (66 km north-east) (Limpus et al. 2002). Hawksbill Turtle (*Eretmochelys imbricata*) (Endangered under the NC Act) is also known to nest in low numbers in the Percy Islands group (Limpus et al. 2002). Loggerhead Turtle (*Caretta caretta*) (Endangered under the NC Act) have been reported as foraging in the waters of Shoalwater Bay.

Extensive aerial transect surveys for marine turtles which included Broad Sound recorded one individual in the Broad Sound DIWA area (on the south-west side of Long Island). Individuals were recorded north of Broad Sound adjacent to the north-west side of Long Island and in the Clairview area. Much higher densities were recorded in Shoalwater Bay (Sobtzick et al. 2017). Green Turtle is known to forage on seagrasses which do not occur in the majority of Broad Sound. The lack of marine turtle observations in the area may be an indicator that the tidal regime in Broad Sound provides low habitat value for marine turtles in general. Given the shallow nature of the river (particularly at low tides) and the lack of suitable instream habitat for marine turtle species in the river, it is not expected that marine turtles occur upstream in the Styx River estuary much further than Rosewood Island.

Shorebirds and Seabirds

Broad Sound comprises wetland habitats including seagrass beds, lower intertidal and supratidal mudflats, and mangroves. Brackish and freshwater swamps and lagoons occur in adjacent upland areas. The wetland is noted as providing significant habitat for waterbirds including substantial aggregations of a range of migratory shorebirds listed under the EPBC Act (DotEE 2017). Several migratory shorebird species are listed as threatened under the NC Act and are therefore considered as MSES. Shoalwater Bay and Broad Sound are noted as sites of international importance (based on survey data from 1995) for the following migratory shorebirds; Bar-tailed Godwit (*Limosa lapponica*), Whimbrel (Numenius phaeopus), Eastern Curlew (*Numenius madagascariensis*), Terek Sandpiper (*Xenus cinereus*), Grey-tailed Tattler (*Tringa brevipes*) and Great Knot (*Calidris tenuirostris*). The intertidal flats of Broad Sound were found to support fewer shorebirds than Shoalwater Bay excepting large numbers of Great Knot (Driscoll 1996).

Surveys of waterbirds in Broad Sound have recorded 66 species, 21 of them breeding, in the eastern wetlands (Torilla Plains) in 2003 and 88 species, 25 of them breeding, mainly in the western wetlands (Styx River and adjacent plains) in 2006/2007 (Birdlife International 2017). Surveys in Broad Sound carried out by Roger Jaensch in 2008 and 2009 recorded nationally important numbers of Eastern Curlew (*Numenius madagascariensis*) (Endangered – NC Act), Great Knot (*Calidris tenuirostris*) (Endangered – NC Act), Red Knot (*Calidris canutus*) (Endangered – NC Act), Red-necked Stints (*Calidris ruficollis*), Sharp-tailed Sandpipers (*Calidris acuminata*) and Curlew Sandpipers (*Tringa stagnatilis*) (Endangered – NC Act) at several wader sites including Charon Point (32 km north-east of the Project) and Hoogly Point (35 km north) (Jaensch 2009). Six high-tide roosts were documented over four survey periods on the west side of Broad Sound comprising up to 3,500 migratory shorebirds (in one survey period) using the areas roost habitat and shallowly-inundated saltpans.

Subsequent surveys at three of the roost sites have been carried out sporadically by Birdlife Capricornia. Surveys have recorded nationally important numbers of similar species to those recorded in 2008 and 2009. In general, Eastern Curlew appears to be present in substantial numbers across Broad Sound. Large numbers have been counted consistently at the Hoogly Point roost across several survey years including internationally significant numbers (505 individuals) counted in September 2013 (refer Appendix A9h for shorebird survey count data from the Broad Sound area).

Although patchy, the existing recent survey data indicates roost sites in western Broad Sound provide 'important habitat' for migratory waders as defined under the Guidelines including the following:

- Charon Point provides nationally important habitat for Eastern Curlew and in some years may be an important staging point for Great Knot on their return migration passage to the northern hemisphere in late summer. At these times Charon Point alone may support nationally important numbers of migratory waders (>2,000 individuals). The Charon Point roost is located to the south of the mouth of the Styx River estuary and is 33 km north-north-east of the Project boundary;
- Other wader roost sites in western Broad Sound also support nationally important numbers of wader species at times, in particular Eastern Curlew. Hoogly Point on one recorded occasion has supported internationally significant numbers of Eastern Curlew. Hoogly Point and Bar Plains Point roost sites are 33 km north and 40 km north of the Project boundary respectively; and
- The evidence suggests that when summarised collectively the wader habitat across western Broad Sound is likely to consistently support nationally important numbers of migratory waders (>2,000 individuals), and nationally important numbers of migratory wader species including Eastern Curlew, Great Knot, Red-necked Stint, Whimbrel, and Sharp-tailed Sandpiper.

Seabirds are considered those birds that forage in open waters such as some tern species, shearwaters, and noddys. These species generally nest on island habitats in the GBR with the majority of seabird nesting occurring on remote coral cays (Hulsman 1997). The southern GBR supports significant seabird colonies on an estimated 22 islands. Coral cays in the Capricorn-Bunker group maintain large numbers of Wedge-tailed Shearwater (*Ardenna pacifica*) and Black Noddy (*Anous minutus*) which comprise approximately 30% and 50% of the global populations of these species (Turner et al. 2006). These islands are located well offshore from Gladstone and are located 250 km east of the Project.

Seabird species in the vicinity of Broad Sound are restricted to inshore and coastal foraging species. There is a known breeding colony of Australian Pelican (*Pelecanus conspicullatus*) in Shoalwater Bay on Akens Island and Pelican Rocks (68 km north-east). This is the only breeding site within the GBR south of Cape York Peninsula (Walker et al. 1993). Little Tern (*Sternula albifrons*) nests on sandy beach areas and is known to have 'primary' nesting sites in Shoalwater Bay with minor nesting also occurring in Broad Sound (FBA 2015). Little Tern was not recorded during shorebird surveys of western Broad Sound in 2008 / 2009 or subsequently.

15.6.2.9 Threatened Ecological Communities

The Protected Matters Search Tool identified five listed Threatened Ecological Communities (as listed under the EPBC Act) as having potential to occur in the Project area, none of which are associated with aquatic or wetland communities.

15.6.2.10 Regional Ecosystems

Assessment of current RE mapping identified nine REs occurring within the Project area. A single RE. RE11.3.25 - *Eucalyptus tereticornis* open forest to woodland, occurs within and directly adjacent to the Project area that may be associated with wetland communities. This RE occurs on fringing levees and banks of major rivers and drainage lines of alluvial plains throughout the region.

15.6.2.11 Matters of State Environmental Significance

Current mapping of MSES for the MLs (DES) indicates the presence of the following features relevant to aquatic ecology:

- 3.4 ha of lands considered to be MSES under 'Criteria 5: High Ecological Significance wetlands on the map of Referable Wetlands';
- 18.92 ha of lands considered to be MSES under 'Criteria 8f: Vegetation Management Wetland Map'; and
- There are also 25.2 km of watercourse vegetation considered to be a MSES under 'Criteria 8e: watercourses shown on the Vegetation Management Watercourse and Drainage Feature Map.' This is considered very likely to be an overestimate as both banks (rather than the centreline) of larger watercourses where present are mapped by the State, increasing the extent of linear features.

These features encompass two wetland areas within the ML and several mapped watercourse / drainage lines. These features are also represented on Figure 15-5.

15.6.2.12 Aquatic Conservation Assessment

The conservation value of riverine and non-riverine wetlands has been assessed in the Aquatic Conservation Assessments of Great Barrier Reef catchments (Inglis and Howell 2009). Assessment sites are given an overall 'Aquascore' that represents the relative conservation value of the wetland. The Aquascore ratings for the Great Barrier Reef Aquatic Conservation Assessments include:

- Very high: very high values across all criteria, or high representativeness combined with very high values of aquatic and catchment naturalness, threatened or special values. They may also be nominated due to special features by an expert panel;
- High: very high aquatic naturalness or representativeness combined with high or very high values of other criteria;
- Medium: a combination of high to low scores across assessment criteria;
- Low: limited aquatic and catchment naturalness with other medium to low conservation values; and
- Very low: limited or no aquatic or catchment naturalness and lack any other known significant value. They may also be largely data deficient (Inglis and Howell 2009).

Current DES reporting and mapping indicates that riverine wetlands within and surrounding the MLs and TLF are considered to be within riverine catchment of High significance. A single non-riverine (palustrine) wetland (located north of Mount Bison Road) mapped within the MLs is of Very High significance and a second wetland is of Medium significance (see Figure 15-5).

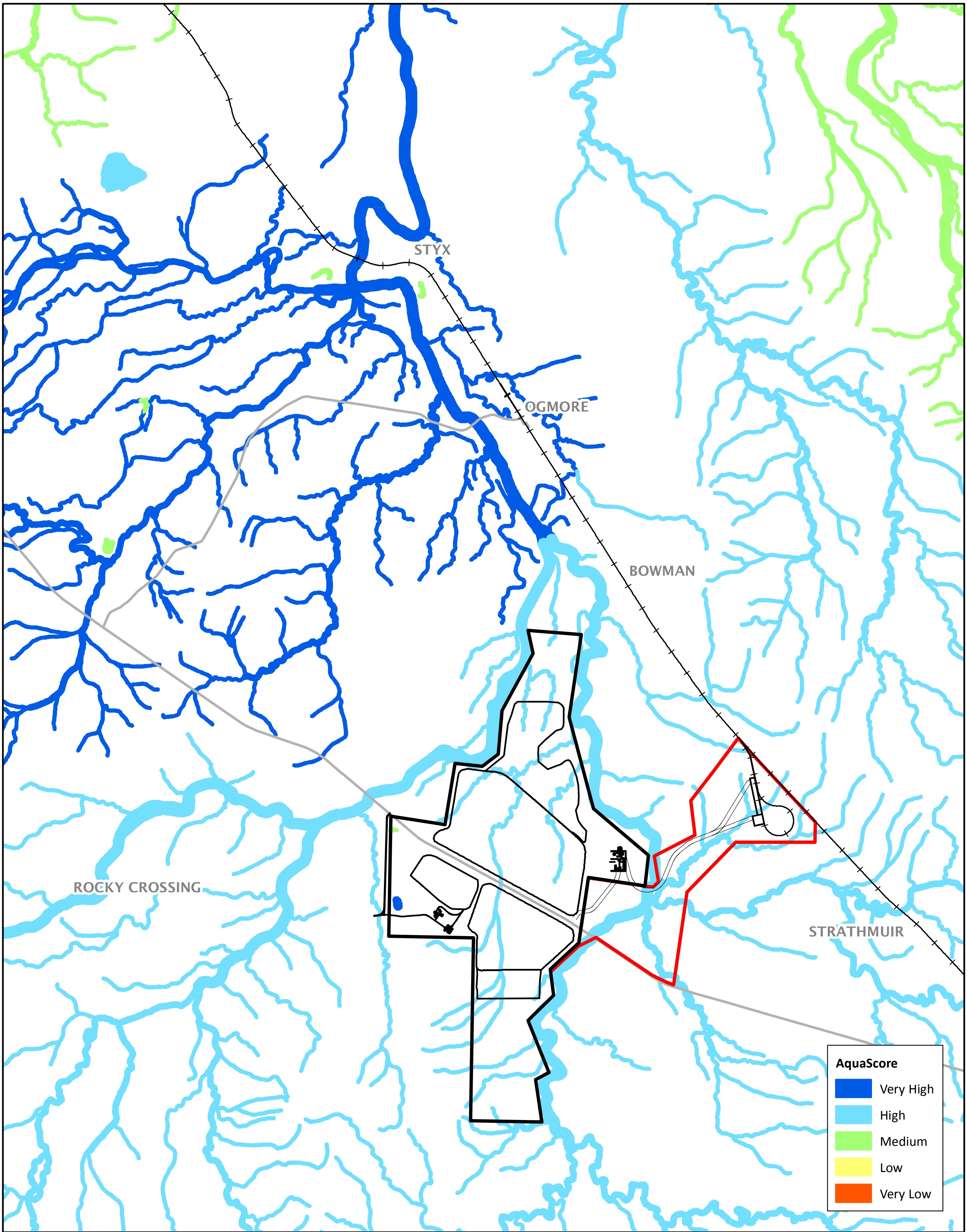


Figure 15-5
Aquatic conservation asssessment mapping for the Project area

CDM Smith

BROTHERSSM \\brbsvr1\PRO\Project\BES170353.01 - Styx Supplementary EIS\7Work\3GIS\Styx\MXD\Jess\BES150160.01 R3 aquatic conservation mapping-figure 15-4.mxd 5/9/2018

15.6.2.13 Vertebrate Fauna

The Project area occurs within the Styx River basin which lies outside of, but adjacent to the Fitzroy Basin. Fifty-eight freshwater fish species are known from the wider Fitzroy Basin (Inglis and Howell 2009) but there is no published data available for the much smaller Styx River catchment. Database searches identified 26 freshwater-associated fish species known to occur within a 50 km radius of the Project area. None of the species identified in database searches are listed under the NC Act or EPBC Act. All species identified within database searches can be found in Appendix A9c – Ecological Desktop Search Results.

Database searches also identified five freshwater turtle species recorded in the wider area: Krefft's River Turtle (*Emydura macquarii krefftii*), Fitzroy Turtle (*Rheodytes leukops*), Southern Snapping Turtle (*Elseya albagula*), Snake-necked Turtle (*Chelodina longicollis*) and Saw-shelled Turtle (*Wollumbinia latisternum*).

The Fitzroy Turtle is listed as Vulnerable under the NC Act and EPBC Act. The species is only found in the drainage system of the Fitzroy River and is primarily known to occur in the Fitzroy, Connors, Dawson, and Mackenzie Rivers, Widah Creek and Develin or Marlborough Creek (Cogger 2000). The species prefers large pools and connecting flowing riffle habitats with clear water. It is known to feed on aquatic insect larvae, freshwater sponges and Ribbonweed (*Valisneria* spp.) (Tucker et al. 2001). The nearest database records for this species are located 30 km south of the Project area on Marlborough Creek which lies within the Fitzroy Basin.

The Southern Snapping Turtle is listed as Endangered under the NC Act and Critically Endangered under the EPBC Act. This is one of Australia's larger turtle species and is considered endemic to flowing waters in the Fitzroy, Burnett and Mary River Basins and associated smaller drainages (TSSC 2014). The nearest database records for the species are located 30 km south of the Project area on Marlborough Creek, and 30 km south-west on the Mackenzie River, both of which lie within the Fitzroy Basin.

15.6.3 Aquatic Ecology – Field Survey Results

15.6.3.1 Stream Health and Water Quality

Water Quality Sampling - 2011 Results

Two parameters from the in-situ water quality variables recorded in June 2011 were outside the WQOs set for the Styx River Basin (refer EHP 2014): Dissolved Oxygen (DO) (%Sat), and pH (Table 15-5). DO (%Sat) was slightly lower than the WQOs at two Deep Creek Sites (De1 and De2) and Granite Creek (Gr1) at both riffle and edge habitats, and higher than the WQO value for two Styx River sites (St1b and St2).

Table 15-5 Water quality data – aquatic ecology sites (June 2011)

Water quality parameter	Site								
	De1[2]	De2[2]	De3[2]	St1[3]	St1b[3]	St2[3]	To1[2]	To2[2]	Gr1[2]
Sample date range	2011	2011	2011	2011	2011	2011	2011	2011	2011
Water Temperature (°C)[1]	16.25	16.78	14.79	16.74	19.94	18.49	16.05	15.64	18.3
Dissolved Oxygen (%sat)[1]	82.3	82.7	85.8	90.9	123.4	114.6	94.7	92.1	83.7
pH[1]	6.81	7.16	7.21	9.19	7.61	7.63	7.59	7.4	6.6
Conductivity-base flow (µS/cm)[1]	461	475	447	987	1,366	1,390	866	848	324
Turbidity (NTU)[1]	13.1	12.9	17.2	5.6	5.8	5.4	5.9	1.7	7.4
Suspended solids (mg/l)	6	6	6	<5	<5	<5	<5	<5	6
Ammonia N (mg/l)	0.03	0.03	0.02	0.02	<0.01	0.03	0.02	0.02	<0.01
Total Phosphorus as P (mg/l)	0.04	<0.01	0.1	0.12	<0.01	<0.01	0.03	0.02	0.04
Filterable Reactive Phosphorus (mg/l)	<0.01	<0.01	-	<0.01	-	<0.01	-	-	-
Sulfate (mg/l)	29	28	24	42	66	68	42	41	2
Total Nitrogen (mg/l)	0.7	0.4	0.6	0.5	0.4	0.4	0.4	0.6	0.6
Nitrate (mg/l)	0.03	0.03	0.12	0.04	0.05	0.04	0.03	0.02	0.05
Total Oxidised Nitrogen (mg/l)	0.03	0.03	0.12	0.04	0.05	0.04	0.03	0.02	0.05
Total Alkalinity as CaC03 (mg/l)	89	88	100	190	204	306	212	209	75
Arsenic (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium (mg/l)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/l)	0.002	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
Nickel (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (mg/l)	0.029	0.006	<0.005	0.005	0.010	0.026	<0.005	<0.005	0.014
Mercury (mg/l)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

1. In-situ water quality measurements
2. WQOs for lowland (< 150 m asl) freshwaters of the Styx River catchment derived from Table 2A of EHP 2014
3. WQOs for middle estuary (moderately disturbed) estuarine waters of the Styx River derived from Table 2A of EHP 2014

The pH result for site St1 from 2011 was above the WQO for estuarine waters associated with the Styx River with a reading of 9.19. This value was retested after re-calibration of the meter when the pH recorded was 9.8. The pH result for site St1 should therefore be treated with caution. Turbidity and suspended solids values recorded in 2011 were all under the associated WQO when flows were observed at all sites.

Electrical Conductivity (EC) values recorded in 2011 varied across sites with both Deep and Granite Creek sites having low values in comparison with the Tooloombah Creek and Styx River sites ranging in values from 987 – 1390 µS/cm. Although the EC at the St2 and St1b sites were high this is not surprising given the proximity of these sites to the estuary. Local landholders advised GHD that large tides pushed well up the river above the Ogmore Bridge and may explain the substantial difference between the two surveys.

Broadly the in-situ water quality values recorded in 2011 can be used to separate the sites into two groups:

- Group 1 (Deep and Granite Creek) - EC <500 µS/cm, pH <7.3, DO (%Sat) < 90%, turbidity >7 NTU, alkalinity <50; and
- Group 2 (Tooloombah Creek and Styx River) – EC >500 µS/cm, pH >7.3, DO (%Sat) >90%, turbidity <7 NTU, alkalinity >50.

Laboratory analyses from the 2011 water quality samples confirmed results from the in-situ analyses and supported the water quality groupings outlined above. The laboratory analyses highlighted four analytes that recorded exceedances of the Styx River Basin WQOs (EHP 2014): total nitrogen, total oxidised nitrogen, ammonia, and total phosphorus (Table 15-5).

Total nitrogen and ammonia marginally exceeded the guidelines at the majority of sites. Total oxidised nitrogen exceeded the guidelines at four sites including all the Styx River sites. Total phosphorus exceeded the guidelines at a single site only (St1). No metals recorded dissolved concentrations above the recommended values (refer to Chapter 9 – Surface Water, for further discussion).

Water Quality Sampling - 2017 – 2018 Results

The results of water quality sampling carried out in 2017 and 2018 are collated in detail in Chapter 9 – Surface Water and Appendix A5a. The mean, median, 20th 80th and 95th percentiles are presented in Table 15-6. The data are compared against the Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values and Water Quality Objectives (EHP 2014) and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000). These water quality objectives have been selected as most relevant to the primary receiving environment.

Table 15-6 Stream water quality including mean, median and 20th, 80th and 95th percentiles

Parameter	WQOs	Combined water quality Results (June 2011 – October 2018)					
		Sample number	Mean	Median	20th%	80th%	95th%
In-situ results							
Water Temperature (°C)	16 – 34[5]	186	23.96	24.3	20	28.4	31.35
Dissolved Oxygen (%S) Lower	6.77 – 8.76[2]	132	15.10	5.59	3.972	8.664	78.1
pH	6.5 – 8.0[2]	203	7.74	7.8	7.368	8.112	8.489
Conductivity- base flow (µS/cm)	-	269	3165.16	683	270.96	1968.6	18169
Turbidity (NTU)	50[3]	176	115.27	13.45	5.41	125	732
Laboratory results							
Total Dissolved Solids (mg/L)	600[4]	178	2074.92	665.5	309.8	1570	10840
Suspended Solids (mg/L)	40[2]	178	62.29	13	6	61.6	249.8
Total Alkalinity as $CaC0_3$ (mg/L)	≥20[1]	135	126.85	114	72	169	264.6
Sulphate (mg/L)	250[4]	178	104.78	12.5	5	41.6	643.15
Chloride (mg/L)	-	178	868.17	137	39.4	453	6014.5
Ammonia N (mg/L)	0.02	178	0.055	0.03	0.02	0.08	0.143
Nitrite (mg/L)	-	178	0.010	0.01	0.01	0.01	0.01
Nitrate (mg/L)	0.7[1]	178	0.018	0.01	0.01	0.02	0.05
Total Nitrogen (mg/L)	0.5[2]	178	0.939	0.5	0.3	1.26	3.115
Total Phosphorus as P (mg/L)	0.05[2]	178	0.177	0.05	0.02	0.244	0.758
Reactive Phosphorus (mg/L)	0.02[2]	174	0.015	0.01	0.01	0.01	0.0435
Fluoride (mg/L)	1.0[2]	171	0.198	0.2	0.1	0.2	0.5
Aluminium (mg/L)	0.055[1]	176	0.479	0.02	0.01	0.1	3.23
Arsenic (mg/L)	0.024[1]	176	0.013	0.002	0.001	0.01	0.1
Barium (mg/L)	1.0[1]	174	0.098	0.087	0.031	0.112	0.2545
Cadmium (mg/L)	0.0002[1]	134	0.0001	0.0001	0.0001	0.0001	0.0001
Chromium (mg/L)	0.001[1]	176	0.001	0.001	0.001	0.001	0.002
Cobalt (mg/L)	0.0014[3]	134	0.001	0.001	0.001	0.001	0.002
Copper (mg/L)	0.0014[1]	176	0.031	0.001	0.001	0.002	0.05
Lead (mg/L)	0.0034[1]	176	0.015	0.001	0.001	0.01	0.065
Manganese (mg/L)	1.9[1]	174	0.143	0.0375	0.01	0.146	0.5
Molybdenum (mg/L)	0.034[3]	134	0.001	0.001	0.001	0.001	0.00235
Nickel (mg/L)	0.011[1]	134	0.001	0.001	0.001	0.002	0.00335
Selenium (mg/L)	0.005[1]	172	0.065	0.01	0.01	0.01	0.1
Silver (mg/L)	0.00005[1]	134	0.001	0.001	0.001	0.001	0.001
Uranium (mg/L)	0.01[6]	33	0.001	0.001	0.001	0.001	0.002
Vanadium (mg/L)	0.006[3]	32	0.011	0.01	0.01	0.01	0.0125
Zinc (mg/L)	0.008[1]	36	0.006	0.005	0.005	0.005	0.025
Iron (mg/L)	0.2[6]	46	0.281	0.05	0.05	0.08	1.625
Mercury (mg/L)	0.0006[1]	40	0.0001	0.0001	0.0001	0.0001	0.0001

Source: 1 – ANZECC 2000 High-reliability TV; 2 - ANZECC 2000 Low-reliability TV; 3 – EPP (Water) 'Aquatic Ecosystem'; 4 – EPP (Water) 'Human Consumer'; 5 – EPP (Water) 'Primary Recreation'; 6 – EPP (Water) 'Irrigation'. 7 – the WQO for dissolved oxygen is based on a conversion from the % saturation to mg/L assuming temperature at 25°C and altitude of 300 mAHD. The dissolved oxygen WQO was a percentage of saturation is 85% to 110%.8 - the ANZECC high reliability TV for Nitrate (as NO_3) of 0.7 mg/L is represented as Nitrate N (0.158 mg/L).

Turbidity shows a seasonal response to rainfall, increasing in the wet season and during residual flows. Water quality within Deep Creek was often elevated above the trigger value of 50 NTU and on occasion in Toolombah Creek during the 2017 / 2018 wet season. Suspended solids exceeded 40 mg/L for twenty-one of the seventy-five water samples. Although turbidity and suspended solids show a seasonal influence it is also likely that natural creek structure and landuse influence levels observed. Exceedances observed in Deep Creek in 2011, 2017 and 2018 are possibly the result of the finer streambed substrate being mobilised by turbulent streamflows and possibly erosion and stock having access to the pools.

Turbidity levels in Tooloombah Creek were less turbid than Deep Creek pools, likely due to a combination of catchment hydrology (less erosion and slower flows), reduced stock access and increased residence time of pool water enabling sediments to settle.

Testing showed that all surface water samples exceeded the ANZECC guideline value for conductivity. High conductivity values can result from excess sodium, magnesium, calcium, chloride, sulphate and bicarbonate in streams. These salts may originate from irrigation water, soils or fertilisers. High salinity values in streams may also result from rising water tables.

The tidally influenced sub-catchments of the Styx River catchment, i.e. below the confluence of Tooloombah and Deep Creeks, are dynamic hydrological environments where terrestrial waters mix with marine waters providing brackish to saline conditions that are markedly different from the higher sub-catchments. Water samples at St1 and St2 in the Styx River show the Styx River is tidally influenced, with electrical conductivity ranging from fresh (125 μS/cm) to brackish (more than 5,000 μS/cm), generally increasing during periods of dry / no flow, and following the first flush of salts experienced at the beginning of the wet season. The higher values at the Styx River site in relation to the other creeks within the catchment is evident (see Section 9.5.5 in Chapter 9 – Surface Water). The elevated levels are likely the result of estuarine influence in this section of the river, particularly at site St2, with dilution occurring following periods of high rainfall and / or streamflow.

Deep Creek water chemistry is more similar to rainfall than it is to seawater and varies between wet and the dry seasons. Surface water samples along Tooloombah Creek shows that the salinity is generally higher than Deep Creek regardless of flow conditions, ranging from around 170 to 2,700 μS/cm EC. Tooloombah Creek is a rocky creek and markedly different in form from Deep Creek. The conductivity results likely indicate a differing geological background or parent source between the two creeks.

The major ion composition of surface water samples collected show that Tooloombah Creek water chemistry is less like rainfall than Deep Creek, with higher concentrations of calcium and chloride. Chloride concentrations increase with distance down the creek (To1 chloride concentrations are generally less than To2 and To3) possibly in response to groundwater discharge and evaporation (refer EIS Chapter 10 – Groundwater Section 10.5.6.7 for further discussion).

Styx River, Deep Creek and Tooloombah Creek show a broad range of pH during the sampling period. The pH typically sits between 7-8 with Tooloombah Creek reporting more alkaline conditions than the other creeks. Elevated pH levels typically occurred during low flow conditions and likely represent the influence of local geology and groundwater inflows, with water quality in the Styx River also influenced by tidal conditions. In general, conditions in the catchment are alkaline.

Total nitrogen exceeded the guideline value of 0.5 mg/L at Deep and Tooloombah Creeks and Styx River, with Deep Creek reporting consistently higher levels with an average concentration of ~1.0 mg/L. Elevated levels occur during both 2017 and 2018 wet season flows although exceedances occur within the dry season potentially associated with stock access (particularly to Deep Creek). The greater responsiveness within Deep Creek to wet season total nitrogen concentrations may also be reflective of the relationship between the size of the sub-catchment inputs and its dominant influence on creek flows and quality.

Between 2017-2018 total phosphorous is reported predominantly within the water quality objective of 0.5 mg/L. Exceedances occur as outliers predominantly in Deep Creek but also in Styx River. The time series data plots (see Section 9.5.5 in Chapter 9 – Surface Water) show that exceedances occur within Deep Creek in February 2017 (De2 and De3), between February and June 2018 (De1-De5) and once in September 2018 (De5). These patterns reinforce the positive relationship with wet season flows with exceedances occurring during the low or no-flow periods likely a response to locally introduced organic matter.

Nitrogen and phosphorus in surface water come from a number of sources. Naturally, organic plant matter and silt containing macronutrients can enter waterways from surrounding environments and riparian vegetation. Elevated nutrient levels can often be the result of anthropogenic sources and given the downstream catchment location of the Project, grazing (through direct defecation and pasture runoff) and the erosion of nutrient laden sediments are likely key sources in and upstream of the Project area.

Ammonia-N was typically elevated above the water quality objective of 0.02 mg/L at all locations with the highest concentrations occurring in Styx River and Deep Creek. Concentrations are observed to increase during the wet season with sustained flows in 2018 resulting in sustained elevation of ammonia-N concentrations into the months of July and August

Dissolved aluminium concentrations within Deep and Tooloombah creeks occur predominantly above the water quality guideline value of 0.05 mg/L, with concentrations in Styx River greater than this level occurring only occasionally. The spike occurring at the Deep and Tooloombah Creek sites in March 2018 is likely reflective of groundwater inputs following the large rain event in February.

The majority of results for the creeks and river show dissolved copper concentrations generally exceed the water quality guideline value 0.0014 mg/L, with Tooloombah Creek reporting the highest spikes in concentrations. Dissolved copper shows a similar seasonal behaviour to aluminium with some spikes following rainfall events in 2017 and 2018. Deep Creek is an exception which reports a higher average dissolved copper concentration throughout the dry season.

Dissolved zinc was consistently higher in Styx River compared with the creek sites, however similar peaks in concentration are observed in both Deep and Tooloombah creeks. The water quality guideline of 0.008 mg/L is exceeded at all three waterways with peaks in dissolved zinc concentration occurring within a month following rain events and may indicate groundwater influence.

No other dissolved heavy metal exceedances were recorded noting that the interim low reliability triggers applied to vanadium is below the limits of detection used in the analyses.

Surface water systems can often exhibit naturally high heavy metal concentrations due to local geology and soil composition; however, concentration levels can often be increased through environmental disturbance (for example soil erosion) and other anthropogenic activities (for example mining and agriculture). Heavy metals present in a system due to soil erosion are typically associated with sediment particulates and although they will be measures under total metals, they are typically not bioavailable. As such, dissolved metals provide a more accurate concentration of bioavailable metals that can accumulate in the food chain through direct ingestion or passive diffusion (for example direct contact) with organisms (ANZECC guidelines).

Levels of dissolved lead above the water quality objective of 0.0034 mg/L were reported for Styx River, Deep Creek and Tooloombah Creek with the greatest levels occurring within the Styx River. Higher levels of reporting in 2011-2012 of 0.01 mg/L (subsequently increased to 0.001 mg/L in 2017-18) contribute to an overall low percentage of detection however the data suggests that elevated levels are observed during first rains and residual flows. This is not well represented in the 2017-2018 time series chart with spikes in dissolved lead only occurring in Styx River in August and October 2018 and in Deep Creek in October 2018. Lead, as with a number of other heavy metals typically becomes more mobile under low pH conditions. This is not reflected in the pH data for the sample events where neutral to alkaline conditions predominated. The form of lead differs between fresh and saltwaters due to chloride interactions and this may account for the higher levels reported within the Styx River in relation the other waterways.

15.6.3.2 Aquatic Flora

No aquatic plants were observed in 2011 other than sedges (*Cyperaceae* sp.) and rushes (*Juncus* sp.). It is likely that most floating, submerged or emergent aquatic plants would have been removed from the waterways during the floods and high flow conditions that occurred in the wet season at that time. Observations during wet and dry season botanical surveys (refer Appendix A9b –Flora and Vegetation Assessment) across the wider area in 2011 recorded a number of sedge / wetland plants associated with ephemeral wetlands including *Eleocharis blakeana* and *Juncus polyanthemus.* Observations in September 2011 at the WPA identified a variety of sedges and a sparse cover of hydrophytes including Swamp Lily (*Otellia ovalifolia*).

Aquatic flora species were relatively sparse again during the February 2017 survey, although dense aquatic algae occurred at the Tooloombah Creek sites. Water Snowflake (*Nymphoides indica*), a floating species, was relatively common on the large pool at To2. Swamp Lily occurred in isolated patches along the edge of De2.

The WPA and a second wetland located on the western boundary of the mine ML (Figure 15-6) are mapped as wetland vegetation communities under the VM Act. The WPA is mapped as RE 11.5.17 - *Eucalyptus tereticornis* woodland in depressions on Cainozoic sand plains and remnant surfaces. The second wetland is mapped as RE 11.3.27b - Freshwater wetlands with or without aquatic species and fringing sedgelands and eucalypt woodlands occurring in a variety of situations including lakes, billabongs, oxbows and depressions on floodplains (Queensland Herbarium 2017). Both wetlands are considered as MSES.

The following sections provide a description of the values of each wetland following on-site observations throughout 2017 and a detailed 'secondary' vegetation assessment (as per Neldner et al. 2017) at each wetland carried out in January 2018 by CDM Smith. In addition, as part of groundwater investigations for the Project groundwater wells were installed in September 2018 to monitor the water table at the two wetlands (WMP25 and WMP27). These wells will form part of a future groundwater monitoring network.

Wetland Protection Area

The WPA is roughly circular and encompasses approximately 4 ha. The wetland is largely surrounded by eucalypt woodland on sandy soils (RE 11.5.8a) with a small area of woodland on clay spoils (RE 11.4.2) adjacent on the eastern edge. The wetland is characterised by a central stand (covering approximately 2 ha) of Broad-leaved Paperbark (with occasional Forest Red Gum also present) surrounded by a vegetated open area with ground cover only. The wetland was inspected during the February 2017 survey and was completely dry at the time. Following heavy rains in May 2017 the wetland had filled up with limited open water around the edge (Plate 15-1). Cattle were present using the wetland area on all occasions the wetland was inspected. Feral Pigs were also observed using the area.

This wetland is mapped as a GDE in the Bureau of Meteorology's GDE Atlas (BoM 2017) and is classified as a Coastal/ Sub-Coastal non-floodplain tree swamp (Melaleuca and Eucalypt) with high potential for reliance on surface expression of groundwater.

Targeted GDE sampling works (refer Section 15.5.2.3) indicate a complicated localised groundwater system. The water table near this location has been measured to be 10.2 mbgl (August 2018) with another zone of moisture at approximately 8 mbgl which appears separated from the water table by calcrete bands and layers of sandstone and clay. The trees and in the centre of the wetland are for the most part accessing the upper zone of moisture which is likely fed seasonally when the wetland is recharged by rains. However, isotopic signatures of deeper soil cores (refer Section15.6.7) suggest there may also be some influence of groundwater. There is some potential the trees may access deeper soil water that is maintained by groundwater to support transpiration requirements during sustained dry periods when the upper soil water reservoir is otherwise depleted (refer Section 15.6.4 for further discussion).

The wetland vegetation assessment was carried out in relatively dry conditions in January 2018. The wetland soil was generally damp with some areas of shallow water (10 cm depth) in the centre and north of the wetland. No open water was present (Plate 15-2) and no water quality samples were able to be taken.

The edge of the wetland was dominated by a continuous cover dominated by *Eleocharis pallens*. The centre of the wetland was wetter and dominated to a lesser extent by *Eleocharis sphacelata* with a variety of other species occurring throughout including Swamp Rice Grass (*Leersia hexandra*), Bunchy Sedge (*Cyperus polystachos*), Olive Hymenachne (*Hymenachne amplexicaulis*) and Mexican Primrose-willow (*Ludwigia octovalvis*). Other species present as scattered occurrences include a variety of sedges (*Cyperus cyperoides*, *C. haspan* and *Fimbristylis sieberiana*), Floating Primrose-willow (*Ludwigia peploides*), Common Nardoo (*Marsilea drummondii*) and Budda Pea (*Aeschynomene indica*). Canopy cover in the centre of the wetland was patchy, with a relatively sparse distribution of Broad-leaved Paperbark (generally less than 30% canopy cover where it occurs).

This area is described under the wetland mapping as RE 11.5.17 (*Eucalyptus tereticornis* woodland in depressions). There is a single Forest Red Gum present in the wetland but none in the surrounds. It is unlikely whether soils associated with this community occur (i.e. always with ironstone concretions on the surface or at depth). The wetland is located in a natural depression, on a gentle slope and does not occur within a flood / drainage line. Given the surrounding vegetation, landscape position and soil type the wetland has been described as RE 11.3.12, although this remains open to question.

Frog species recorded in January 2018 included Eastern Sedgefrog (*Litoria fallax*) and Desert Froglet (*Crinia deserticola*). Few waterbirds were observed as present during any field inspection with only Pacific Black Duck (*Anas superciliosa*) recorded. Cattle were present using the wetland area on all occasions the wetland was inspected in 2017 and 2018.

Plate 15-1: WPA in wet conditions (May 2017)

Plate 15-2: WPA during vegetation assessment (January 2018)

Wetland – as mapped under DNRME Vegetation Mapping

The second mapped wetland (Plate 15-3) encompasses approximately 0.6 ha being 180 m in length and 40 m wide at its widest point. The wetland is surrounded by intact woodland (RE11.4.2) and is likely to be used by cattle. The wetland has been inspected on several occasions with water levels appearing to be relatively constant, thereby indicating the wetland may be permanent.

This wetland is mapped as a GDE in the Bureau of Meteorology's GDE Atlas (BoM, 2017) and is classified as a Coastal / Sub-coastal floodplain grass, sedge and herb swamp with high potential for reliance on surface expression of groundwater. The water table near this location has been measured to be around 20 mbgl. Targeted GDE sampling (in August 2018) did not find groundwater down to 15 mbgl and indicated surrounding trees were water-stressed. The wetland is considered a surficial feature with no hydraulic link to either shallow perched or regional groundwater aquifers (refer Section 15.6.4).

Water depth in the centre of the wetland could not be measured but is likely to be in excess of 1 m based on the water depth encountered around the vegetated edges during the vegetation assessment. The wetland is characterised by a dense fringing area of erect aquatic plant species. The centre of the wetland is for the most part covered by floating vegetation (Plate 15-4).

In-situ water quality analyses recorded low turbidity (6.4 ntu) and electrical conductivity (56 µs/cm), with a neutral pH (7.03) present. Laboratory analyses recorded the following:

- Low suspended solids (56 mg/L);
- Similar to surface water samples taken in Deep Creek and Tooloombah Creek total nitrogen (0.9 mg/L) and total phosphorus (0.08 mg/L) were both above the water quality objectives for lowland fresh waters in the Styx River Basin (refer SoQ 2014); and
- Similarly, low levels of metals also recorded elsewhere from surface water sites in the catchment (manganese, barium, aluminium and zinc) excepting iron which was recorded in comparatively high concentrations (0.76 mg/L).

The edges of the wetland feature a dense cover with several species dominating including Giant Sedge (*Cyperus exaltatus*), *Eleocharis sphacelata*, *Digitaria divaricatissima*, and Olive Hymenachne. Open water comprises the remainder of the wetland with floating aquatic vegetation present dominated by a relatively constant cover of Blue Lotus (*Nymphaea caerulea*), with Swamp Lily, and Water Snowflake also present to a lesser extent. Other plant species recorded included Floating Primrose-willow, Common Nardoo, Swamp Rice Grass and Red Water Fern (*Azolla pinnata*).

This area is described under the wetland mapping as RE 11.3.27b (lacustrine wetland). The wetland is fringed by sparse Forest Red Gum and is located on a floodplain and appears connected to an indistinct floodplain drainage line feeding into Tooloombah Creek. The wetland mapping is considered to be correct.

Low numbers of wetland bird species have been recorded at the wetland including Straw-necked Ibis (*Threskiornis spinicollis*), Brolga (*Antigone rubicunda*), Pacific Black Duck, Cotton Pygmy-goose (*Nettapus coromandelianus*) and Plumed Whistling-duck (*Dendrocygna eytoni*). No fish were present in the wetland. Evidence of Feral Pig (*Sus scrofa*) damage was observed around the edges of the wetland in January 2018.

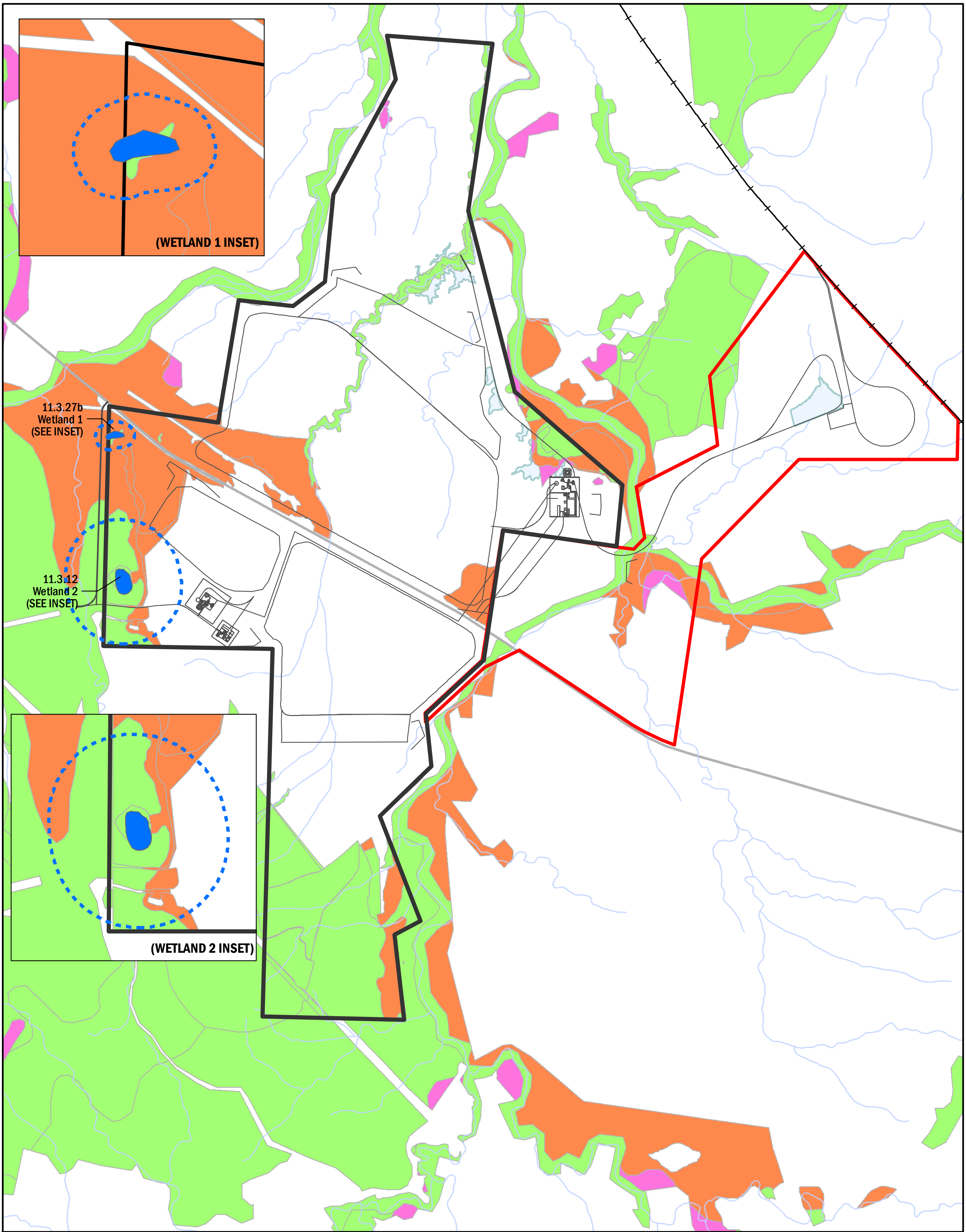
Plate 15-3: View across wetland (January 2018)

Plate 15-4: Floating vegetation in centre of wetland

Weeds

Parthenium (*Parthenium hysterophus*) was observed in the creek bed at To2 during the 2017 survey and was commonly observed along the creek banks adjacent to the site following heavy rains later in the year. This is listed as a Category 3 Restricted Matter (under the State's Biosecurity Act) and a Weed of National Significance, although is not an aquatic plant. Olive Hymenachne is an aquatic weed and was observed in the northern extent of the ML at a farm dam (February 2017) and in a water-filled gilgai (May 2017). This species was observed in several wetlands (including both the wetlands described above) and dams in January 2018 having evidently expanded its occurrence in the area. This species is also listed as a Category 3 Restricted Matter (under the State's Biosecurity Act) and a Weed of National Significance.

This is a large semi-aquatic grass species that can reproduce from small fragments of the plant stem. It forms dense stands crowding out native plant species and degrading habitat for aquatic fauna including commercial and recreational fish species. Olive Hymenachne can grow to such densities as to impact the ability of drainage networks to deal with flooding (DAF 2016).



Legend

Remnant Vegetation (DNRME)

- Endangered
- Least Concern
- Of Concern
- Non-remnant
- Wetland (VM Act)
- Wetland buffer
- ML 700022
- ML 80187
- Mine infrastructure
- Main Road
- North Coast Rail Line
- Watercourse
- Dam

Scale @ A4 1:50,000
Date: 01/11/18
Drawn: J Parnwell

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018
QLD Department of Environment and Heritage Protection, 2016

Figure 15-6
Wetlands as mapped under the VM Act

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 15_Supp_Report_Aquatic Ecology\1000111 Wetlands__15-6.mxd 11/1/2018

15.6.3.3 Vertebrate Aquatic Fauna

A total of 736 fish comprising 28 native fish species were collected across all the sites during the 2011 survey. This included 14 of the 26 species identified from the desktop database search from the wider area. The lack of any records of introduced species from either the desktop review or field results indicates the catchment may be relatively free of introduced taxa such as Tilapia (*Oreochromis* sp.) and Mosquito fish (*Gambusia* sp.). The fish taxa recorded during the June 2011 sampling round are generally typical of what would be expected to occur in a Central Queensland coastal catchment. The most abundant catches were in Deep Creek and Granite Creek. The highest fish diversity for individual sites was recorded from the Styx River at site St2 and at Tooloombah Creek at site To1, which both recorded 15 species (Table 15-7). Both of these sites had large pools that enabled sampling from a boat.

The lowest diversity sites were a Deep Creek site (De1), and a Tooloombah Creek site (To2). Both of these sites were sampled with a back-pack electrofishing unit only. The highest diversity of fish overall was recorded from the Styx River where 22 species were caught over the three sites (Table 15-7). This was well ahead of Tooloombah Creek (15 species from two sites), Granite Creek (12 species from a single site), and Deep Creek (11 species from three sites) and is a result of the estuarine influence in the Styx River.

The taxa recorded were a mix of freshwater and estuarine / marine associated species. Eastern Rainbowfish (*Melanotaenia splendida*) and Empire Gudgeon (*Hypseleotris compressa*) were the most commonly caught in terms of both abundance and distribution across all study sites. Agassiz‟s Glassflsh (*Ambassis agassizii*), Spangled Perch (*Leiopotherapon unicolour*), Purple Spotted Gudgeon (*Mogurnda adspersa*) and Barramundi (*Lates calcarifer*) were also relatively common, but these did not occur across all sites. Sixteen of the twenty-nine species recorded in June 2011 were represented by fewer than 10 individuals across all sites. No introduced species were collected in this Project which indicates that the region may be relatively free of introduced taxa.

Two specimens of an unidentified eel were recorded during the 2011 survey. These were tentatively identified as swamp eels of the genera *Ophisternon* (Family: Synbranchidae). At that time, there was no record of this genus or family occurring in the Styx River or the wider region. However, this group of eels has been poorly studied and there is limited taxonomic information available. Swamp eels spend their life living and feeding in burrows within soft sediments and are rarely recorded as a result. Recent information suggests that the Synbranchidae occur as far south as the Moreton Bay region and there are up to three undescribed species from the southern and central coast of Queensland (pers. comm. Dr Jeff Johnson).

Fish sampling in 2017 was limited to bait traps and did not take place at the estuarine sites on the Styx River as occurred during the 2011 survey. A total of 274 fish comprising four species were collected across the five sites that were sampled. By far the highest abundance of fish trapped was at To2 (183 individuals across all four species).

Multivariate analysis of the 2011 fish community data indicated that Deep Creek had a distinct community from that of the other creek systems assessed (refer Figure 5-3, Appendix A9e - Aquatic Ecology Results) reflecting the strong average similarity for Deep Creek sites (73.68%). Fish community composition was more variable in the Styx River and Tooloombah Creek. Further analysis indicated that this related to shallow stream versus deep pool habitat, though further sampling would be required to confirm this. Granite Creek fish fauna most closely matched that of site To1, though this is based on only one sample from that creek system. Further analysis is provided in Appendix A9e - Aquatic Ecology Results.

While most freshwater fish in Australia have some migratory behaviour during their lifespan this can vary substantially from entirely within freshwater systems through to catadromous taxa such as Barramundi which breeds in estuaries but migrates upstream into freshwater as yearlings. The migratory nature of most Australian fish means that connectivity within the rivers and estuaries is important to maintain healthy breeding populations. The migratory aspect of fish observed in the Central Queensland Coal Project in June 2011 is shown in Table 15-7. Connectivity within the waterways of the study area was observed to be generally good.

Two commercially targeted fish taxa were recorded: the Sea Mullet (*Mugil cephalus*), and Barramundi. Sea Mullet was only caught at the two lowest Styx River sites (St1b and St2). This was expected as these sites are in the upper reaches of the estuary and made up of pools over 200 m in length which provide ideal habitat for this species.

A total of 51 Barramundi were caught during the 2011 survey. Barramundi were caught in all creeks sampled except Deep Creek. This is most likely due to the fact that Barramundi were only captured in large pools and no large pools were sampled from within Deep Creek. Barramundi ranged in size from 150 mm to 610 mm with smaller fish (< 500 mm) accounting for 86% of the catch. A key finding is that where Barramundi were recorded, a range of size classes were represented. This indicates that the study area is a nursery area for juvenile Barramundi and that there have been successive cohorts utilising the study area.

The main sightings of aquatic reptiles in 2011 were of turtles which occurred at the following sites: Gr1, De2, De3, To1, and To2. Turtles were most abundant at sites To1 and Gr1 which were both large pools sampled late in the day. These two sites recorded a total of 26 turtles that were observed during routine sampling. Four turtles were caught, photographed and positively identified including Krefft's River Turtle and Eastern Snake-necked Turtle. Southern Snapping Turtle was incorrectly reported as a result during this survey (see Section 15.6.3.4). In 2017 turtles were trapped at a single site (To1) where nine Saw-shelled Turtles were caught across two sampling events.

During the June 2011 survey evidence of the presence of Estuarine Crocodile (*Crocodylus porosus*) slides was observed at two Styx River sites (St1b and St2). Anecdotal evidence for the presence of estuarine crocodiles was also noted for the Deep Creek, Granite creek, and the Styx River. Local amateur fishermen observed four crocodiles downstream of St2 in June 2011. It is considered likely that estuarine crocodiles are also present in parts of Tooloombah Creek. No evidence of the presence of Estuarine Crocodile was observed during the February 2017 survey.

Table 15-7 Aquatic fauna species recorded by site (June 2011 / February 2017)

Scientific name	Common name	De1[1]	De2[1]	De3	De4[1]	St1	St1b	St2	To1[1]	To2[1]	Gr1	Habitat and life history (Allen et al. 2003)
Fish												
Ambassis agassizii	Agassiz's Glassfish	20 14	28 2	3	22	4	2	4	4	94	20	Inland freshwaters to estuarine systems
Amnitaba percoides	Barred Grunter	1										Fresh to brackish waters
Anguilla reinhardtii	Marbled Eel		1	1		14	1	4	6	5	13	Catadromous, adults migrate from freshwater to breed in marine waters
Anguilla obscura	Pacific Short-finned Eel						4	1	3	1		Catadromous, adults migrate from freshwater to breed in marine waters
Craterocephalus stercusmuscarum	Fly-speckled Hardyhead								1 65		4	Freshwater only
Elops hawaiensis	Giant Herring							3				Mainly marine, but also lower reaches of freshwater
Gerres filamentosus	Threadfin Silver Biddy							2				Mainly marine, but also lower reaches of freshwater
Glossamia aprion	Mouth Almighty					1						Usually found in still freshwaters with abundant aquatic vegetation.
Glossogobius giurus	Flathead Goby					1	3	3				Freshwater, brackish and estuarine habitats
Hypseleotris compressa	Empire Gudgeon	7 2	12 2	40	7	20	8	2	9 23	3 16	7	Freshwaters to upper estuary
Hypseleotris klunzingeri	Western Carp Gudgeon		1					2				Inland freshwaters to upper estuary
Hypseleotris species 1	Midgley's Carp Gudgeon		7	1		1					8	Mainly freshwater
Lates calcarifer	Barramundi					9	12	8	8		14	Catadromous, spawns in estuarine / coastal areas. Inhabits a variety of fresh, brackish and coastal marine habitats
Leiognathus equulus	Common Ponyfish						4	4				Mainly marine, but also lower reaches of freshwater
Leiopoterapon unicolor	Spangled Perch	16	18	18					6	2	3	Widespread species, freshwater only
Megalops cyprinoides	Oxeye Herring		2	3				2	6		3	Mainly marine, but also lower reaches of freshwater
Melanotaenia splendida	Eastern Rainbowfish	38 8	18 1	20	3	3	20	20	20 5	20 8	19	Freshwaters to upper estuary

Scientific name	Common name	De1[1]	De2[1]	De3	De4[1]	St1	St1b	St2	To1[1]	To2[1]	Gr1	Habitat and life history (Allen et al. 2003)
Mogurnda adspersa	Purple-spotted Gudgeon	20	15	13		1			1	2		Mainly freshwater
Mugil cephalus	Sea Mullet						20	12	1			Marine / estuarine to lower freshwater reaches of streams
Nematelosa erebi	Bony Bream						4	1	8		5	Mostly freshwater, widespread species
Neoarius graeffei	Blue Catfish								1		1	Marine / estuarine to freshwater streams and lagoons
Neosilurus hyrtlii	Hyrtl's Tandan		3	8					2		1	Freshwater only
Pomadasys kaakan	Javelin Fish							1				Marine / estuarine
Pseudomugil signifer	Pacific blue-eye					5						Marine / estuarine to freshwater reaches of coastal streams
Redigobius bikolanus	Speckeld Goby						1					Marine / estuarine to lower freshwater reaches of streams
Scatophagus argus	Spotted Scat						1					Marine / estuarine to lower freshwater reaches of streams
Selenotoca multifasciata	Banded Scat						6					Marine / estuarine to lower freshwater reaches of streams
Potential *Ophisternon* species	Unidentified swamp eel					1			1			Unknown, recorded at estuarine and fresh sites
Total species recorded		**6**	**10**	**9**	**3**	**11**	**13**	**15**	**15**	**6**	**12**	
Other aquatic fauna												
Chelodina longocollis	Eastern Snake-necked Turtle								1			
Emydura macquarii krefftii	Krefft's River Turtle								1		1	
Wollumbinia latisternum	Saw-shelled Turtle			1					9			

1. Numbers in red indicate sampled in 2017 /2018 sampling events

15.6.3.4 Threatened Aquatic Fauna

There are three freshwater aquatic fauna species listed as conservation significant and predicted to occur in the Study area or surrounds by the EPBC Protected Matters search tool and / or DES' Wildnet database. These species are addressed in the following sections – the Fitzroy Turtle (Vulnerable – NC Act and EPBC Act), Southern Snapping Turtle (Endangered – NC Act and Critically Endangered – EPBC Act) and Estuarine Crocodile (Vulnerable – NC Act and Migratory – EPBC Act).

Fitzroy Turtle (*Rheodytes leukops*)

Status: Vulnerable – NC Act and EPBC Act

Ecology and habitat: It possesses enlarged cloacal pouches, allowing it to absorb most of its oxygen needs from the surrounding water (Cann 1998). The species prefers large pools and connecting flowing riffle habitats with clear water. It generally does not move far within its home range. It is known to feed on aquatic insect larvae, freshwater sponges and Ribbonweed (*Valisneria* spp.) (Tucker et al. 2001). The species maintains a home range of between 400 m to 700 m and generally remains sedentary.

Distribution: The species is only found in the drainage system of the Fitzroy River and is primarily known to occur in the Fitzroy, Connors, Dawson, and Mackenzie Rivers, Widah Creek and Develin or Marlborough Creek (Cogger 2000).

Occurrence in the study area: No individuals were recorded within the Project area at any of the sites investigated. The Styx River is isolated from the Fitzroy River basin and the species is not known to occur in the area. The nearest records for the species are located 30 km to the west (Mackenzie River) and 30 km to the south-west (Marlborough Creek). Both of these areas lie within the Fitzroy Basin. Given the species is only known to occur in the Fitzroy River basin it is considered unlikely to occur within the Project area or surrounds. The nearest potential habitat for the species based on current information is in Marlborough Creek to the south.

Southern Snapping Turtle (*Elseya albagula*)

Status: Endangered – NC Act, Critically Endangered – EPBC Act

Ecology and habitat: One of Australia's larger turtle species. It is a slow-growing species that reaches maturity between 15 to 20 years old (Limpus 2008). This species prefers clear, flowing and well-oxygenated waters. Like the Fitzroy Turtle it takes in oxygen through cloacal respiration (Clark et al. 2008). The species still occurs in non-flowing waters but at much reduced densities. The young are largely carnivorous feeding on benthic invertebrates. Older individuals become largely herbivorous feeding on fallen fruits from riparian vegetation and aquatic macrophytes (Limpus 2008; Limpus et al. 2011).

Most available females will breed in each successive year. When breeding, the species is known to travel long distances to known nest site aggregations. In recent years the species has been found to be heavily impacted by nesting failure. Most available females will breed in each successive year, however successful incubation of nest clutches has been heavily impacted by stock trampling and predation with close to 100% of eggs lost (Limpus 2008; Limpus et al. 2011). Turtles sampled at multiple study sites across the three catchments indicate a 'severe depletion' of immature turtles (Limpus 2008; Limpus et al. 2011), and therefore little recruitment into the breeding population.

Distribution: Endemic to flowing waters in the Fitzroy, Burnett and Mary River Basins and associated coastal drainage basins in southeast Queensland.

Occurrence in the study area: In the original EIS submission Southern Snapping Turtle (*Elseya albagula)* (Endangered NC Act, Critically Endangered EPBC Act) was listed as having been encountered close to site. This was based on a recorded capture of the species in Deep Creek during aquatic ecology surveys in June 2011. This was despite the species not being known to occur in the Styx River catchment and the presence of unsuitable habitat (i.e. the species prefers flowing waters whereas the catchment streams are ephemeral with sporadic flow events).

CDM Smith requested the photo records of the captured individual (as noted in the report) from the original survey by ALS Water Resources Group. The photos were located and passed on to CDM Smith and an expert with experience of the species (Dr. Col Limpus) for verification. The photos depicted a juvenile Saw-shelled Turtle (*Wollumbinia latisternum*) (Plate 15-5 and Plate 15-6) which is not listed as threatened under the NC Act or EPBC Act.

Similar to the previous species, the nearest records for the species are located 30 km to the west (Mackenzie River) and 30 km to the south-west (Marlborough Creek). Both of these areas lie within the Fitzroy Basin. The species is known to occur in the Fitzroy River basin but not the Styx River. Given the ephemeral nature of the creeks associated with the area it is considered unlikely to occur within the Project area or surrounds. The nearest potential habitat for the species based on current information is in Marlborough Creek to the south. As such, Southern Snapping Turtle is no longer considered as 'occurring' or 'likely to occur' in or near the Project area and therefore, no longer considered to be impacted by the Project's activities.

Plate 15-5: Saw-shelled turtle - plastron (ALS Water Sciences 2011)

Plate 15-6: Saw-shelled turtle (ALS Water Sciences 2011)

Estuarine Crocodile (*Crocodylus porosus*)

Status: Vulnerable – NC Act, Migratory – EPBC Act

Ecology and habitat: Their habitat includes marine habitats such as mangroves, but they also commonly occur in freshwater habitats such as rivers, lakes and swamps. Crocodiles have wide and varied diets which differ between habitats. Prey size increases with the size of the crocodile, with the diet of juveniles consisting of smaller prey such as insects, crustaceans and occasionally small mammals such as rats. Larger crocodiles feed on fish, crabs, turtles, birds and mammals including large prey items such as wallabies, pigs, water buffalo, cattle and horses.

Distribution: Widespread throughout northern Australia and its range includes all of the Gulf of Carpentaria and the Queensland east coast south to the latitude of approximately Gladstone.

Occurrence in the study area: There are no Wildnet database records of the species from the wider area. The nearest ALA database records are from the Fitzroy River approximately 50 km south of the Project. Species known to occur in low numbers in the Shoalwater Bay area (DoD 2009).

During the June 2011 survey evidence of the presence of estuarine crocodiles was observed at two Styx River sites (St1b and St2) and at De2 on Deep Creek. Anecdotal evidence collected at the time suggested crocodiles have occurred in Deep Creek, Granite Creek as well as the Styx River. No evidence of crocodile presence was observed at any of the aquatic ecology sampling sites in February 2017 and in general habitat conditions appeared less suitable for the species i.e. isolated pools largely with steep banks. Anecdotal evidence collected in May 2017 suggested an individual was resident in the Styx River in the area of water sampling site down river from the confluence of Deep Creek and Tooloombah Creek (St1). However, no evidence of the species presence has been observed during monthly water sampling activity May 2017 to April 2018) at this site, or sites located on the two creek lines. It is assumed for the purposes of the Project EIS that the species is considered likely to occur in the Styx River, and 'potentially' occurring in Deep Creek and Tooloombah Creek.

15.6.3.5 Aquatic Macroinvertebrates

A total of 46 higher taxa were identified from the nine samples collected in June 2011 (Table 15-8). Macroinvertebrates were sampled from riffle habitats along the creeks and edge habitats were sampled on the Styx River sites. The riffle habitats sampled in Deep, Tooloombah, and Granite Creeks had a total of 31 taxa across all the riffle sites. The highest diversity in the riffle habitats was found on Deep Creek (De2) which had 24 taxa. The lowest diversity for any site was found at Tooloombah Creek (site To1) which had 13 taxa present. The edge habitats sampled along the Styx River had higher diversity than the riffle habitats with a total of 35 taxa collected from all edge sites. The highest diversity at any site was found at St1 which had 26 taxa present.

Overall, macroinvertebrate abundance was much higher at the creek sites than those sampled on Styx River which may be a reflection of the sampling regime (riffle vs edge) and / or saline influence at sites on the Styx River.

The most abundant macroinvertebrate taxa at surveyed creek sites were Diptera species, particularly those of the Families Chironomidae (comprising the subfamilies Chironominae, Tanypodinae and Orthocladinae) and Simulidae. Diptera species have the capacity to tolerate a range of water quality conditions including degraded systems (Odume and Muller 2011; Oliveira et al. 2010). Other fauna found across all or most sites included shrimps of the Family Palaeomonidae, Hydropsychidae (caddis flies - Trichoptera), and Caenidae (mayflies - Ephemeroptera).

PET richness is a measure based on the presence of macroinvertebrate taxa considered to have a low tolerance to poor water quality: the Plecoptera (stone flies), Ephemeroptera (may flies); and Thrichoptera (caddis flies). The PET taxa richness value in the riffle habitats ranged between five and nine taxa. In comparison, the number of PET taxa in the edge habitats ranged between three and five taxa. In general, all riffle habitats had higher PET taxa richness than Edge Habitats which is expected as sensitive taxa are generally more abundant in riffle habitats than edge habitats (Boulton and Brock 1999).

Signal-2 analyses are based on the presence and abundance of macroinvertebrate taxa, and can be used to infer habitat quality, stream health and potential disturbance. Each macroinvertebrate taxon is assigned a grade between one and 10 with lower grades indicating more tolerance to poor environmental conditions (Chessman 2003b; Chessman et al. 2006).

Results from Signal-2 analyses are presented through a quadrant diagram where:

- Quadrant 1 indicates favourable habitat and chemically dilute waters;
- Quadrant 2 indicates high salinity or nutrient levels (could be natural);
- Quadrant 3 indicates toxic pollution or harsh physical conditions; and
- Quadrant 4 indicates urban, industrial or agricultural pollution.

Signal-2 scores were on average higher in riffle habitats than edge habitats, which is somewhat expected given that riffle habitat tends to host a greater number of PET taxa than edge habitat. Edge habitat Signal-2 scores were broadly similar, albeit that data was only recorded for this habitat at three sites. Signal-2 scores ranged from around 6 from Granite Creek (Gr1) to around 4.7 from Deep

Creek (De2). This suggests that site Gr1 riffle habitat hosted the highest ratio of the number of pollution sensitive macroinvertebrate taxa to pollution – tolerant taxa and riffle habitat at site De1 the lowest. The reasons for this are not known, but a Signal-2 score of 4.7 is still relatively high and site De1 had a greater number of taxa than expected, which is not intuitively indicative of a degraded habitat.

The Signal-2 scores across the creek sites (Table 15-8) indicated a relatively healthy habitat with five samples occurring in Quadrant 1 (Figure 15-7). The three Styx River sites occur in Quadrant 2 which may be an indication of estuarine influence (higher salinity) at these sites as well as the impact of sampling type (riffle vs edge). Macroinvertebrate sampling in February 2017 produced substantially poorer results with low abundance and generally few taxa apart from one site on Tooloombah Creek (T02). This may be attributed to several factors. The generally poor and dry conditions causing highly turbid pools in Deep Creek and a lack of flow at the time and hence, lack of instream habitat i.e. there was no riffle habitat to sample at the time. Samples were collected from edge habitat only. The 2017 survey was also carried out at a much reduced survey intensity as only a single sample was collected from each edge site compared to three samples collected in June 2011. No samples were collected from the Styx River.

The Signal-2 scores were all low with the majority (excepting To2) occurring in Quadrant 4 indicating polluted waters. However, given the previous 2011 results and difference in conditions at the time of each survey, this is unlikely to be a fair reflection of instream habitat quality for macroinvertebrates.

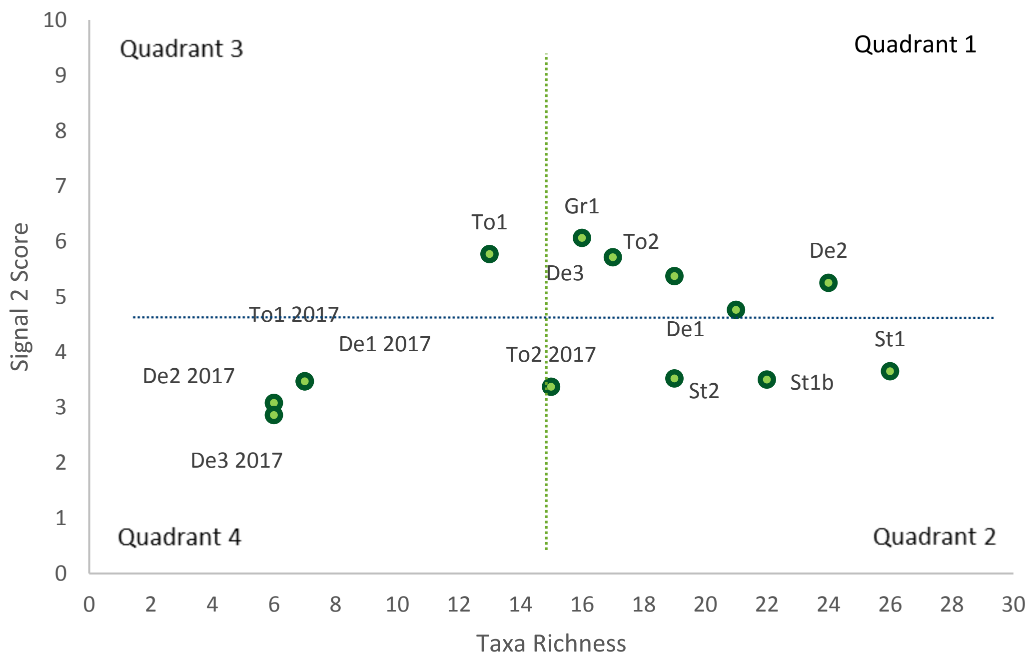


Figure 15-7 Scattergram of signal-2 weighted abundance scores and family richness

Macroinvertebrate habitat condition was measured in terms of the AusRivAS model parameters and associated scores for the 2011 data only. The results are summarised below and presented in further detail in the technical report, as is further multivariate analysis of macroinvertebrate community composition and habitat associations (Appendix A9e – Aquatic Ecology Results).

Under the AusRivAS method the reference condition is defined as 'the condition that is representative of a group of minimally disturbed sites organised by selected physical, chemical and biological characteristics' (Reynoldson et al. 1997). The AusRivAS Model for Coastal Queensland found that nearly all sites had the expected number of macroinvertebrate families expected at a reference riffle site in this area. The only site that failed to have the expected number of macroinvertebrate families was the site To1 which was classified by the model as 'significantly impaired.'

All the edge sites sampled for macroinvertebrates were in similar condition to 'reference condition.' The riffle habitats sampled varied from:

- 'More biologically diverse than reference' (De1, De2, Gr1), meaning taxa richness exceeded the expected number of taxa predicted by the AusRivAS model;
- 'Similar to reference' (De3, To2), where taxa richness is within the range expected at such sites within the model; and
- 'Significantly impaired' (To1), where taxa richness is lower than expected indicating a decline in the health of the river at this location.

These results can be influenced by a range of conditions including the presence of organic pollutants and altered flow patterns, although it could also mean that the AusRivAS model itself requires further calibration, particularly given the macroinvertebrate of the study area has not been subject to much investigation.

Table 15-8 Macroinvertebrate taxa measures for June 2011 and February 2017

Site		De1		De2		De3		St1	St1b	St2	To1		To2		Gr1
Sample		June 2011	Feb 2017	June 2011	Feb 2017	June 2011	Feb 2017	June 2011	June 2011	June 2011	June 2011	Feb 2017	June 2011	Feb 2017	June 2011
Annelida	Oligochaeta	1		2	5	2	2	1						7	
Gastropoda	Bithyniidae								2						
	Corbiculidae							3					1		
	Planorbidae		1				1	1						5	
	Physidae								2						
	Spaeriidae											1			
	Thiaridae							9	12			2	1	1	
Crustacea	Atyidae		6		5		3	4				1		26	
	Palaeomonidae	7		2		2		5	17	9	9		7		1
	Parastacidae	2	1	1										1	
Arachnida	Acari	4		9				1	1	1			2		
Coleoptera	Curculionidae			1											
	Dytiscidae				10		10	4	13	13		4	2	2	
	Elmidae														3
	Gyrinidae			5		6							3		
	Hydrophilidae							1	9	3					
	Hydraenidae	1							1	1					
	Hydrochidae										1				
Hemiptera	Corixidae							7	13	14				4	
	Gerridae			1				1	2	1	1				
	Hydrometridae							1	1						
	Mesovelidae									2					
	Naucoridae							1						1	
	Nepidae							2							
	Notonectidae							11	1	2					
	Pleidae									2					
	Velidae	2		3				1	2	2					
Diptera	Chironominae	13	28	16		8	11	6	1	5	44	53	17	3	1
	Tanypodinae	1	1	4	1			3	1	2					
	Orthocladinae	30	26	31	4	22	7	1	1	1	11	24	24	21	11
	Culicidae								1						

Site		De1		De2		De3		St1	St1b	St2	To1		To2		Gr1
Sample		**June 2011**	**Feb 2017**	**June 2011**	**Feb 2017**	**June 2011**	**Feb 2017**	**June 2011**	**June 2011**	**June 2011**	**June 2011**	**Feb 2017**	**June 2011**	**Feb 2017**	**June 2011**
	Ceratopogonidae				8									6	
	Dolichopodidae	1		6		13							1		
	Simulidae	79		111		57				1	139		113		83
	Tabanidae	1		3		8					1				1
Trichoptera	Leptoceridae	6		8		4		17	9	4			2	1	7
	Ecnomidae													1	
	Hydrobiosidae	3		1		9					5		1		2
	Hydropsychidae	68		85		112				1	92		32		37
	Hydroptilidae			2				1	1		5		3		1
	Calamoceratidae			1											
	Philopotomidae	8		2		6					5		12		77
	Unidentified Trichoptera							1							
Odonata	Gomphidae	1	1			1			2				1	1	1
	Libellulidae	8		7		18		3			10		12		4
	Protoneuridae							2		1					6
Ephemeroptera	Baetidae	20		28		76		2			19		52	3	18
	Caenidae	20		12		8		1	1	1		4	8	1	13
	Leptophlebiidae	8		3		4		3	1						4
Total individuals		284	64	344	33	356	34	93	94	66	342	89	294	84	270
No. of taxa		21	7	24	6	17	6	26	22	19	13	7	19	16	16
Signal 2 score		4.76	3.47	5.25	3.07	5.71	2.85	3.65	3.5	3.52	5.77	3.47	5.37	3.38	6.06
PET richness		7	0	9	0	7	0	5	4	3	5	1	7	4	8

15.6.3.6 Habitat Assessment

Overall, all sampling sites visited in June 2011 as part of the baseline survey were shown to be in a healthy state as evidenced by the generally high water quality results with only marginal exceedances for a few parameters. Cattle access to creeks has the potential to degrade instream habitat conditions through the addition of nutrients from cattle defecation in or close to waterways, increased turbidity through bank erosion and compaction of riffle and edge habitat through trampling, all of which can affect the status of the macroinvertebrate community. In general, the area had very low levels of grazing perhaps due to de-stocking caused by recent drought conditions in the area prior to 2011. Despite this there was evidence of some cattle pugging and droppings in many shallows and riffles, although this did not impact detrimentally on water quality at the time.

Observations from the 2017 survey indicate that substantial cattle access occurs at De2 which likely reflects the poor water quality indicators recorded at this site (refer Table 15-5 and Table 15-6). There was also some evidence of cattle access at To2. The remaining sites appear to be relatively inaccessible for cattle although signs of access by feral pigs was evident at To2 and De4.

Erosion is a major problem in the Styx catchment with many of the soils prone to erosion (Meltzer et al. 2008). The 2011 water quality analyses showed very low levels of both turbidity and suspended solids, although this was likely influenced by the flowing conditions at the time. Riffles in the Deep, Tooloombah, and Granite Creeks also showed no evidence of siltation from erosion; however, pool habitats in the Styx River did show evidence of sand and silt deposition.

Habitat diversity varied throughout the catchment. The main aquatic habitats noted were rocky pools, sandy pools, rocky runs, sandy runs, riffles, large woody debris, and undercut banks. Rocky pools were found at all sites except one site on Deep Creek (De3), while sandy pools were found at all sites except for Tooloombah Creek (To1), and Granite Creek (Gr1). Rocky run habitats were only found at the Tooloombah sites (To1 and To2). Sandy-gravel runs only occurred on the Styx River at site St1. Large woody debris was found at all sites, indicating there has been little if any de-snagging in the catchment.

All sampling sites within the study area scored highly in terms of physical habitat assessment indicating high structural integrity at both a site and catchment level (refer Table 5-4 in Appendix A9e – Aquatic Ecology Results). This outcome was reflected in the biological and water quality indices which indicated a healthy aquatic ecosystem.

The present habitat condition within the Styx catchment is typically composed of cleared land for grazing with a narrow band of riparian vegetation alongside the creeks and rivers. Despite wide spread erosion throughout the catchment the riparian vegetation was in relatively good condition. Riparian vegetation varied with Deep Creek having medium to large sized *Eucalyptus* and *Melaleuca* species and steep banks that were eroding in some parts of the creek. The shrubs were dominated by Weeping Bottlebrush (*M. viminalis*), the exotic Lantana and other native sclerophyllous taxa. Along Tooloombah Creek both of the survey sites riparian vegetation along the steep western / northern bank was dominated by rainforest species in close to pristine condition in strong contrast to the right bank which was eroded badly with patchy riparian tree and shrub cover. The riffles at both Tooloombah Creek sites had dense stands of Weeping Bottlebrush.

The Granite Creek site had excellent riparian cover with riffles well shaded and a wide pool that was shaded in parts by large Eucalyptus and Melaleuca trees. The riparian vegetation was relatively poor along virtually all of the Styx River and condition decreased downstream so that at site St2 the majority of riparian vegetation was of Noogoora Burr (*Xanthium occidentale*). It is likely that tidal impact may reduce tree and shrub cover at the lower Styx River Sites.

Noogoora Burr is an annual pest species that is well established along the left bank of the Styx River around site St2. It produces burrs which can tangle in animal coats and produces seeds that are poisonous to stock. Its impact on the riparian vegetation is relatively minor and of nuisance value except to farmers. The main ecological pest weed recorded is Rubber Vine which is a serious threat to rainforest and in particularly dry-land rainforests. This exotic vine from Madagascar was found along parts of Deep Creek, Tooloombah Creek and the Styx River, as well as the un-named tributary that intersects the northern section of the Project area.

Wetlands

The Project area encompasses a range of natural and artificial wetlands including an ephemeral wetland mapped as HEV and a WPA (refer Figure 15-6). This wetland encomapasses approximately 4 ha and was inspected during the February 2017 survey being completely dry at the time. Following heavy rains in late April 2017 the wetland had filled up (Plate 15-1). Cattle were present using the wetland area on both occasions. This community is characterised by a central patch (approximately 2 ha) of Broad-leaved Paperbark surrounded by an open area (subject to inundation). The wetland vegetation is described in Section 15.6.3.2. The wetland is surrounded by intact woodland.

Although the more permanent wetlands, such as farm dams (Plate 15-7) are likely to provide habitat for freshwater turtles and amphibians, it is uncertain to what extent these habitats support strictly aquatic fauna (i.e fish). These habitats are described in more detail in Chapter 14 – Terrestrial Ecology.

Plate 15-7: Artificial (dammed) wetland area within MLs (February 2017)

15.6.4 Groundwater Dependent Ecosystems

15.6.4.1 Overview

Whilst regional groundwater systems provide water sources for pastoral and other anthropogenic uses, groundwater also supports surface (above ground) and subsurface (below ground) ecosystems that are assessed as beneficial users of groundwater. The Australian GDE toolbox (Richardson et al. 2011) provides a framework to assist with the identification of GDEs and the management of their water requirements. The toolbox adopts the approach of Eamus et al. (2006) and classifies GDEs based on the role groundwater plays in maintaining biodiversity and ecological condition.

Three types of GDEs are defined by the GDE toolbox:

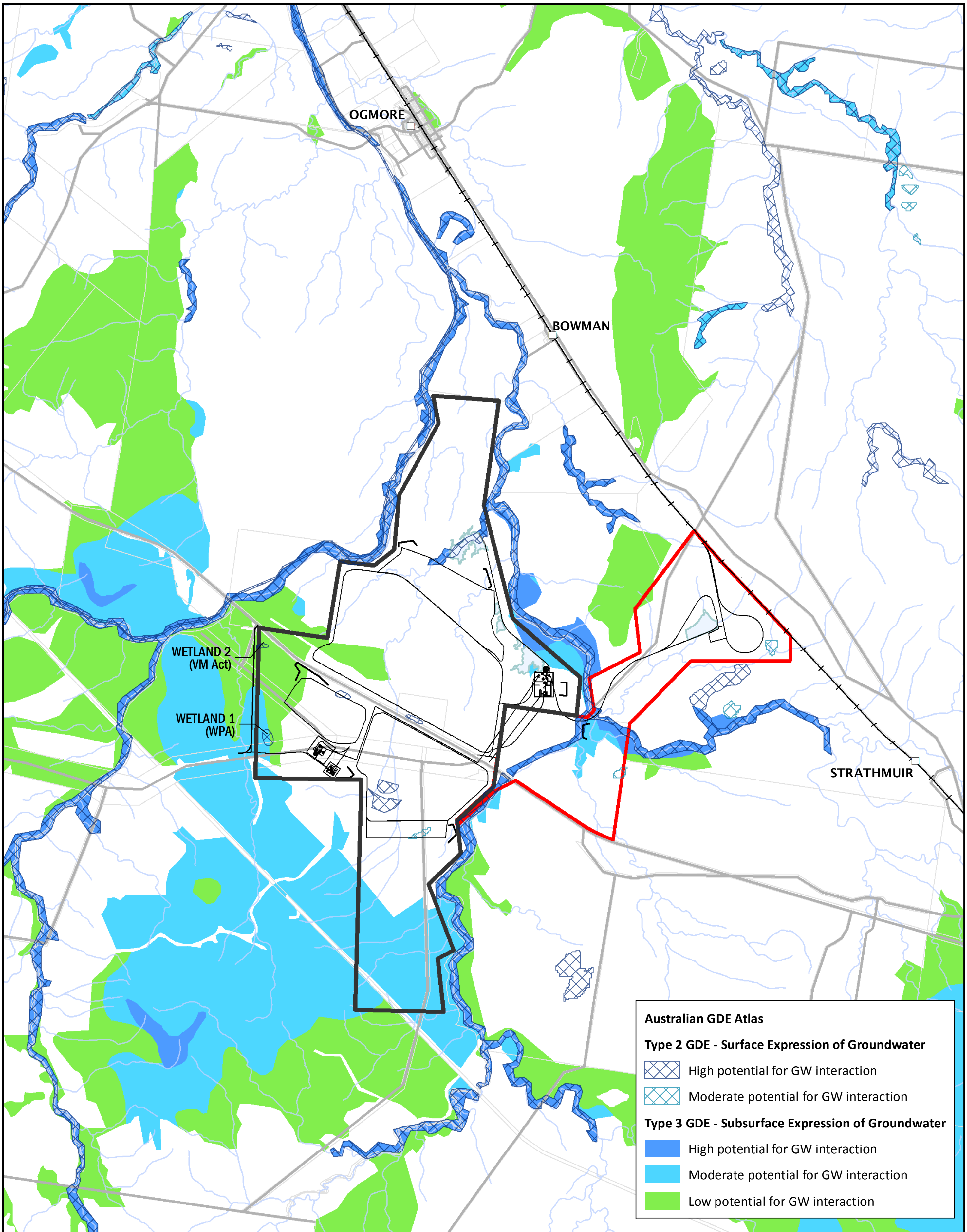
- Subterranean ecosystems dependent on water held in aquifers (e.g. stygofauna) or inundated caves (Type 1 GDEs). These ecosystems typically include karst aquifer systems and fractured rock groundwater environments;
- Ecosystems dependent on the surface expression of groundwater (Type 2 GDEs), including wetlands, lakes, seeps, springs, and river baseflow systems. In these cases, surface expression of groundwater exists, providing water that can support aquatic biodiversity through access to habitat (especially when surface run-off is low or non-existent) and regulation of water chemistry and temperature; and
- Ecosystems dependent on subsurface presence of groundwater (Type 3 GDEs), including terrestrial and riparian vegetation that depends on groundwater either seasonally, episodically or permanently to prevent water stress and avoid adverse impacts to their condition. Groundwater that Type 3 GDEs depend on is not visible from the surface. Type 3 GDEs can exist wherever the water table and capillary fringe is within the root zone of the plants, either permanently or episodically. The capillary fringe is the semi-saturated zone of soil above the water table.

There are two sources of information pertaining to the presence of GDEs:

- Queensland Wetland GDE layer provides information regarding Type 2 and 3 GDEs and presents the current knowledge of ecosystems likely to have some degree of reliance on groundwater across Queensland; and
- The National Atlas of GDEs (GDE Atlas) presents the current knowledge of ecosystems that may depend on groundwater across Australia. At the beginning of 2017, the GDE Atlas was updated with the latest information pertaining to GDEs from the Queensland Wetland GDE Layer, and therefore the GDE Atlas can be considered as the primary data source for this assessment.

Information pertaining to GDEs is sourced from surveys for stygofauna undertaken for the Project in 2011 and 2012 (Yeats Consulting 2012) and targeted GDE investigations in 2018. The results are covered in the following sections.

The methods undertaken to assess the GDEs and the results are summarised in the following sections. Further detail is provided in Chapter 10 – Groundwater and Appendix A6 – Groundwater Technical Report.



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0 0.5 1 km

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Date: 21/11/18
Drawn: Gayle B.

Legend

- ML 80187
- ML 700022
- Mine infrastructure
- Cadastral boundary
- Main Road
- North Coast Rail Line
- Watercourse
- Dam

Figure 15-8
Groundwater dependent ecosystems – Australian GDE atlas mapping

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018
GDE Atlas, BoM, 2018

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 15_Supp_Report_Aquatic Ecology\1000111 GDEs__15-8.mxd 11/21/2018

15.6.4.2 Targeted GDE Investigations in 2018

Targeted investigations were undertaken in August 2018 to better understand vegetation water use at three sites where groundwater use by vegetation was considered likely (see Figure 15-9).

The Wetland 1 Assessment Area is listed under the VM Act as having High Ecological Value and is also listed as a Wetland Protection Area. It is identified in the BoM GDE Atlas as an artificial/highly modified wetland reliant on surface expression of groundwater. It consists of a clay plan, inhabited predominantly by Broad Leaf Tea Tree (*Melaleuca viridiflora*). A single Forest Red Gum (*Eucalyptus tereticornis*) is located in the centre of the wetland. Soils are heavy clays to a depth of 1.5 m.

The Wetland 2 Assessment Area is also listed under the VM Act as having High Ecological Value and is identified in the BoM GDE Atlas as a coastal / sub-coastal floodplain swamp reliant on surface expression of groundwater. It comprises an internally draining swamp that inhabited by sedges and fringed by larger red gums.

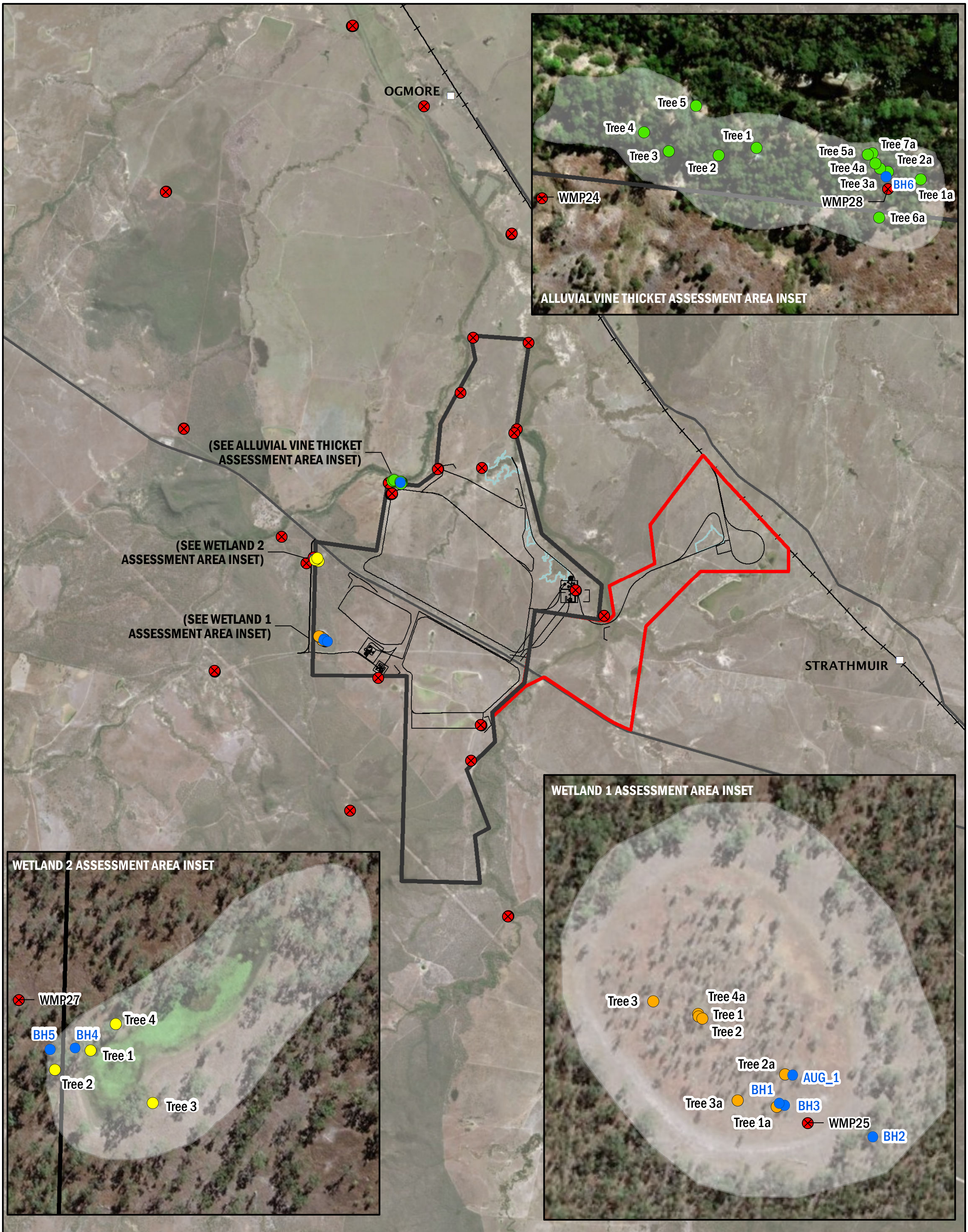
The Alluvial Vine Thicket Assessment Area is located on the southern alluvial terraces of Tooloombah Creek and consists of a community of low canopy (7–10 m) trees comprising a variety of species with occasional emergent red gums. A varied understory with abundant vines is present. Soils are relatively sandy.

Methodology

Theory

Several tests can be used to evaluate the dependence of vegetation on groundwater (Eamus et al. 2006). Each test is subject to limitations, but a combination can be used to provide a robust assessment in which multiple lines of evidence are examined. The following tests have been selected for this GDE investigation:

- <u>Stable isotopes of water</u>: Stable isotopes are those that do not radioactively decay over time. The stable isotopes of water are those derived from hydrogen (deuterium; ^{2}H) and oxygen ($^{18}0$). The ratio of ^{2}H to ^{1}H and the ratio of ^{18}O to ^{16}O varies for different bodies of water due to isotopic fractionation caused by transport processes and phase transitions through the atmosphere, lithosphere and biosphere (Barnes and Alison 1988). Since the fractionation processes are likely to be different for groundwater, surface water and soil water, different sources of plant water will often, but not always, have different isotopic compositions that will be reflected in the plant xylem water. Knowing the isotopic composition of these sources and plant water can assist in conceptualising plant water uptake.



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Legend

- Wetland 1 sampling location
- Wetland 2 sampling location
- Alluvial Vine Thicket sampling location
- Bore location
- Project monitoring bore
- GDE Assessment Areas
- Dam
- ML 80187
- ML 700022
- Mine infrastructure
- Main Road
- North Coast Rail Line

Figure 15-9
GDE assessment sites

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD B:\1000111_Styx_SEIS_post-submission\GIS\DATA\MXD\TEMP\1000111 GDE_working.mxd 11/8/2018

- Soil-plant water relations: Plants require water for photosynthesis. Transpiration is the process of plant water use in which plants take up water through their roots, passively transport this water through the xylem, and regulate the diffusive evaporation of this water through the stomata in their leaves. The rate of transpiration is controlled by solar radiation, the evaporative demand of the atmosphere (which is influenced by temperature, humidity, wind speed and incident sunlight), soil water supply, and stomatal regulation. For plants to transpire they must maintain a LWP that is more negative than the soil water potential (SWP). A dry soil will have a highly negative SWP and a plant must be able to regulate their stomatal conductance and lower their LWP to be more negative than the SWP to extract water. By contrast, a moist soil or one that is maintained in moist state by shallow groundwater will not require plants to lower their LWP excessively to extract water. Thus, measuring LWP and SWP concurrently provides an indication of where in the soil profile plants are drawing their water from and it also provides an indication as to whether plants have access to groundwater (at the water table, SWP approaches zero). Measurements of LWP are usually made pre-dawn when the difference between LWP and SWP is likely to be smallest because nocturnal transpiration is minimal (Ritchie and Hinckley 1975).

Drilling, Sampling and Analysis

Six boreholes were drilled as shown in Figure 15-9. BH1, BH2 and BH3 were drilled at Wetland 1. BH4 and BH5 were drilled at Wetland 2. BH6 was drilled at the Alluvial Vine Thicket site.

Drilling was undertaken using a combination of direct push, and RC drilling methods. Direct push tubes were taken until refusal, with extended drilling undertaken using an RC rig. Care was taken to avoid the use of RC drilling and use of drilling fluids where possible—which compromise soil moisture and soil water isotope analysis—but in a few cases this could not be avoided, and drilling continued with the use of applied water to the base of the borehole. It is also noted that the use of air likely influenced the moisture content of the samples returned. Drilling logs are provided in Appendix A6 - Groundwater Technical Report, Attachment 1 and a summary of the drilling undertaken is outlined in Table 15-9.

Table 15-9 Summary details of GDE investigation bore holes

GDE assessment area	Hole ID	Drilling method	Refusal (mbgl)	Total depth	Comments
Wetland 1	BH1	Direct push	1.4	5.0	Drilled in rotary mode from 1.4 to 5 m with applied water
	BH2	Direct push	0.35	5.0	Drilled in rotary mode from 0.35 to 5 m with applied water and not sampled
	BH3	RC		15	Water cut at 13.5 m
Wetland 2	BH4	Direct push	4.2	4.2	Push tube to 4.2 m
	BH5	Direct push/RC	4.2	14.5	RC from 4.2 to 14.5 mbgl, dry to total depth
Alluvial vine thicket	BH6	Direct push/RC		9.85	

Samples were taken in metre increments or at a finer scale. For isotope analysis, samples were immediately sealed in an air-tight sample bag, kept on ice and transported to a freezer before dispatch to the ANU Stable Isotope Laboratory where they were analysed. Soil moisture potential was measured in the field on sub-samples using a WP4C dew-point potentiometer from push tube or from RC cuttings.

Vegetation Sampling and Analysis

Pre-dawn LWP measurements were made using a pressure chamber device. Measurements were taken on leaves collected from several trees in close proximity to the boreholes at each site. Stem samples were also taken from the outer branches of trees for isotope analysis. As per sampling protocols, they were cut into 5 cm lengths, stripped of bark, stored in leak-proof containers, kept on ice and transported to a freezer for dispatch to the ANU Stable Isotope Laboratory where they were analysed.

Well Installation and Groundwater Sampling

Groundwater wells were installed in September 2018 to monitor the water table at Wetland 1 (WMP25) and Wetland 2 (WMP27). These wells will form part of the monitoring network and can be sampled for isotope analysis if necessary.

15.6.4.3 Results

Wetland 1

Drilling logs for the boreholes completed at Wetland 1 (BH1, BH2 and BH3) are shown in Attachment 1 of Appendix A6 – Groundwater Technical Report. The lithology consists of heavy clay at the surface associated with the clay plan, which is underlain by calcrete bands and layers of sandstone and clay. A moist zone was encountered from 8 mbgl (alluvials and calcrete) and the water table at 10.2 mbgl.

Soil and LWP at Wetland 1 are presented on Figure 15-10. Much of the soil profile is very dry and well below the agronomic wilting point of -1.5 MPa, noting that native tree species can often tolerate soil moisture potentials well below this level. Root water uptake is indicated where the LWPs are equivalent to or less than the soil water potential. For two of the trees measured, Tree 1 (Broad Leaf Tea Tree) and Tree 4a (forest Red Gum) root water uptake was indicated from depths of 0.5 to 1.0 m. For the remaining trees, several Broad Leaf Tea Tree and one forest Red Gum specimen, root water uptake was indicated at 8 m where the soil water reservoir appears to be more moist than higher up, possibly linked to the capillary fringe above the water table or to a 'perching' layer in the soil profile at around 8 m depth. The soil samples below the water table do not reflect saturated conditions and may have been influenced by the drilling method which required compressed air to retrieve the samples.

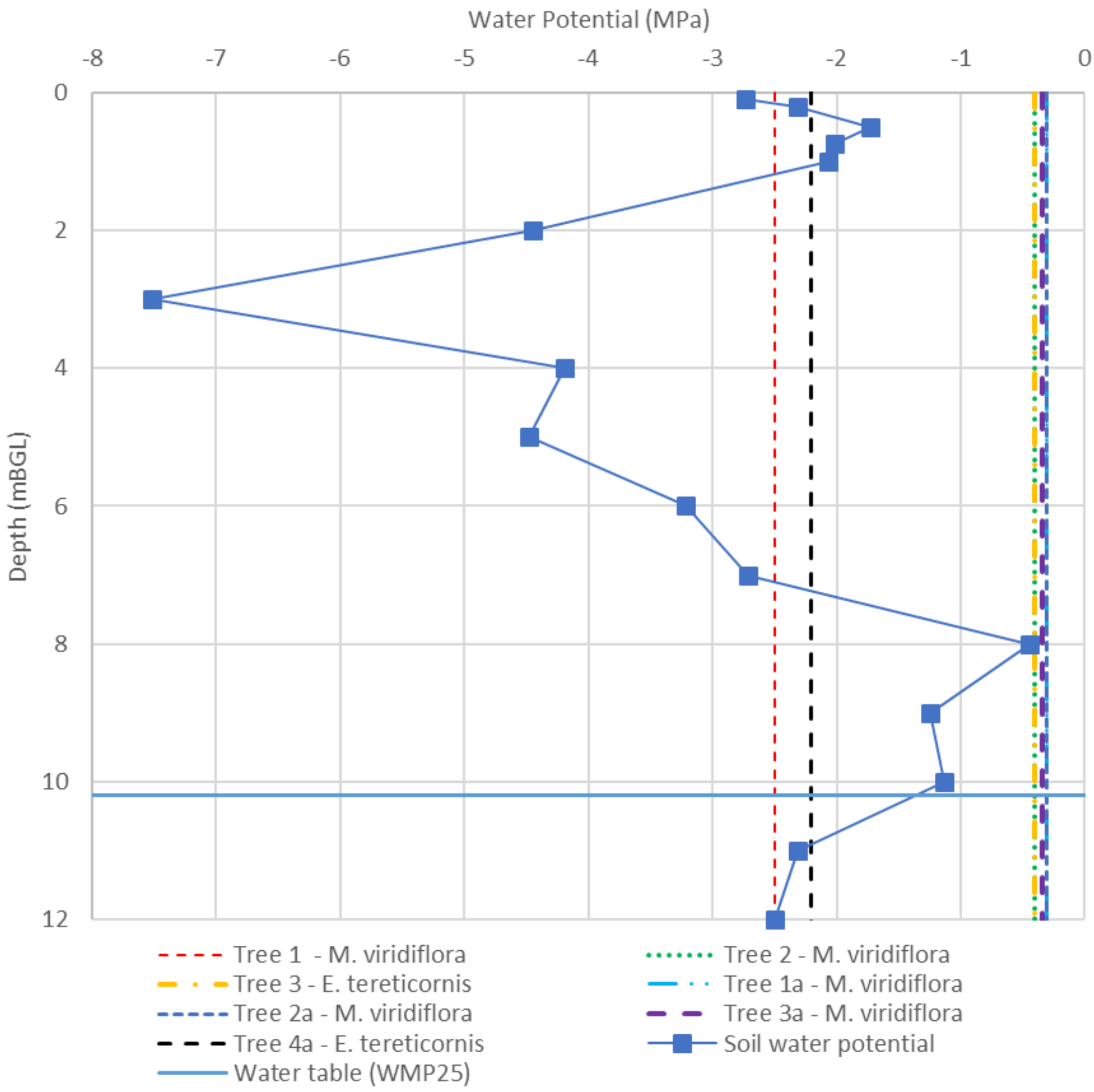


Figure 15-10 Soil and leaf water potentials with depth, Wetland 1

The stable isotopes of water in soil water and vegetation are plotted with respect to depth in Figure 15-11. The shallowest soil sample at 0.1 m is enriched in heavy isotopes due to the fractionation that occurs during evaporation whereby the lighter, standard water molecules (composed of ^{1}H and ^{16}O) are preferentially converted from the liquid to the vapour phase, compared to heavier water molecules composed on ^{2}H and ^{18}O. The isotopic enrichment is mostly confined to the upper few metres of the soil profile.

Groundwater is yet to be sampled directly for isotopic characterisation but the slight enrichment in the deeper samples, below 8 m, may reflect the influence of a groundwater signature.

Figure 15-12 presents a scatter plot of $\delta^{18}O$ against $\delta^{2}H$. The Global Meteoric Water Line (GMWL) is presented as an approximate reference for rainfall, noting there may be local deviations from this relationship due to local meteorological processes. The relative enrichment of the ^{18}O molecule reflects an evaporation trend[1] which is interpreted on Figure 15-12 . The vegetation at Wetland 1 has xylem water that plots along this trendline, indicating the xylem water has been sourced primarily from the upper 2 m of the soil profile.

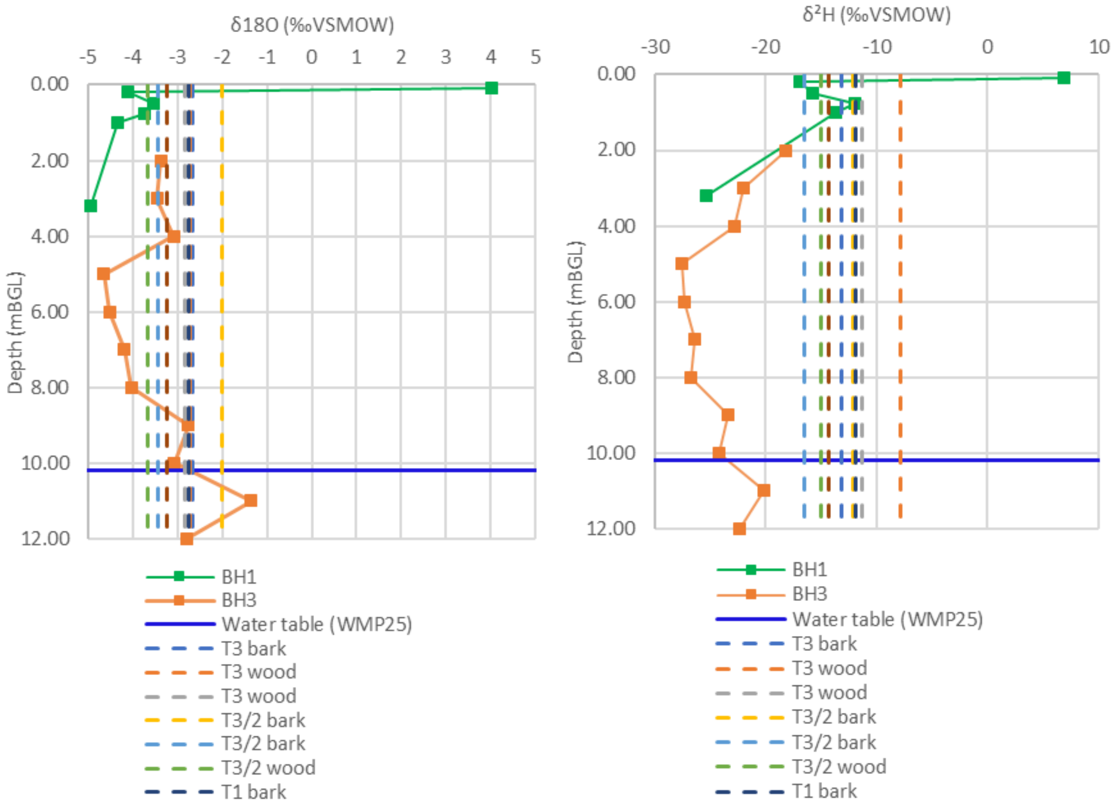


Figure 15-11 Stable isotopes of water in vegetation samples and in soil water with depth, Wetland 1

[1] Because oxygen has a higher atomic weight than hydrogen, the $^{1}H_2{}^{18}O$ molecule is less likely to change from the liquid to the vapour phase than the $^{1}H^{2}H^{16}O$ molecule. For this reason, the relationship between $\delta^{18}O$ and $\delta^{2}H$ will deviate from the GMWL during evaporation.

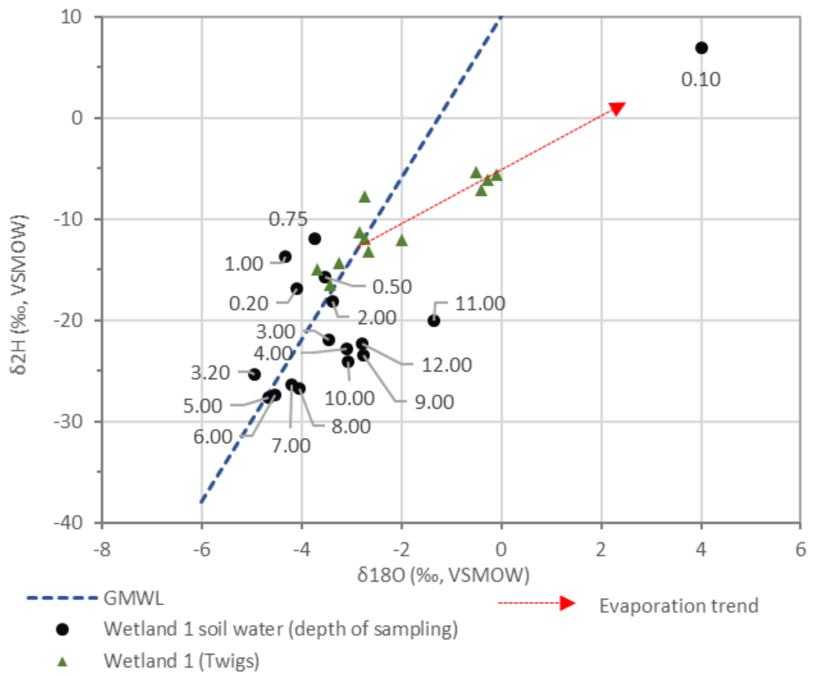


Figure 15-12 Stable isotopes of water in soil and vegetation samples, Wetland 1 (GMWL: Global Meteoric Water Line)

Together, the water potential measurements and the isotope data indicate vegetation at Wetland 1 is sourcing most of its water from the near surface, and maintenance of the surface hydrological regime (run-off and inundation) of the wetland is important for maintaining the wetland's environmental water requirements. However, the trees may access deep soil water that is maintained by groundwater to support transpiration requirements during sustained dry periods when the soil water reservoir is otherwise depleted.

Wetland 2

Drilling logs for the boreholes and well completed at Wetland 2 (BH4, BH5 and WMP27) are shown in Attachment 1 of Appendix A6 – Groundwater Technical Report. The lithology consists of clay at the surface underlain by layers of sand and clay, with sandstone from 15 mBGL. The water table is at about 20 mBGL.

Soil and LWPs at Wetland 2 are presented in Figure 15-13 . Much of the soil profile is very dry and well below the agronomic wilting point of -1.5 MPa, noting that native tree species can often tolerate soil moisture potentials well below this level. Root water uptake is indicated where the LWPs are equivalent to or less than the soil water potential and the results point to root uptake from depths of 2 to 4 m at the time of sampling. There is no indication of groundwater use at this site.

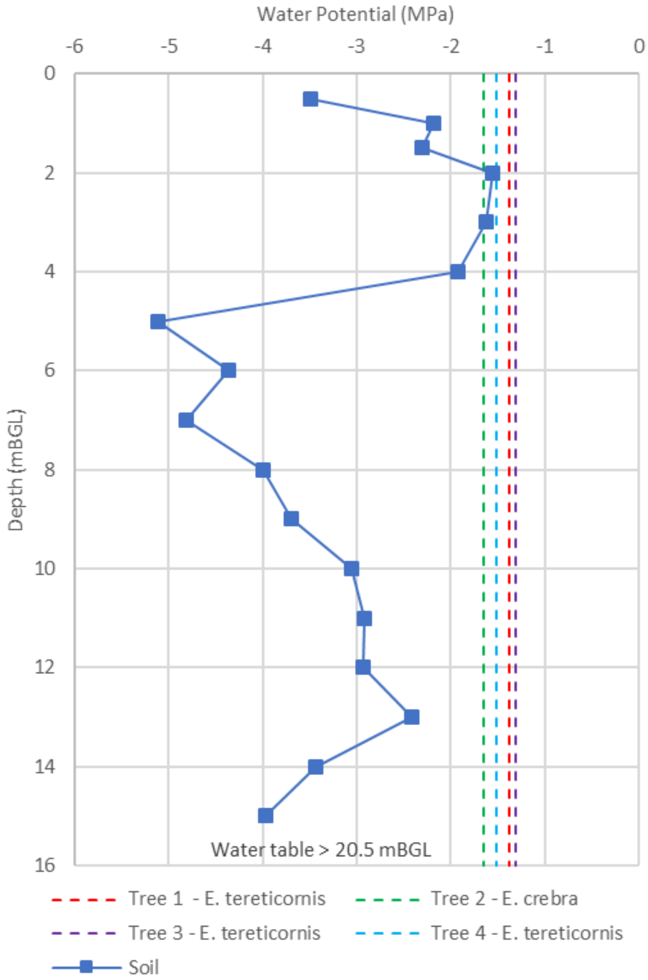


Figure 15-13 Soil and leaf water potentials with depth, Wetland 2

The stable isotopes of water in soil water and vegetation are plotted with respect to depth in Figure 15-14. Samples very near to the surface (e.g. at 0.1 m depth) were not analysed at Wetland 2 so an evaporative zone is not indicated. There is also a clear distinction between the samples taken at BH4 and BH5. This could be due to spatial variability, differences in sampling methods (push-tube vs RC drilling) or a combination of both.

Figure 15-15 presents a scatter plot of $\delta^{18}O$ against $\delta^{2}H$. The vegetation at Wetland 2 has Xylem water which is enriched in ^{18}O relative to the GMWL and is consistent with the majority of soil water samples at BH5. This is indicative of root water uptake throughout the soil profile. No groundwater use is indicated at Wetland 2 from either the water potential measurements or the isotope data.

No groundwater use is indicated at Wetland 2 from either the water potential measurements or the isotope data. The assessment presented indicates that maintenance of the surface hydrological regime (run-off and wetland inundation) as being important for maintenance of Wetland 2 environmental water requirements.

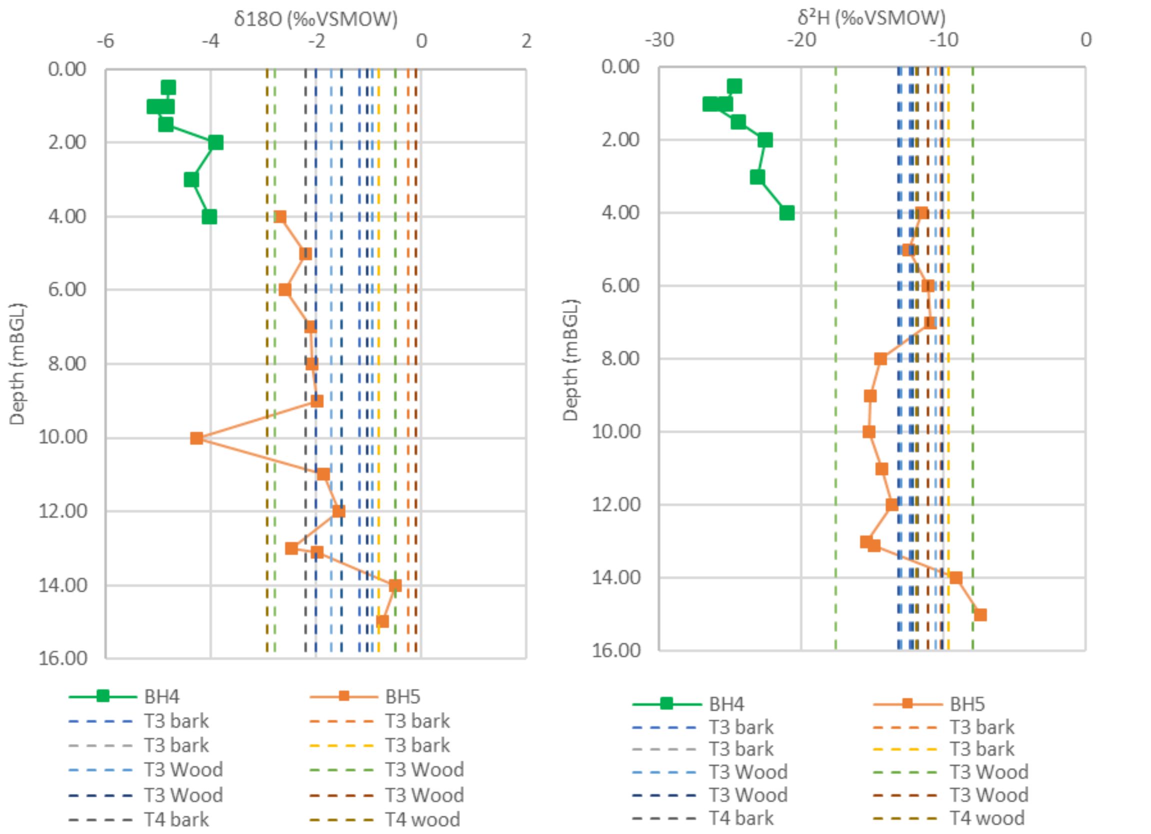


Figure 15-14 Stable isotopes of water in vegetation samples and in soil water with depth, Wetland 2

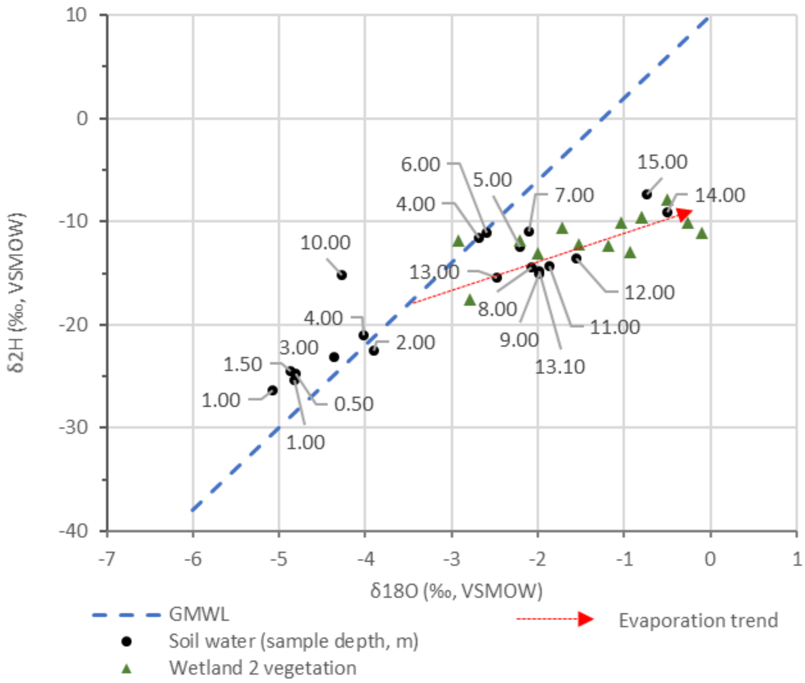


Figure 15-15 Stable isotopes of water in soil and vegetation samples, Wetland 2 (GMWL: Global Meteoric Water Line)

Vine Thicket

The drilling log for the borehole completed at the Vine Thicket (BH6) is shown in Attachment 1 of Appendix A6 – Groundwater Technical Report. The lithology consists of mostly sandy sediments to a depth of 8.5 m, where weathered sandstone is encountered. The water table was not encountered during drilling; thus, it is at least 10 mBGL.

Soil and LWPs at the Vine Thicket are shown in Figure 15-16 . Much of the soil profile is very dry and well below the agronomic wilting point of -1.5 MPa, noting that native tree species can often tolerate soil moisture potentials well below this level. Root water uptake is indicated where the LWPs are equivalent to or less than the soil water potential and the results point to root uptake from depths of 2 m to 3 m at the time of sampling. There is no indication of groundwater use.

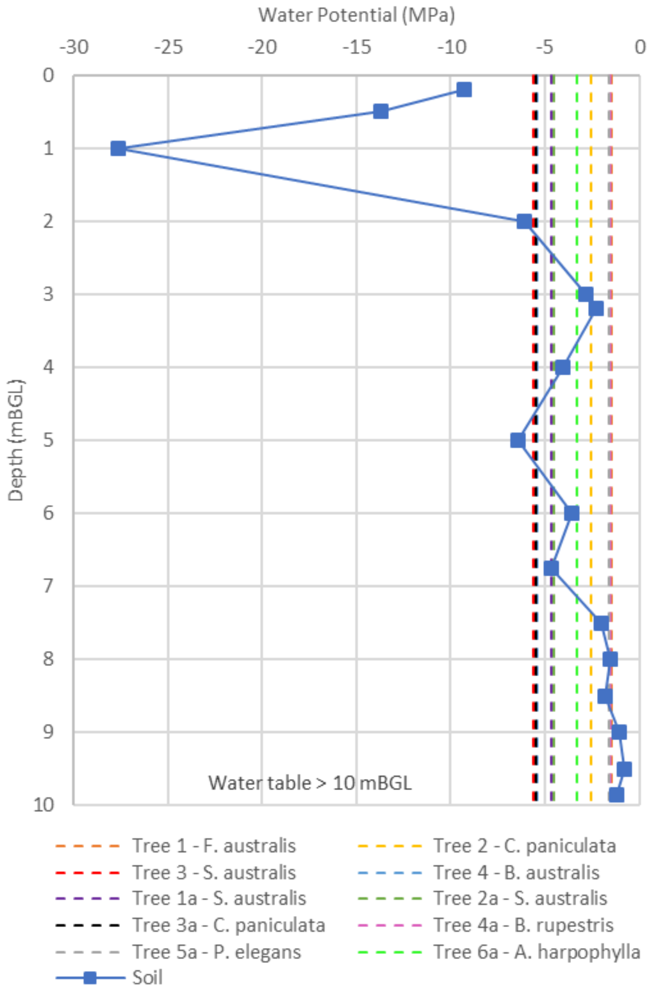
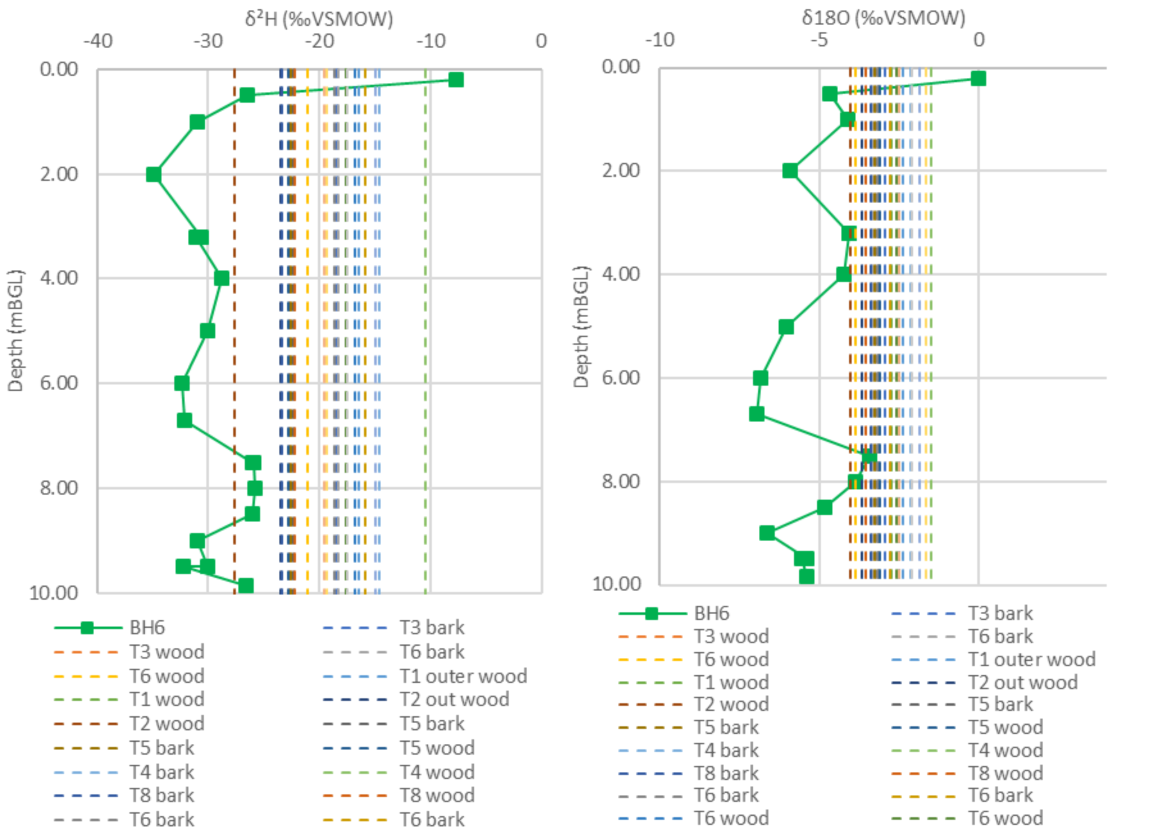


Figure 15-16 Soil and leaf water potentials with depth - Vine Thicket vegetation

The stable isotopes of water in soil water and vegetation are plotted with respect to depth in Figure 15-17. The shallowest soil sample at 0.2 m is enriched in heavy isotopes due to the fractionation that occurs during evaporation whereby the lighter, standard water molecules (composed of ^{1}H and ^{16}O) are preferentially converted from the liquid to the vapour phase, compared to heavier water molecules composed on ^{2}H and ^{18}O. The isotopic enrichment is mostly confined to this near-surface zone.



(see Figure 6-8 of Appendix A6 – Groundwater Technical Report for vegetation sample legend)

Figure 15-17 Stable isotopes of water in vegetation samples and in soil water with depth at the Vine Thicket

Figure 15-18 presents a scatter plot of $\delta^{18}O$ against $\delta^{2}H$. The relative enrichment of the ^{18}O molecule reflects an evaporation trend which is interpreted on Figure 15-18. The vegetation at the Vine Thicket has xylem water which plots along this trendline, indicating the xylem water has been sourced primarily from the top 0.5 m of the soil profile.

There is no indication of groundwater use by the Vine Thicket vegetation. The assessment presented indicates that maintenance of the surface hydrological regime (stream flows and run-off) as being important for maintenance of Vine Thicket environmental water requirements.

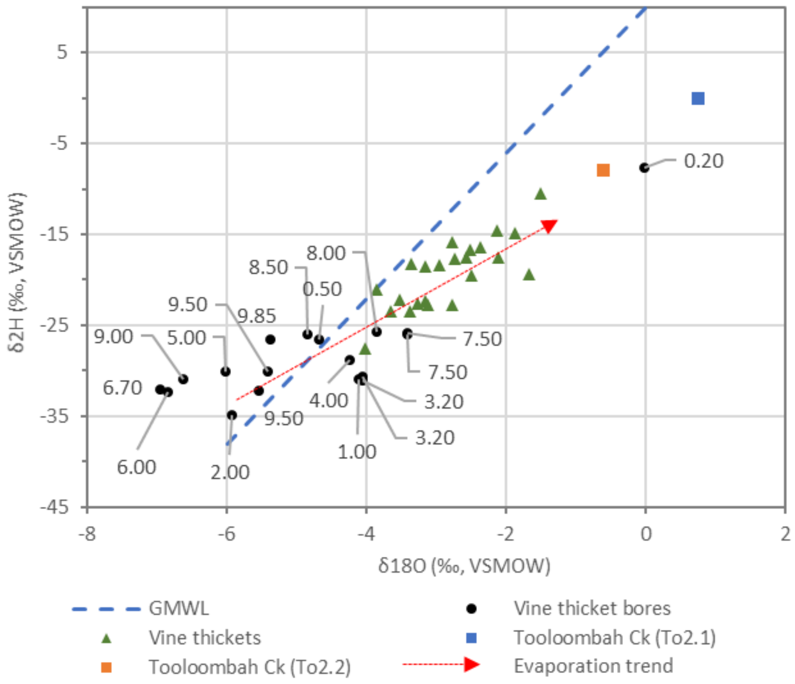


Figure 15-18 Stable isotopes of water in soil and vegetation samples, Vine Thicket (GMWL: Global Meteoric Water Line)

15.6.4.4 GDEs – Mine Area – General Discussion

GDEs Reliant on the Surface Expression of Groundwater (Type 2)

Wetland 1 and Wetland 2 are formed in shallow depressions of less than around 1 m depth that become inundated after large rainfall runoff events, as evidenced during two field surveys in early-2017 (see Plate 15-1 and Plate 15-2), which likely serve to maintain the soil water reservoir at these locations. Nevertheless, there is some evidence from stable isotope sampling that the tall woody vegetation (*Melaleuca* species and Forest Red Gum) occurring within Wetland 1 potentially accesses groundwater at times. Future monitoring work is expected to elucidate this relationship.

Field investigations have identified the presence of surface pools along the ephemeral watercourses (Tooloombah and Deep Creeks) some of which have persisted through dry periods (refer Table 15-1 for details). The observations indicate a potential seasonal reliance of surface expression of groundwater, which is supported by available data (refer Section 10.5.6.7 of Chapter 10 – Groundwater for more detail), including:

- Groundwater elevation contours and flow lines which show relatively steep horizontal hydraulic gradients and local groundwater flow along the length of Tooloombah Creek, the down-catchment reach of Deep Creek near the confluence with Tooloombah Creek, and along Styx River;
- Water table mapping, which shows depth to water table along riparian zones is typically between 10 and 15 mbgl. The streambeds (which are deeply incised into the landscape to depths of up to around 10 m) are likely to intersect the water table in places and at different times, e.g. in response to water table fluctuations due to recharge;
- Measured water levels at paired groundwater monitoring bores which indicate upward vertical hydraulic gradients likely exist in the dry season, possibly supporting groundwater discharge to the surface and preventing drainage of pools;

- Water chemistry data, which shows similarities between surface waters and nearby groundwaters, indicating that watercourse pools are likely to be sustained, at least partly, by groundwater;
- Analysis of surface water samples for radon isotopes (refer Section 15.6.7.3 for method) reported concentrations of 222Rn in Tooloombah Creek pools that are indicative of groundwater discharge. Pools sampled in Deep Creek indicated a much lower connectivity during the time of sampling (July 2018 during very dry conditions) although groundwater discharge is still evident. Plots of 222Rn against chloride concentrations and bicarbonate / chloride ratios indicated the following:
  - Groundwater contributes only a limited amount of water to Deep Creek while Tooloombah Creek possibly receives a comparatively higher amount of groundwater inflow; and
  - Groundwater baseflow to some extent contributed to water sampled from pools in both creeks at the time of sampling. The isotope analysis indicates that, overall, both creeks are connected to groundwater to some extent and undergo evaporation
- Observations of thick stands of potentially groundwater dependent vegetation along riparian zones and algae and aquatic vegetation in areas where pools are permanent, indicating permanence of water that is likely supported by a shallow water table; and
- Observed watercourse pools are broadly consistent with the mapped Type 2 GDEs along riparian zones.

The nature of surface water – groundwater interactions supporting Type 2 GDEs in the area have been classified based on the two typical stream reach types that can be inferred from the available data. These stream reach types are described by the temporal nature of connection and flow dynamics, as outlined in Table 15-10 and depicted in Figure 15-19. Both stream reach types are interpreted to have a period of losing conditions during high flows but differ according to their connection to groundwater during low / no flow periods.

Table 15-10 Classification of Type 2 GDEs by stream reach type

Temporal nature of GDE	Flow dynamics
Stream flow critically important for meeting environmental water requirements of ecosystem	Streamflow recharges bank storage and adjacent water table aquifer (i.e. losing conditions)
	Groundwater baseflow (discharge) to stream from shallow water table and / or bank storage return (i.e. gaining conditions), baseflow may or may not persist between rainfall runoff generated stream flow events
Groundwater baseflow likely to be critically important for meeting environmental water requirements	Streamflow recharges bank storage (i.e. losing conditions)
	Groundwater baseflow (discharge) to stream from shallow water table and / or bank storage return (i.e. gaining conditions), baseflow persists between rainfall runoff generated stream flow events
	Groundwater discharge can occur during ebb from and flow to high tide, when the hydraulic gradient is towards the stream (i.e. gaining conditions)

Figure 15-20 presents those areas mapped as potential GDEs based on available Project-specific data (i.e. they have been ground-truthed). The presence of Type 2 GDEs is confined to the riparian environments, but not to the identified wetlands (1 and 2). Type 2 GDEs are likely to have year-round access to groundwater in the lower catchment (i.e. Styx River and lower reach of Deep Creek, near the confluence) and along the mid- to lower-reach of Tooloombah Creek (at least from the confluence up to the Bruce Highway). Elsewhere (e.g. middle and upper reaches of Deep Creek), Type 2 GDEs, if present, are likely to only be seasonally connected to groundwater. The dominant source of groundwater supporting Type 2 GDEs in the area is likely to be discharge from the shallow alluvial aquifer, whilst bank storage return after streamflow events will contribute some water back to the watercourses.

GDEs Reliant on the Sub Surface Expression of Groundwater (Type 3)

The GDE Atlas identifies potential GDEs that are highly likely to be reliant on the subsurface expression of groundwater (Type 3 GDEs) along the drainage lines (i.e. waterholes, riparian zones and adjacent floodplain vegetation in some areas) associated with Styx River, Deep Creek and Tooloombah Creek. Areas of low to moderate potential Type 3 GDEs occur on the southwest and southeast margins of the Project area (Figure 15-20). At least four of the vegetation communities mapped in these areas during field surveys have the potential for incorporating some component of groundwater in their water requirements. These include:

- Forest Red Gum woodland fringing drainage lines (RE 11.3.25) - Occur along riparian areas of drainage lines. Vegetation is dominated by Forest Red Gum and Weeping Tea Tree;
- Forest Red Gum woodland on alluvial plains (RE 11.3.4) - Occurs in patches to the east of ML 80178 where it is associated with the alluvial plains adjacent to Deep Creek. Vegetation is dominated by Forest Red Gum, Poplar Gum (*E. platyphylla*) with Carbeen (*Corymbia tessellaris*);
- *Melaleuca viridiflora* woodland on alluvial plains (RE 11.3.12) - This is an isolated community occurring on a natural depression on the western side of the Project area (i.e. Wetland 1). The wetland is characterised by a centralised patch of Broad-leaved Paperbark with a variety of low sedges and forbs on the margin, and hydrophytes in the centre when surface water is present; and
- Areas of Semi-evergreen Vine Thicket (SEVT) (RE 11.13.11) along Tooloombah Creek and the downstream portion of Deep Creek.

In riparian areas, the depth to water varies from around 10 m along floodplain terraces, to being very shallow in areas adjacent to the watercourses themselves. Vegetation communities in areas of shallow water table are likely to use groundwater during dry periods when the soil water reservoir becomes depleted (i.e. seasonally), but groundwater use is expected to be less where the water table is deeper.

To summarise:

- The results indicate no groundwater use by the riparian SEVT vegetation, with sampled vegetation accessing the soil water reservoir at depths well above the water table measured in this area;
- During dry periods, although the results of the study are inconclusive, there is some potential for groundwater to support the tall woody vegetation occurring on palustrine Wetland 1, Forest Red Gum woodland fringing drainage lines (RE 11.3.25), and Forest Red Gum woodland on alluvial plains (RE 11.3.4), where water tables are less than 10 mbgl; and
- There is no indication Wetland 2 and other terrestrial areas are reliant on groundwater, particularly where depths to water table are more than 10 mbgl.

In all instances, the results of the GDE assessment indicates that maintenance of the surface hydrological regime (stream flows and run-off to wetlands) will be critically important for maintenance of environmental water requirements for all identified GDEs.

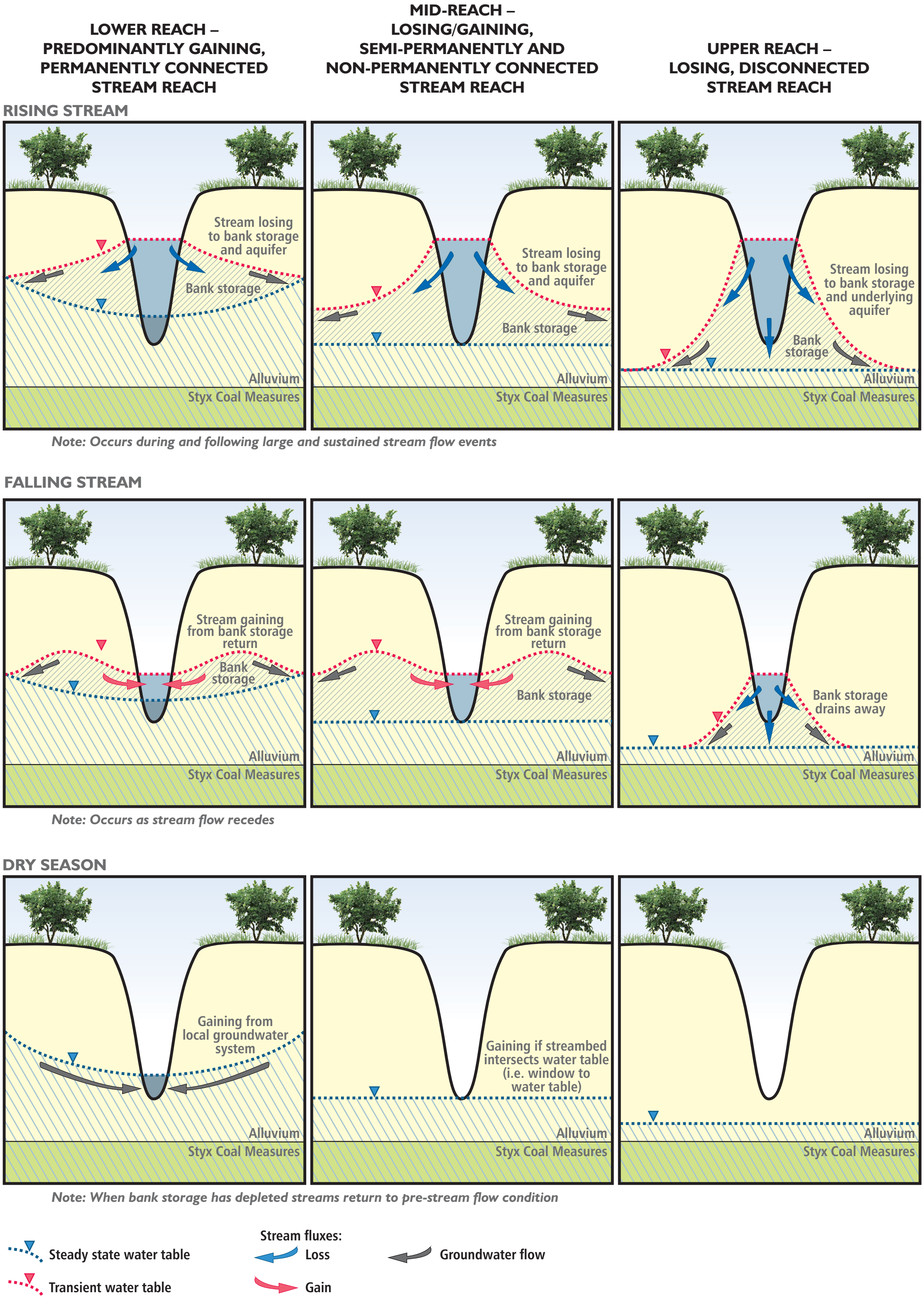


Figure 15-19

Mechanisms of surface water – groundwater interactions

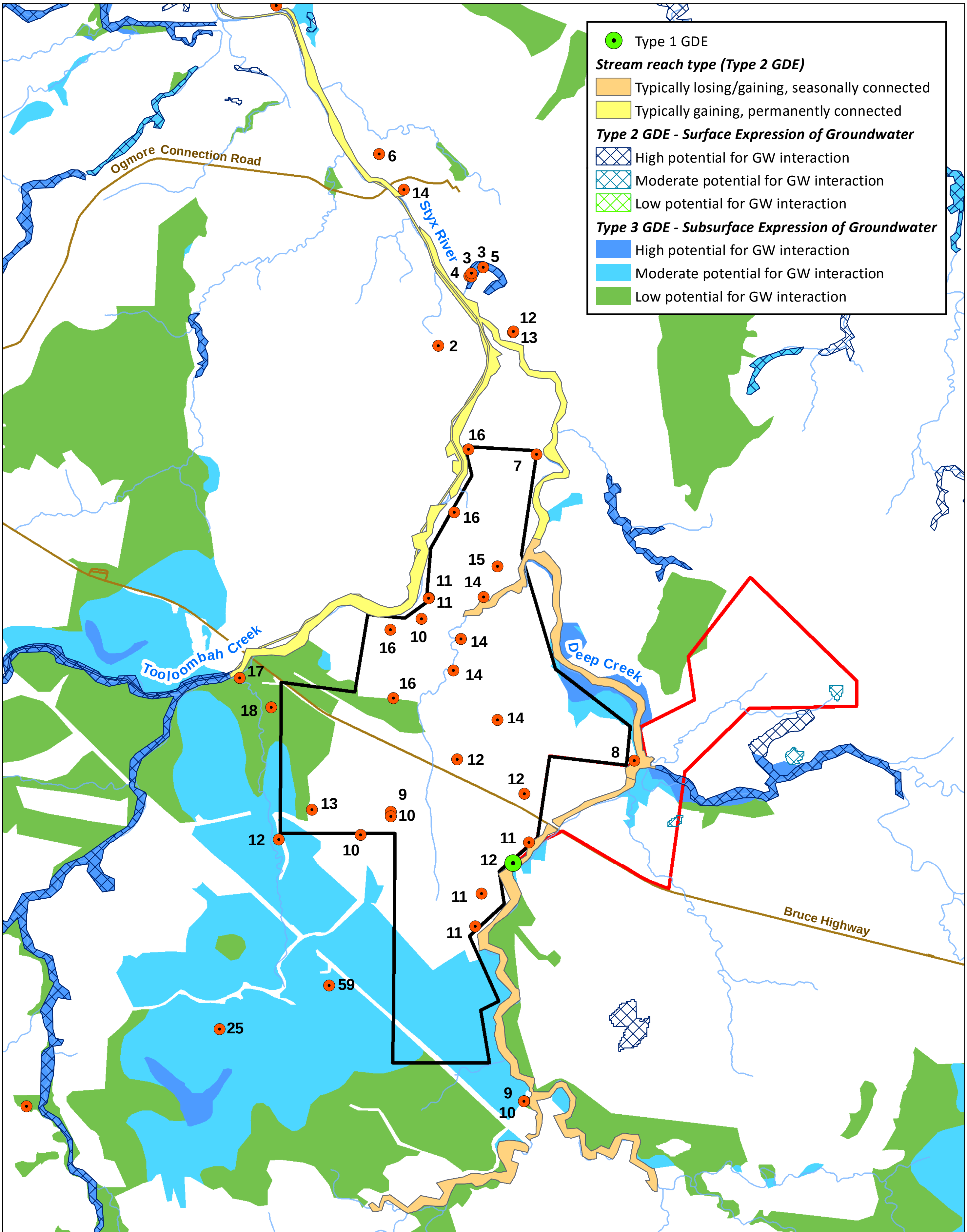


Figure 15-20
Groundwater dependent ecosystems
- ground-truthed

Legend

- Bore (DTW mbgl)
- Major watercourse
- Main road
- ML 80187
- ML 700022

N

0 1 2
Kilometres

Scale @ A4 1:80,000
Date: 08/05/18
Drawn: A. Aird

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

airda I:\BES170353.01 - Styx Supplementary EIS\GIS\DATA\MXD\FINAL\Groundwater Chapter\BES170353.04_Ground-truthed_GDEs_R4.mxd 8/05/2018

15.6.5 Stygofauna Assessment

The following assessment is informed by a desktop review and field studies carried out onsite by GHD Water Sciences in November 2011 and March 2012. The full report is located in Appendix A9f – Stygofauna Results.

15.6.5.1 Desktop Assessment

Stygofauna may be found in a variety of geological formations including: unconsolidated sediments associated with alluvial deposits; limestone karsts; porous sedimentary rocks such as sandstone; and fractured rocks composed of volcanic rocks, metamorphic rocks or limestone permeated with cracks, faults and other voids. Stygofauna require permanent groundwater and are a sign of the long-term residence of a groundwater aquifer. Most stygofauna communities occur close to the surface in shallow aquifers as they rely on connections to the surface to provide food. However, they may occur in any aquifer with sufficient hydraulic connection to the surface allowing food and oxygen transport to the groundwater table.

Stygofauna distribution in eastern Australia is correlated with temperature, specific conductivity, proximity to the water table, the roots of vegetation in the hyporheic zone (the saturated soil and sediment below and adjacent to waterbodies), coarse sediments and hydraulic conductivity (Hancock and Boulton 2008). The preferred conditions for stygofauna habitat are summarised from several Australian studies in Table 15-11.

Table 15-11 Preferred conditions for stygofauna

Parameter	Conditions conducive to stygofauna
Aquifer geology	Cavities, fractures or intersects
Depth to groundwater	Within 0 to 21 m below ground level (bgl)
Groundwater conductivity	Largely under 3200 μScm^{-1}
Groundwater pH	Majority found at pH 6.7 to 7.37; however, species found at pH 4.3 to 8.5

Source: Hancock and Boulton 2008

Geographical extent of stygofauna species is often poorly known and many species are only known from a single area. As a result, there is only a limited amount of publicly available information which is largely restricted to occurrence data and rarely identifies fauna beyond the level of genera (that is to species level) and often only to Family level.

For instance, a species of Parabathynellidae was recorded from three bores in the Burdekin River Alluvial Aquifer in Queensland, with two of these bores located approximately 20 km apart (Cook et al. 2012), suggesting a potential distribution of approximately 400 km^2. Additionally, studies in both Western Australia and Queensland have found evidence that sub-catchment boundaries can demarcate locations of turn-over of stygofaunal species (Finston et al. 2007; Little et al. 2016). Therefore, areas of approximately 400 km^2 to 600 km^2 within a single sub-catchment may represent reasonable estimates of distribution of most stygofaunal species, acknowledging that site-specific factors (e.g. highly confined aquifers) may impose further restrictions on distribution in some cases, or create strong population subdivision within species on smaller spatial scales (Cook et al. 2012; Little et al. 2016).

Stygofauna have the potential to occur in aquifers composed of any geological unit with sufficient pore space to complete their life cycle (Tomlinson and Boulton 2008). Consequently, stygofauna are less likely in geological units with relatively small pore spaces, such as those dominated by mudstone, siltstone and clays. Preliminary discovery rates of stygofauna in Queensland indicate that:

- No stygofauna have been recorded in mudstone and siltstone to date;
- Stygofauna are less common in clay, coal and basalt dominated geologies; and
- Stygofauna are most common in alluvium, granite, gravel, sand, sandstone, silt, and volcanic geological units (Glanville et al. 2016).

The majority of stygofauna tend to be small crustaceans. Approximately 40 species of stygofauna are currently known to occur within Queensland (ALS 2010). Four stygofauna taxa have been previously identified within the Bowen Basin (one Copepod, one Amphipod and two Bathynellacea species) in a study by Hancock and Boulton (2008).

The majority of studies in the Bowen Basin are a result of requirements under EIS ToR which do not require identification below the classification level of Family or Order. As a result, the endemism of the groundwater fauna of the region is poorly known despite widespread sampling.

A review of 13 groundwater studies carried out in the Bowen Basin found 12% of samples (15 of 127 sites) contained stygofauna (4T Consultants 2012). The majority of these were collected in alluvial (shallow) aquifers. In alluvial aquifers in eastern Australia the average number of stygofauna taxa was higher within 6 m of the water table, and where the water table was less than approximately 15 m below the ground (Hancock and Boulton 2008). Other studies have shown similar results, with a statistically lower diversity of stygofauna in deeper aquifers than shallow aquifers (Halse et al. 2014). All of the specimens collected in the Hancock and Boulton Study (2008) were collected from alluvial or shallow sedimentary aquifers, although other types of aquifer (including coal seam aquifers) were not sampled. Such aquifers are hydraulically and ecologically connected to terrestrial ecosystems. The degree of connectivity to other habitats is crucial to the presence of stygofauna, as it allows the transfer of materials, energy and pathways for faunal dispersal (Eberhard et al. 2004). Nevertheless, in Queensland, stygofauna have been recorded from over 60 m below ground (Glanville et al. 2016), indicating that deep groundwater ecosystems can also support stygofaunal communities.

The stygofauna community of coal seam aquifers is poorly known with little published data. GHD (2012) reports a total of eight taxa collected during sampling from coal seam aquifers across Queensland including: four species of water mites (Arachnida), two Copepods, one Amphipod, and a syncarid crustacean of the Bathynellacea order (*Notobathynella* species). Two of these (one each of Amphipoda and Copepoda) were collected from a site in the northern Bowen Basin (GHD 2012).

There is no readily available data related to stygofauna in the region surrounding the Central Queensland Coal Project area. Within the catchment of the Fitzroy River basin the majority of stygofauna surveys have failed to find any taxa, particularly where high salinity groundwater occurs (see AARC 2010). Nevertheless, stygobite taxa (obligate groundwater aquatic fauna) have been found in several shallow aquifers within the Fitzroy River basin (frc environmental 2013).

15.6.5.2 Description of Project Area Aquifers

The Project is in a geological basin comprising early-Cretaceous sediments and coal measures and is referred to as the Styx Basin. The infill sediments of Styx Basin are known collectively as the Styx Coal Measures.

Prior knowledge of the aquifers in the area appears relatively poor. The BoM National Groundwater Information System reports the Styx River Basin lies outside of declared groundwater management areas, including alluvial aquifer boundaries declared by the Department of Natural Resources, Mines and Energy. The BoM database lists the purposes of all bores located within Styx catchment as "unknown." A bore census conducted for the Project in 2011 found that most landholder bores are used for stock watering, with some domestic use (Styx Coal and Fairway Coal 2012). The Groundwater Cartography product of the Australian Hydrological Geospatial Fabric classifies the Styx River Basin as an "unknown" water table aquifer. The shallow hydrogeological units containing the water table are shown to consist mainly of Cenozoic alluvium within surface drainage areas and associated slopes, and fractured rock outcrops along ridgelines and higher areas between the alluvial deposits.

Hydrogeological modelling of the aquifers and the underlying groundwater conditions that occur in the mine area is provided in Chapter 10 – Groundwater. At the broadest level, the basin contains usable groundwater supplies in shallow water-table aquifers that are hosted in the Cenozoic surface deposits, particularly within the alluvial sediments associated with surface drainage, and within fractured and weathered zones of outcropping Cretaceous rocks (Styx Basin) and older Permian rocks. Shallow unconfined groundwater flow in Cenozoic sediments and fractured and weathered rocks within Styx River Basin is driven by diffuse groundwater recharge from rain falling within the basin. The deeper sediments underlying the Cenozoic surface deposits and below the zone of surface fracturing and weathering have much lower permeability and are not known to yield useable groundwater supplies.

Twenty exploration bore holes were drilled within the Project area boundary targeting the Styx Coal Measures (25 to 100 m hole depth). A coal seam will not generally be classified as an aquifer because of its low hydraulic conductivity; however, within a sequence of coal seams and typical interburden rocks—such as claystone and shale— coal seams are sometimes referred to as 'aquifers' because they are more permeable than the much less-permeable interburden layers (IESC 2014). A further three drill holes are located south of the Project area (Neerim 1, 2 and 3) and a single drill hole is located to the north (Riverside 2) (refer Figure 15-2).

Six landholder bores across the wider area to the north of the MLs were also selected for sampling groundwater and stygofauna. All of the bores are located within, or at the fringes of the mapped Cenozoic deposits which indicates the bores are targeting alluvial groundwater, and possibly groundwater supplied through fracture zones in adjacent and underlying rocks.

Information on the groundwater quality in deeper rocks was limited at the time of the initial works carried out for the Project. Therefore, the precautionary principle was applied, and it was considered there was a moderate potential for stygofauna to occur in the Project area given the dominance of shallow aquifers in the area.

15.6.5.3 Field Assessment

Forty samples from 30 different bores were assessed during the surveys for the presence of stygofauna by GHD Water Sciences in November 2011 and March 2012. Nineteen of the bores are located within, or on the boundary of the mine ML and the potential area of predicted groundwater drawdown related to the Project (refer Figure 15-2 and Appendix A6 – Groundwater Technical Report). Of the additional bores, nine are located outside of the likely area of groundwater drawdown impact and may therefore be considered as 'control' survey sites. All of the sampled bores are relatively shallow with the deepest water depth recorded being 16.6 m below ground level.

Groundwater Quality

Average groundwater quality differed between November 2011 and March 2012 (Table 3 in Appendix A9f - Stygofauna Results). In March 2012 pH was generally lower than recorded in November 2011 (by 0.7 of a pH unit), EC was slightly higher (by 800 µS/cm), dissolved oxygen lower (by 7.5% or 0.6mg/L) and water temperature was higher (by 0.4^{o}C). The March 2012 sampling event was preceded by a significant rainfall event across the Styx catchment which lasted a number of days. The data reflects the generally variability in water quality both spatially and temporally across the wider area.

The pH across all groundwater bores was slightly alkaline with mean values of 8.16 in November 2011 and 7.47 in March 2012. These elevated pH values are supported by historic data (YEATS 2011) which shows average pH levels from registered well records in the proximity to EPC 1029 of between 7.5 and 7.7. The highest pH recorded from the current study was 9.77 which occurred at site Stx 105 in November 2011 and the lowest pH was recorded at site Plainvue 1 (6.03) also in November 2011.

Historic data (YEATS 2011) showed average groundwater conductivity levels from registered well records across the wider area range between 1,580 µS/cm (Quaternary alluvium) and 8,000 µS/cm (unconsolidated / consolidated material on terraces and lower slopes). This is in agreement with the data collected during the survey which showed mean values ranging from 6,275 µS/cm in November 2011 to 7,085 µS/cm in March 2012 (Table 3 in Appendix A9f – Stygofauna Results). Ranges in conductivity also reflected the extreme variability in water quality across the survey area with the lowest conductivity recording of 377 µS/cm occurring at site Neerim 2 in November 2011 and the highest EC recording of 30,237 µS/cm occurring at site Plainvue 1 in March 2012. Stygofauna have been reported as preferring an EC concentration of generally less than 5,000 µS/cm and preferably less than 1,500 µS/cm (Boulton and Hancock 2008). Of the groundwater bores sampled for stygofauna across November 2011 and March 2012, 24 bores recorded conductivity concentrations below 5,000 µS/cm and 5 bores recorded concentrations below 1,500 µS/cm.

An updated analysis of current groundwater conditions informed by recent data collected for the Project is located in Chapter 10 – Groundwater.

Stygofauna Presence

Two of the sites surveyed (Riverside 1 and Granite Vale Old Windmill) registered one species at each site in November 2011. Four sites registered five species in March 2012 (Riverside 1, 3 and Well bores and STX 093) (Table 15-12). A total of seven species were collected. The Riverside bores are all located in a concentrated area approximately 8 km north of the MLs. The Old Windmill bore is 13 km northwest of the MLs boundary. The Project specific bore (STX 093) is located on the eastern boundary of the Project area close to Deep Creek (Figure 15-21). Both species can be classed as stygofauna, including obligate groundwater species associated with the hypogean and permanent hyporheic environments (Table 15-12).

Table 15-12 Stygofauna sampling data

Bore site	Sample date	No. of species	Order	Family	Genus	Life habit
Riverside 1	Nov 2011	1 (single individual collected)	Oligochaeta	Capilloventridae	*Capilloventer*	Stygobite
Riverside 1	Mar 2012	1 (single individual collected)	Oligochaeta	Naididae	*Nais*	Stygobite
Granite Vale Steel (Windmill)	Nov 2011	1 (two individuals collected)	Copepoda	Cyclopoidae	Unknown	Phreatobite
STX 093	Mar 2012	2 (one individual and five indivduals collected)	Collembola	Entomodryidae	Unknown	Edaphobite (not stygofauna)
			Astigmata (Class: Acari)	Unknown	Unknown	Stygophile
Riverside Well	Mar 2012	1 (single individual collected)	Oligochaeta	Enchytraeidae	Unknown	Stygobite
Riverside 3	Mar 2012	1 (four indivduals collected)	Bathynellacea	Parabathynellidae	c.f. *Notobathynella*	Phreatobite

A total of five sites recorded the presence of subterranean fauna with four sites recording subsurface species which can be classed as stygofauna, including obligate groundwater species associated with the hypogean and permanent hyporheic environments. Stygofauna are grouped into one of several classes based on the degree of requirement for subterranean life (Tomlinson and Boulton 2008). Edaphobites are deep soil dwelling (or endogean) species that frequently display troglomorphisms and may sometimes occur in caves. These animals are not classified as stygofauna and the taxa detected at STX 093 is not considered further. For the purpose of this survey, three classes of stygofauna are considered:

- Stygobites are obligate groundwater aquatic fauna with specialised adaptations to underground life and that live within groundwater systems for their entire life;
- Stygophiles are facultative subterranean species, able to complete their whole life cycles both underground and on the surface. Stygophilic species often have populations above and below ground, with individuals commuting between them; and
- Phreatobites are stygobites (obligate subterranean species) restricted to the deep groundwater substrata of alluvial aquifers. All species within this classification have specialised morphological and physiological adaptations.

The shallow water table levels within the riverine bores (Riverside Well, Riverside 1, Riverside 3 and Granite Vale Old Steel Windmill 1) and the presence of Bathynellacea (of the Superorder Syncarida), three families of Oligochaeta and Copepoda suggests a fine to moderate grained unconsolidated alluvial aquifer with direct association / connectivity of the baseflow river system with an interconnected hyporheic zone (Boulton et al. 2008) and moderate to high water quality.

Stygobite Fauna

The hyporheic zone of a river is characterized by being nonphotic, exhibiting chemical / redox gradients, and having a heterotrophic food web based on the consumption of organic carbon sourced from surface waters (Feris et al, 2003). The subsurface fauna collected included three species and families of Oligochaeta. Although occurring within the subterranean environment these three groups have their highest biodiversity within the riverine, hyporheic zones and are classed as members of the "permanent hyporheos' or the community that occurs within the shallow to deep sand and gravel beds associated with areas of groundwater discharge. They typically characterize the transition zone between the permanent shallow hyporheic ecozone and the groundwater hypogean environment (Gilbert et al. 1994).

The Riverside 1 site contained a single Oligochaeta specimen belonging to the family Capilloventridae. This finding suggests that the stratum was a fine to moderate grained unconsolidated substrate with a strong connection to the river as the freshwater species of this family have only been recorded from baseflow sandy bed streams associated with riverine hyporheic zones (Pinder and Brinkhurst 1994). The Capilloventridae is a relatively rare aquatic Oligichaete family that has only previously been recorded in Australia from NSW and Victoria, and one species in south-west WA. As there is almost nothing known of their biology or ecology, little can be said of their environmental requirements except to say that they are found in environments with high water quality and porous sediments.

Stygophile Fauna

Site Stx 093 recorded the presence of water mites. There is little known of the biodiversity and distribution of water mite fauna in Queensland. They have been described by Smit (2007), as typically having a high diversity, and can reach high densities in the substrates of streams and rivers. This taxa has been commonly found in groundwater ecosystems elsewhere in the Bowen Basin. The distribution of individual species (morphospecies) within this taxa may be geographically restricted within the Bowen Basin as they are stygobiont, but is likely greater than the survey area.

Phreatobite Fauna

The presence of the obligate groundwater fauna characterised by the Syncarida (Riverside 3) and Copepoda (Granite Vale Old Steel Windmill 1) is an indicator of a permanent flow of water through the interstitial spaces these taxa inhabit. Other interstitial species can be found in both the permanent hyporheic and hypogean whereas the Syncarid and Copepod belong intrinsically to the hypogean (true groundwater) ecosystem. Cyclopoida represent a common group of stygofauna found in association with riverine alluvial aquifers with a strong connectivity between the aquifer and the river (Gibert et al. 1994).

The absence of stygofauna from the remaining groundwater bores sampled for this Project does not indicate that they are not present in the aquifers sampled, rather, it may be due to unsuitable geological conditions (low porosity, low hydraulic conductivity), poor water quality (e.g. high EC or presence of other toxicants) or sampling from a recently drilled bore that has yet to stabilise and attract stygofauna (reduced likelihood of collection).

The results of the two surveys carried out show the majority of the stygofauna community were recorded in the alluvial aquifer associated with the Styx River and located more than 8 km away from the boundary of the Project area. A single taxa (five individuals) was collected adjacent to the Project boundary and Deep Creek. It is; however, considered very unlikely this species will be restricted to the predicted zone of impact (related to groundwater drawdown) from the Project which is relatively minor in overall area. Given the results detailed in Table 15-12 it is considered highly unlikely this morpho-species is restricted to the predicted zone of impact related to the Project.

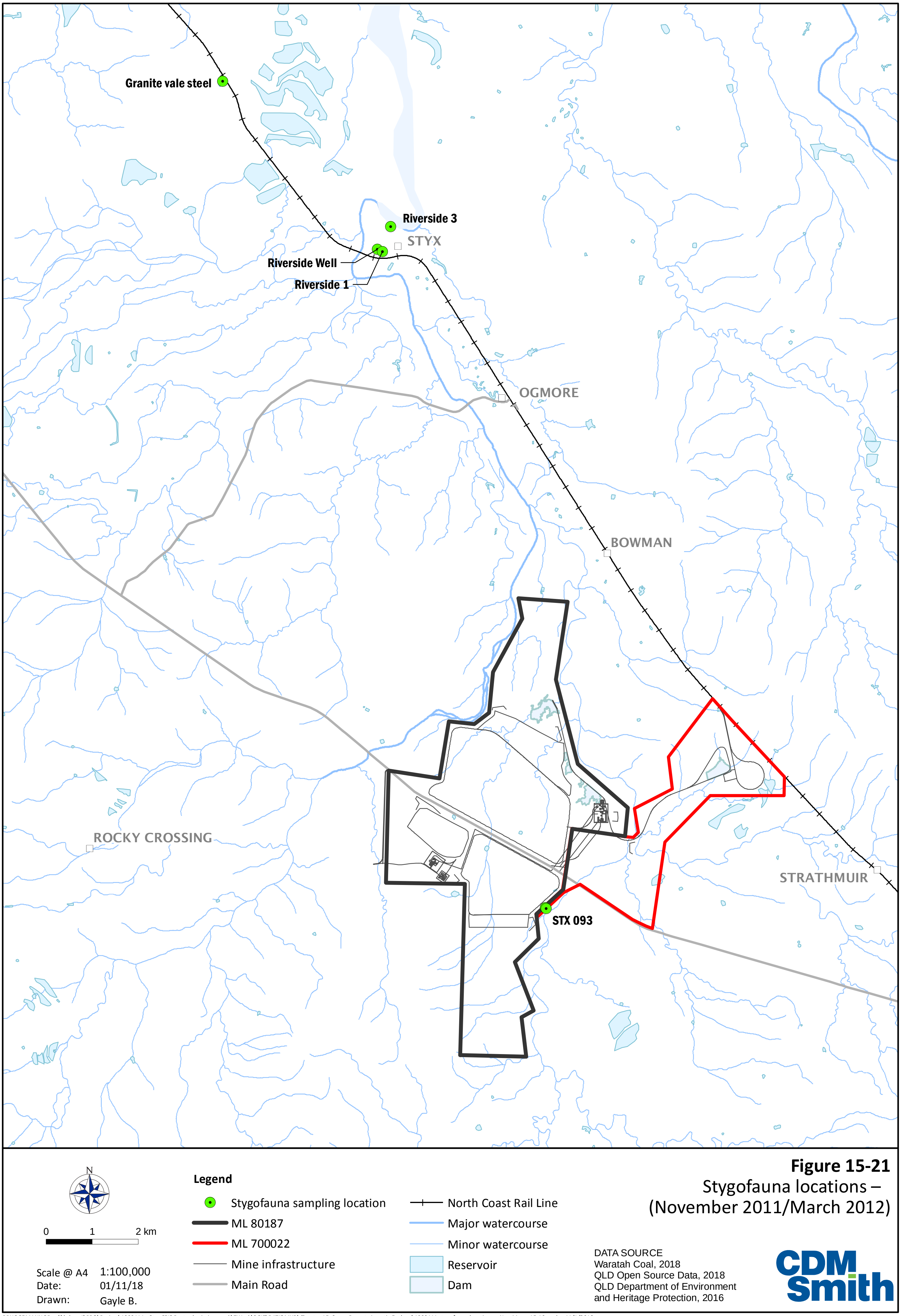


Figure 15-21
Stygofauna locations – (November 2011/March 2012)

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018
QLD Department of Environment and Heritage Protection, 2016

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 15_Supp_Report_Aquatic Ecology\1000111 stygofauna locations__Nov-Mar__15-10.mxd 11/1/2018

15.6.6 Tooloombah Creek In-stream Pool Water Balance

Permanent pools have been observed along Tooloombah Creek and Deep Creek. The pool levels appear to remain relatively stable across the whole dry season (generally from April to July). Groundwater level observations in the alluvium aquifer indicate an upward hydraulic gradient (from aquifer to pools) across the wet and dry seasons, however the gradients are not strong gradients (i.e. there is less than a metre difference in heads).

The primary objective of the mass balance model is to understand the mechanisms that sustain the permanent and semi-permanent pools in the Tooloombah Creek and Deep Creek catchments.

The pool at To2 was selected for this assessment as it is the main largest permanent pool in the closest vicinity of the mining operations with sufficient data available to apply a mass balance model.

15.6.6.1 Methodology

The water level in a pool is a balance between the pool inflows (incident rainfall, rainfall runoff, groundwater inflow, transfer along alluvial sediments) and outflows (evaporation, leakage to groundwater, transfer along alluvial sediments). Figure 15-22 illustrates the conceptual understanding of permanent pool hydrology.

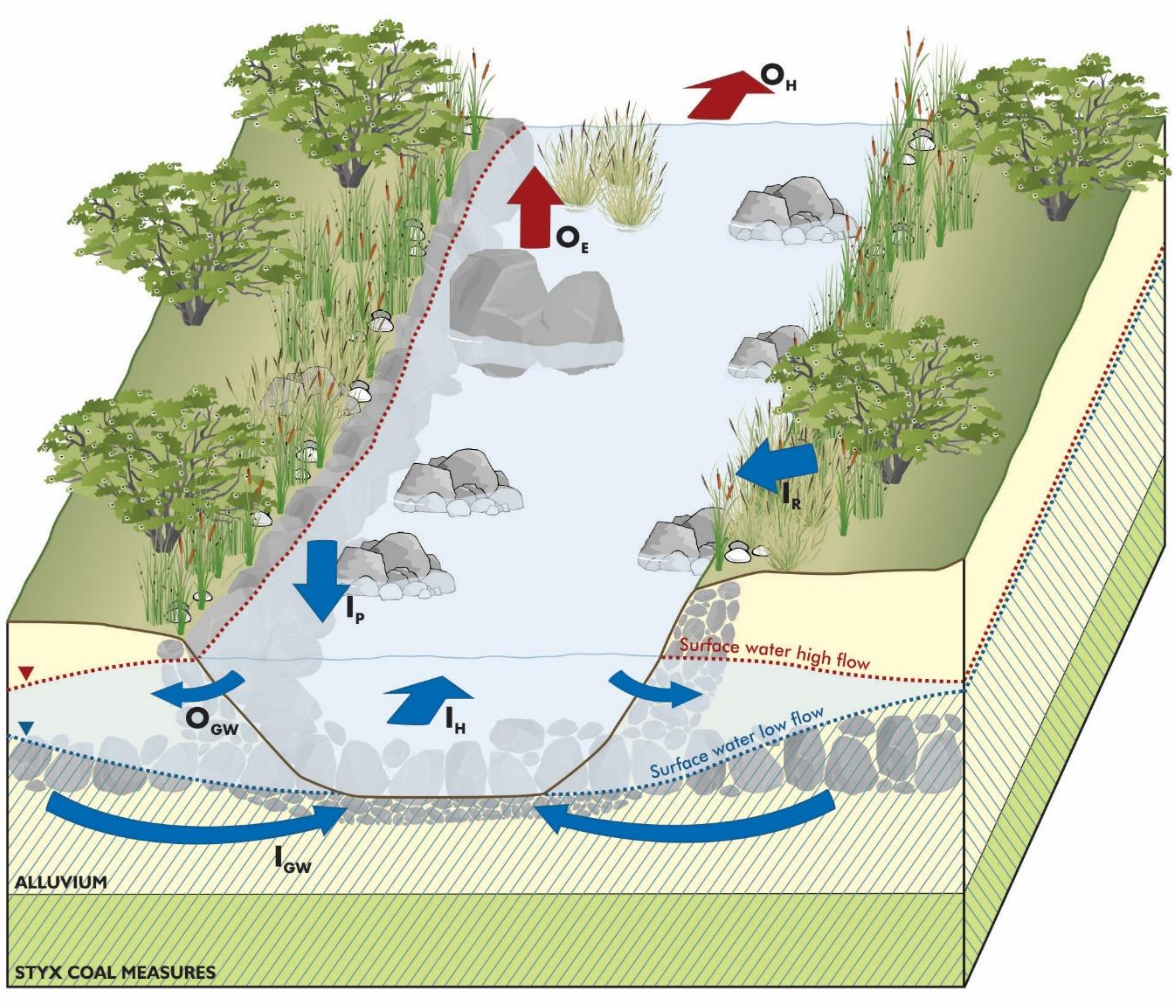


Figure 15-22 Pool conceptualisation

The mass balance can take the form of equation 1.

$$\Delta_{Storage} = I_{GW} + I_P + I_R + I_S - O_E - O_S - O_{GW} \qquad (1)$$

where: $\Delta_{Storage}$ is change of storage within the pool (L^3/t)
I_{GW} is groundwater discharge to the pool[2]
I_P *is the* rainfall into the pool (L3/t)
I_R is the runoff to the pool (L3/t)
I_H is the upstream hyporheic zone inflow (L3/t)
O_E is the evaporation from pool (L3/t)
O_H is the downstream hyporheic zone outflow (L3/t)
O_{GW} is the water loss from pool to alluvial aquifer (L^3/t)

During a dry period (defined as the period with no stream flow) with a stable pool water levels, the terms I_R, I_H, O_H, O_{GW} and $\Delta_{Storage}$ become negligible, and the mass balance for a permanent or semi-permanent pool becomes:

$$\Delta_{Storage} = I_{GW} + I_P + O_E = 0 \qquad (2)$$

or

$$I_{GW} = O_E - I_P \qquad (3)$$

For a dry period, the groundwater contribution to the pool (I_{GW}) is equal to the amount removed by evaporation (O_E) less incident rainfall over the pool.

The groundwater contribution component is made up of water from a number of possible sources. Understanding and quantifying the various contributions is key to predicting the potential impact of mine water affecting activities on the pool water body as not all components will be equally affected.

The possible sources of water for the alluvial aquifer include:

- Rainfall diffuse recharge - Infiltration of rainfall water directly to the alluvial aquifer;
- Bank storage - The recharge of the near stream bank by streamflow during a flood event;
- Aquifer interactions - The exchange of water between adjacent and/or deeper aquifers and the alluvium. The contribution is positive if the head in the aquifer(s) is higher than in the alluvium aquifer, and negative otherwise; and
- The creek hyporheic zone – The stream bed is recharged during a stream flow event. The upstream positive contribution to a pool might be matched by a similar negative contribution downstream of the pool if the structure and profile of the alluvium remains unchanged and evaporation is ignored.

Quantifying the respective contribution of all these parameters would be a complex task as the processes change both temporally and spatially (Table 15-13) and because only limited information can be made available to characterise them. The assessment could be made by exploring various lines of evidence including geochemical evidence (identify the chemical signature of each source

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[2] I_{GW} is made of groundwater from various contribution including bank storage release (I_B), contribution from the creek hyporheic zone (Iss), from deeper aquifer and from the diffuse rainfall recharge over the alluvium and generating potentially localised perched conditions.

and modelling the potential mixing) and physical evidence (based on respective water level observation; see Table 15-14 for detail).

A detailed analysis of those contributions would allow to understand which portion of the groundwater inflow will be affected by the mining operation. A first approximation and conservative approach is to assume that all the groundwater contribution will be affected by the mining operation.

As illustrated in Table 15-13, the key water source for the alluvial aquifer that may be affected by the proposed mining operation is "aquifer interaction".

Table 15-13 Characterisation of the alluvium aquifer

Component	Dynamic	Spatial distribution	Affected by mining operations
Bank storage return	The recharge of the alluvial aquifer - episodic and brief (possibly less than 1 month).	Localised in the vicinity of the pool. The extension is controlled by the area flooded and the water level in the creeks during flood events.	Limited as diversions of watercourses are not proposed. However, the bank return could be altered if the vertical gradient between the alluvium and underlaying unit is inverted during mining operations.
Diffuse rainfall recharge	Seasonally variable. Controlled by soil and unsaturated zone water content, rainfall patterns and evapotranspiration.	Spread uniformly over the extent of alluvium.	Limited to the extent of the mine activities. Watercourses are unaffected.
Sub surface flow	The recharge of the alluvial aquifer is episodic and brief (possibly less than 1 month).	Localised upstream and downstream, including the pool (small transversal section).	Limited as watercourse diversions are not proposed. However, sub surface flow could be altered if the vertical gradient between the alluvium and underlaying unit is inverted during mining operations.
Aquifer interactions	Relatively stable. Controlled by the head differences between heads in the adjacent and/or deeper aquifer(s) and the alluvial aquifer.	Spread variably/unevenly over the extent of the alluvium. The general gradient would support discharge of water from deeper aquifers (and the alluvium) near to watercourses and vice versa away from the watercourses.	The drawdown caused by mine dewatering will alter these dynamics during mining and for some time after the completion of mining.

Table 15-14 Approach to identify pool groundwater contribution

Component	Hydrochemistry	Physical constraint	Other assessments approaches
Bank storage return	Young water (weeks) with little mineralization. Hydrochemical signature likely to be similar to rainfall.	Limited extent restrained by the flood zone, with bank storage estimates based on physical dimensions.	- Bank storage volume assessment; - Analytical model; and - 2D cross section numerical model

Component	Hydrochemistry	Physical constraint	Other assessments approaches
Diffuse rainfall recharge	Young water (years). Chloride and Carbonate likely to be dominant anions, and sodium the dominant cation.	Evapotranspiration demand, soil type(s), rainfall patterns and intensity.	- Bucket type model; - Unsaturated / saturated model; - Analytical model; and - 2D or 3D numerical models.
Sub surface flow	Young water (weeks) with little mineralization. Hydrochemical signature likely to be similar to rainfall.	Pre-stream flow moisture content of sediments, homogeneity of hyporheic zone (connectivity, hydraulic conductivity, cross-sectional area).	- Analytical solution (Darcy); and - Numerical solution.
Aquifer interactions	Old water (>10 years). Hydrochemical signature likely to be similar to deeper aquifer(s). Chloride likely to be dominant anion, and sodium the dominant cation.	Hydraulic head gradients (direction and scale), vertical hydraulic conductivity in sediments and Styx Coal Measures.	- Analytical solution (Darcy); and - 3D numerical model (check from the existing model).

15.6.6.2 Pool Water Balance Calculations

The pool at “To2” is on average approximately 1 m deep and has a total surface area of around 4,060 m^2.

For the period from April to July 2018, minor rainfall occurred in the Project area (total of 60 mm for the four months, for an average of 0.5 mm/d) and the creeks didn’t experience any stream flow. Over the same period the average rate of evapotranspiration is estimated at 4.1 mm/d. The pool water level has remained stable during the period. By applying equation (2) over this dry period, the groundwater contribution is estimated about 3.6 mm/d. Assuming that all groundwater contribution will be affected by mining operations, 3.6 mm/d would need to be supplied for each affected pool to sustain their level during the dry seasons.

Over the To2 pool area, rainfall is estimated to have contributed approximately 244 m3 (0.5 mm/d over 4,060 m2 for 4 months), and ET is estimated to remove around 2000 m3 (4.1 mm/d over 4,060 m2 for 4 months). Based on equation (2), groundwater is estimated to have contributed 1,756 m3 (14.6 m3/d, or around 3.6 mm/d). For a longer dry season (i.e. time between creek flow events) of six months long, at 3.6 mm/d it is conservatively extrapolated that groundwater might contribute 2,635 m3 to the permanent pool.

The numerical model (Section 3 of Appendix A6) estimated that a well in the Styx Coal Measures could sustain an average pumping of 0.2L/s (17 m3/d). At this rate, the well could support 4,800m2 of pool during the dry season. Such a well could be enough to support To2 water level during the dry season.

The water balance model indicates the amount of water required to sustain in-stream pools during the dry season is around 3.6 mm/d.

15.6.7 Connectivity Assessment Results Using Isotope Analysis

15.6.7.1 Overview

A preliminary isotope study has been undertaken to provide an initial indication of water sources supporting the watercourse pools, which are hypothesised to be supported to some extent by groundwater discharge (i.e. Type 2 GDEs, see SEIS Chapter 10 - Groundwater). This study forms part of the planned additional scope of works required to assist in improving the understanding of the water requirements of the GDEs and potential impacts arising from mining operations which will in turn enable appropriate management objectives and approaches to be developed to manage these GDEs during and post-mining.

To better understand the relationship between the surface water and groundwater, the stable isotopes of water (δ^2H and $\delta^{18}O$) and radon isotope (^{222}Rn) were analysed from water samples collected from the site.

15.6.7.2 Environmental (Stable) Isotopes

Craig (1961) observed that when stable isotopes of water (δ^2H and $\delta^{18}O$) have not undergone evaporation, they would have a linear relationship which can be represented by:

$$\delta^2H = 8\,\delta^{18}O + 10$$

This equation is referred to as the GMWL and was developed based on precipitation data from across the globe. A “Local Meteoric Water Line” (LMWL) is usually developed from precipitation data collected from either a single location or a set of locations within a “localised” area of interest (USGS, 2018), noting that there are limited data available in the Project area to construct this trend, thus there is some uncertainty in the LMWL derived.

The stable isotopes of water can be used to discriminate between different sources of water. The method relies on the distinct isotopic compositions which can arise as a result of isotopic fractionation caused mainly by transportation processes (i.e. mixing) and phase transitions (i.e. evaporation) through the atmosphere, lithosphere and biosphere (Barnes and Allison, 1988).

Six grab water samples were collected from Tooloombah Creek in-stream pools (two sampling points each from three pools within the creek) and another three from Deep Creek in-stream pools (a sampling point from three pools within the creek) between 16th and 18th July 2018. Groundwater samples were collected from six monitoring wells that are close to the surface water sampling points, using a low-flow groundwater sampling pump.

Water samples were analysed by Environmental Isotopes (contracted via Australian Laboratory Services, ALS). The hydrogen and oxygen isotope ratios were measured using a Wavelength Scanned-Cavity Ring-down Spectrometer (Picarro L2120) based on Munksgaard *et al*. (2011). Lake Eacham and Cairns Tap water were used as reference waters to develop localised water standards.

Laboratory results are presented in Table 15-15 while the results and water standards along with the relevant MWLs are plotted in Figure 15-23.

Table 15-15 Stable isotopes of water measured in groundwater and surface water samples

Location	Sample type	δ2H (‰, VSMOW)	δ18O (‰, VSMOW)
WMP02	Groundwater	-23.11	-3.94
WMP04		-27.23	-4.42
WMP04D		-25.12	-4.23
WMP05		-34.07	-5.44
WMP06		-11.77	-1.69
WMP10		-24.06	-4.04
De2	Surface water: Deep Creek	2.34	1.28
De3		-14.4	-1.71
De5		0.37	0.92
T01.1	Surface water: Tooloombah Creek	2.04	0.9
T01.2		0.49	0.65
T02.1		-0.07	0.76
T02.2		-7.98	-0.61
T03.1		-1.87	0.45
T03.2		1.51	1.07

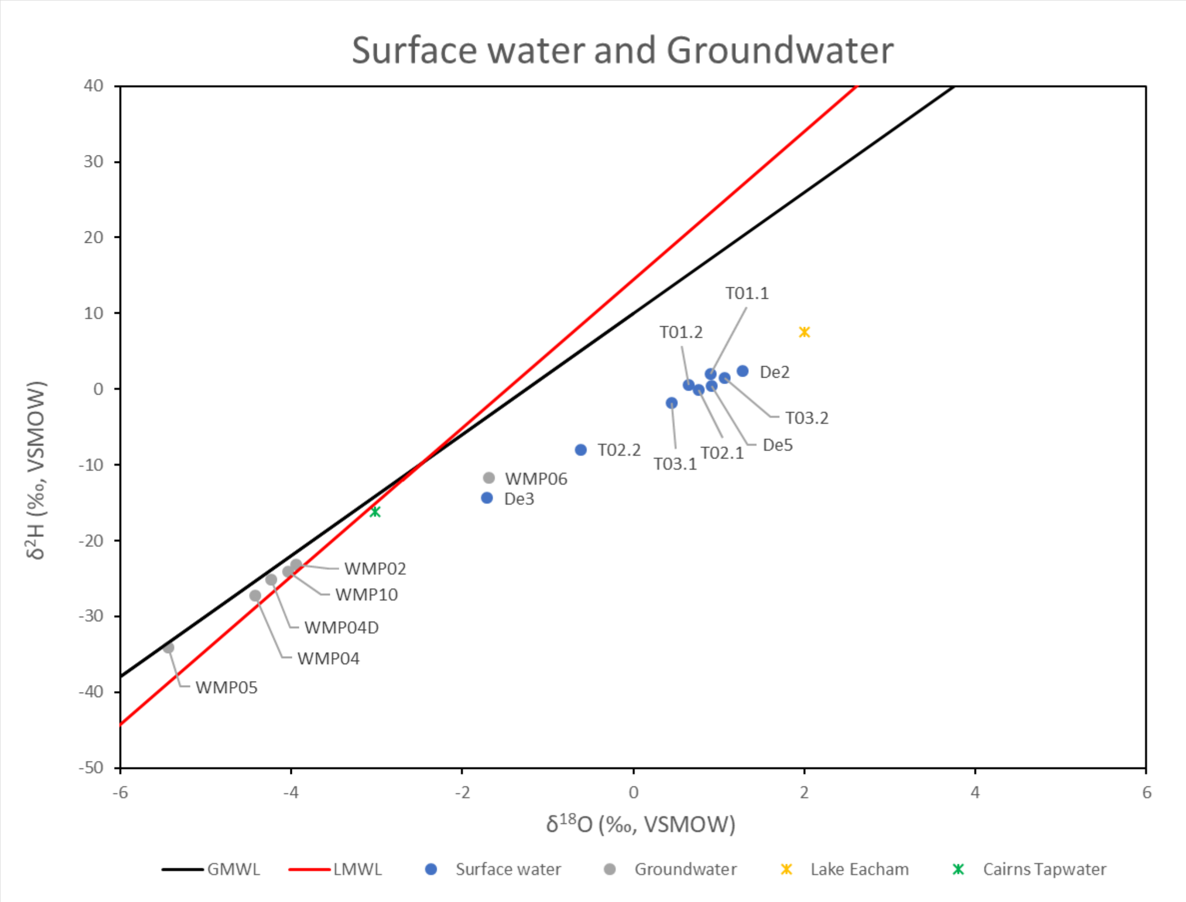


Figure 15-23 Environmental (stable) isotopes

The GMWL is based on precipitation data from numerous locations across the globe while the LMWL was developed from data collected by CSIRO between February and March 2010 in Rockhampton, Queensland (Crosbie et al., 2010).

The laboratory reported Lake Eacham and Cairns Tapwater are reference standards that the samples can be compared with. There is clear distinction between the isotopic values of samples from the surface water and groundwater, indicating different processes have affected the two sample groups. Gonfiantini, (1986) noted that when water undergoes evaporation, the residual isotopes become progressively enriched in heavier isotopes of δ^2H and $\delta^{18}O$, and the ratio of $\delta^{18}O$ to δ^2H increases. However, when isotopic composition of a water sample plots close to the MWL, it is indicative of its meteoric origin.

The groundwater samples plot on or near the GMWL and LMWL, indicating that groundwater is derived mainly from rainfall recharge and that they underwent little to no evaporation prior to recharge. Surface water samples collected from in-stream pools plot well below the GMWL and LMWL, indicating that they have been affected by evaporation (heavier isotopes, relative to the groundwater samples), which is not unexpected. The data suggest that groundwater could be the source of water sampled from the pools.

15.6.7.3 Radioactive Isotopes – Radon

Radon-222 (^{222}Rn) is a radioactive daughter isotope of Radium-226 and is the longest-lived and most-studied isotope of radon (it has a half-life of 3.82 days). Radon is a gas and will tend to seek a gaseous phase. This means that the natural waters that come into contact with the atmosphere will readily lose radon to the atmosphere, which has very low radon concentrations (USGS, 2018). For this reason, groundwater usually has a much higher concentration of ^{222}Rn than surface water.

^{222}Rn is often used in groundwater and surface water interaction studies because the surface water will have a very low natural ^{222}Rn due to degassing and any elevated concentrations can be used to indicate local discharges of groundwater.

Six grab water samples were collected from the Deep and Tooloombah Creeks (three each) between 16th and 18th July 2018. Groundwater samples were not collected for radon analysis during this preliminary assessment as the current monitoring bores are not in proximity to surface water bodies. Radon was extracted from the groundwater samples into a 20 mL mineral oil scintillant based on the method proposed by Leaney and Herczeg (2006).

Water samples were analysed on the 26th July 2018 at the Australian Nuclear Science and Technology Organisation (ANSTO) laboratory.

Table 15-16 provides a summary of the radon results. Notably, the holding period between the sampling and analysis was between 8 and 10 days, and given ^{222}Rn has a 3-day half-life, corrections have been required to account for this (using a correction equation described by Dawood *et al.*, 2012).

Table 15-16 ^{222}Radon data

Date of sample collection	Date of sample analysis	Holding time (in days)	Sample ID	Lab result (Bq/L)	Corrected values (Bq/L)
16-07-18	26-07-18	10	DE3	0.19	1.17
17-07-18	26-07-18	9	De5	0.06	0.30
18-07-18	26-07-18	8	DE2	0.11	0.48
18-07-18	26-07-18	8	To1	0.65	2.75
18-07-18	26-07-18	8	To2	0.83	3.54
18-07-18	26-07-18	8	To3	0.45	1.93

The ranges of observed ^{222}Rn concentrations in the pools at Tooloombah Creek indicate that there is a likely connection between the creek and the groundwater while the concentrations from Deep Creek indicate low connectivity during the time of sampling (July 2018, which is dry season).

With the understanding that radon, bicarbonate and chloride are higher in groundwater than in surface water and that long residence time would facilitate the loss of radon from water to the atmosphere, O'Grady *et al*. (2007) plotted ^{222}Rn isotopes against chloride and ^{222}Rn against bicarbonate / chloride to determine the amount of groundwater inflow into wetlands. Comparing the ^{222}Rn and Cl^- present in different locations, the authors noted that sites with:

- low ^{222}Rn and low Cl^- concentrations are considered to have short residence times and low groundwater input;
- high ^{222}Rn and medium Cl^- concentrations are considered to have short residence times and a reasonable input of groundwater;
- high ^{222}Rn and very low Cl^- concentrations are considered to be unlikely as low chloride concentration indicates surface water is predominant, which would have negligible radon concentration; and
- high ^{222}Rn and high Cl^- concentrations are also considered to be unlikely as high concentrations of Cl^- would indicate long residence time resulting in high evaporation which would have led to the loss of ^{222}Rn to the atmosphere, exceptional cases include where groundwater is rich in chloride.

Comparing the ^{222}Rn and the ratio of bicarbonate and chloride values (HCO_3^-/Cl^-) present in different locations, the authors also noted that sites with:

- low ^{222}Rn concentration and low ratio of HCO_3^-/Cl^- are considered to have low groundwater input;
- low ^{222}Rn concentration and high ratio of HCO_3^-/Cl^- are considered to have higher groundwater input and long residence;
- high ^{222}Rn concentration and high ratio of HCO_3^-/Cl^- are considered to have higher groundwater input and short residence; and
- high ^{222}Rn concentration and low ratio of HCO_3^-/Cl^- are considered to be unlikely as a low ratio of bicarbonate to chloride indicates that groundwater input is negligible, meaning radon should not be present.

Figure 15-24 and Figure 15-25 show the plots of radon vs. chloride concentrations and radon vs. bicarbonate / chloride ratios, respectively. Figure 15-24 indicates that groundwater contributes only a limited amount of water to Deep Creek (very low chloride and ^{222}Rn) while Tooloombah Creek receives relatively higher amount of groundwater inflow (higher amounts of chloride and ^{222}Rn). Deep Creek also has longer residence time relative to Tooloombah Creek due to lower ^{222}Rn values. This is further buttressed by Figure 15-25, which indicates that groundwater contributes to some extent in both creeks (medium values for the bicarbonate / chloride ratio, 0.4 – 1.8) at the time of sampling.

Overall, both creeks appear to be connected to groundwater to some extent and undergo evaporation.

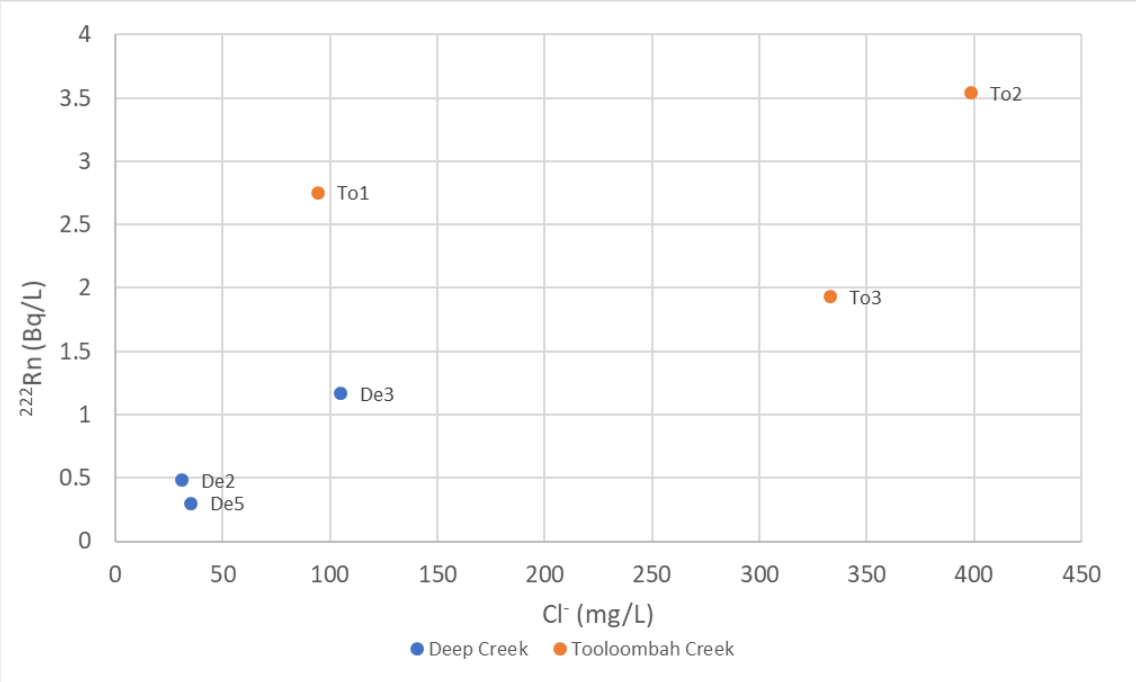


Figure 15-24 Radon vs. chloride

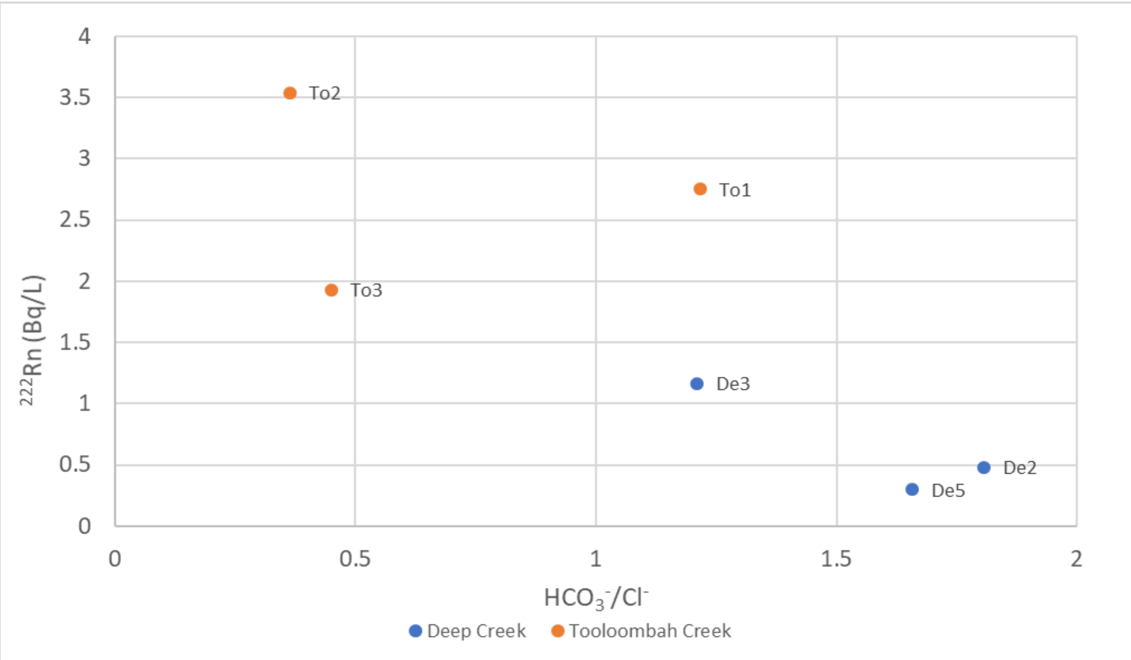


Figure 15-25 Radon vs. bicarbonate/chloride ratio

15.6.7.4 Summary

The environmental isotopes along with the radon isotopes indicate the creeks are, to some extent, connected to groundwater at the time of sampling. The clear distinction between the environmental isotopes of groundwater and the surface water samples indicate surface water has undergone more evaporation (longer residence time) relative to groundwater. The groundwater samples are less depleted and where they plot on the global and local MWL indicate rainfall is the main source of recharge and that the water underwent little to no evaporation prior to recharge.

δ^2H and $\delta^{18}O$ results from the Deep and Tooloombah Creeks pools shows the isotopes have been enriched as a result of evaporation. It also indicates they have higher retention time (relative to the recharge source of the groundwater).

The radon analysis on Deep and Tooloombah Creeks water samples indicate Deep Creek is less connected to groundwater and has longer residence time relative to the Tooloombah Creek (relatively higher chloride and ^{222}Rn). The presence of bicarbonate and chloride in both creeks (HCO_3^-/Cl^- ratio ranging between 0.4 and 1.9) indicate groundwater baseflow supports creek pools, albeit not in significant quantities.

15.7 Potential Impacts on Environmental Values

The Project has the potential to impact aquatic EVs, including threatened fauna, wetland-associated vegetation communities and other aquatic EVs within the Project area. These include:

- Remnant vegetation (including riparian communities associated with watercourses in the Project area);
- Potential populations of threatened aquatic fauna - Estuarine Crocodile;
- Habitat for aquatic fauna including natural or man-made wetlands, stream habitat and GDEs;
- Ecological functioning (e.g. riparian habitat connectivity, surface water flow diversions, and flood harvesting); and
- Groundwater drawdown impacts to GDEs and stygofauna communities.

Project activities may have potential to impact aquatic values associated with MSES on or adjacent to the site, and associated with downstream estuarine / marine waters including:

- Waters and habitats of the GBRCMP;
- Waters and habitats of the Broad Sound FHA;
- Protected wildlife habitat –adjacent to the Project area (Estuarine Crocodile habitat within the Styx River) and to a much lesser degree of likelihood and severity, downstream habitat for migratory shorebirds (estuarine habitat including mudflats, mangroves and saltmarsh) and large marine fauna potentially utilising the Broad Sound area such as inshore dolphins, Green Turtle and Flatback Turtle);
- HEV waters in the Styx River and Broad Sound as mapped downstream of the Project area;
- WPAs – one located within the Project area boundary, and five downstream WPAs located offstream of the Styx River. All are the same vegetation community - RE 11.3.1a (palustrine wetlands with estuarine influence with woodland overstorey of *Melaleuca* species and Forest Red Gum). The downstream WPAs are more than 13 km north of the Project and offstream of the Styx River, thereby making the potential for Project-associated impacts extremely low; and
- Marine plants located downstream of the Project area including mangrove, saltmarsh, and estuarine grass species such as Marine Couch.

15.7.1 Vegetation and Wetland Clearing

The Project will require the clearing of remnant vegetation for construction of the open-cut mine pits, spoil dump areas, dams, coal conveyors, haul roads and TLF. The layout of the proposed mine, associated infrastructure and the existing remnant vegetation on the site is depicted in Figure 15-26.

The Project will result in limited clearing of riparian habitat (RE 11.3.25) for the haul road along Deep Creek and Barrack Creek (total of 0.34 ha predicted based on ground-truthed vegetation assessment). Riparian habitat along a minor tributary of Deep Creek located north of the highway will also be impacted as it lies within the footprint of the Open Cut 2, Waste Rock Stockpile 2, and Dam 1 (total of 20.9 ha predicted based on ground-truthed vegetation assessment). Although onsite observations indicate this waterway is minor and degraded with a narrow riparian zone surrounded by cleared lands.

Remnant riparian vegetation may provide habitat values for aquatic fauna such as shading, bank stability and inputs of instream leaf litter, fallen woody debris and seasonal fruits. There is potential for additional impacts including extended in-stream sediment loads (turbidity) (Crerar et al. 2010), and further riparian vegetation loss and degradation due to bank instability as a result of construction activity at creek crossings.

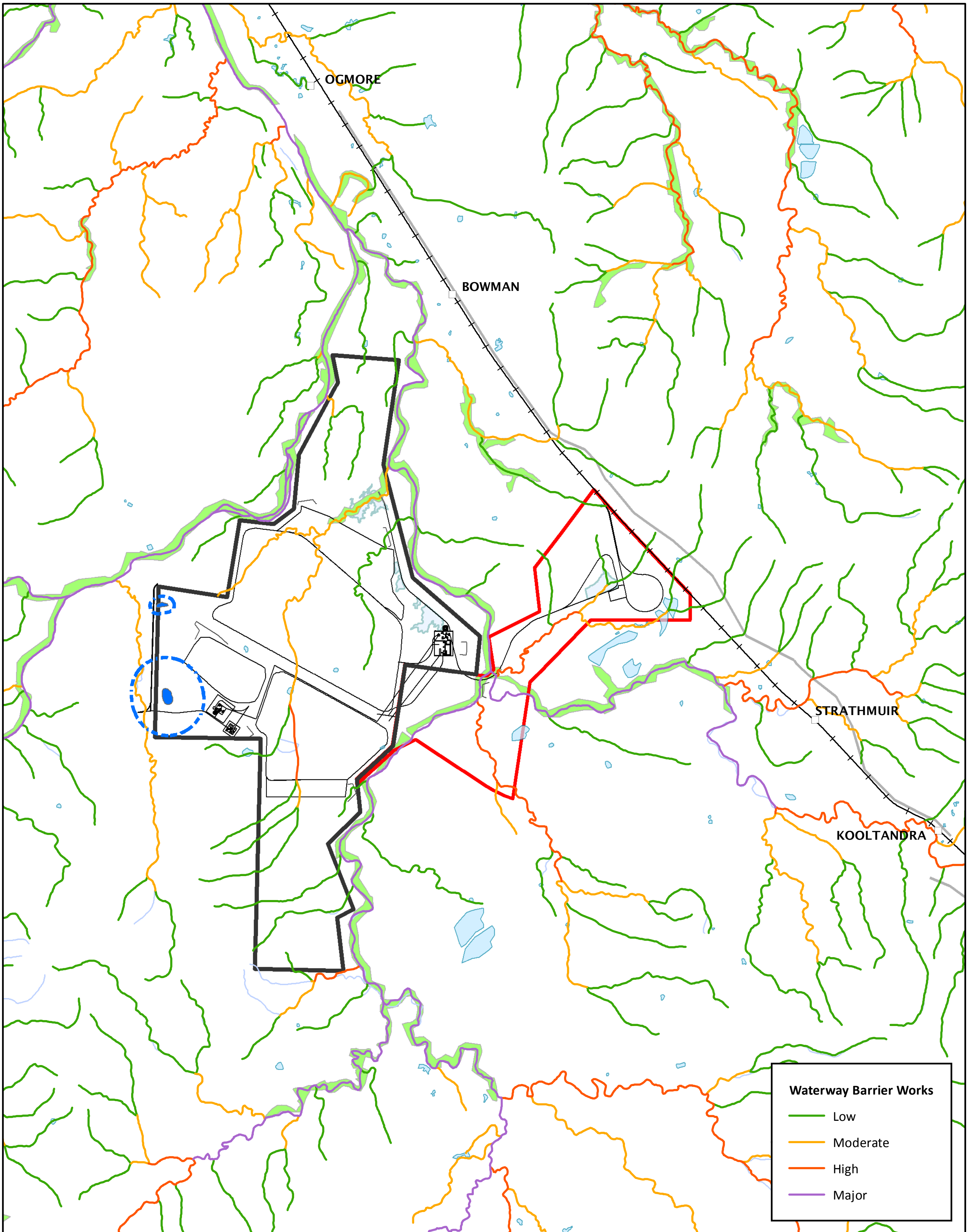
Two wetlands mapped as MSES are located within the site, including a single WPA mapped as a HEV wetland (Wetland 1). Both occur in the western portion of the site. No mine infrastructure will intersect the 500 m buffer area surrounding the WPA. The proposed new access road for CHPP / MIA 1 and Mount Bison Road will intersect the buffer area of the WPA approaching to 130 m at its closest point (Figure 15-26). The access road is predicted to remove a linear strip of vegetation comprising approximately 1.8 ha within the WPA buffer area (based on the maximum road width of 20 m). The Mount Bison Road and an unmapped track already occurs within the buffer area to the south and west of the WPA respectively. The WPA occurs on a gentle slope from south to north and the proposed clearing impact is not expected to impact water quality entering the wetland area. Central Queensland Coal will configure the final design / route for the access road in such a way as to avoid impacts to the WPA.

Wetland 2 is located on the western boundary of the ML encompassing an area of approximately 0.6 ha. The Project design has been reviewed since the SEIS was submitted and this wetland will no longer be impacted by Project infrastructure. It is located approximately 550 m north-west of the nearest Project infrastructure – Environmental Dam 1b.

15.7.2 Waterway Barrier Works and Fish Passage

The Fisheries Act deals with the use, conservation and improvement of Queensland's fisheries resources and fish habitats. The Act seeks to ensure adequate provision for fish movement and habitat access during development processes. The waterways of the area, as mapped in the DAF waterway barrier works spatial data layer, are shown on Figure 15-26*.* Waterways are depicted as a coloured-coded stream network from the upstream limit, downstream to the tidal or wetland conclusion. The colour-coding along the watercourse length indicates the risk of potential adverse impact from instream barriers on fish movement. Streams that are not coloured on the data layer are not considered waterways. Structures or potential barriers on uncoloured features do not require approval or assessment as waterway barrier works under the Act. The Guide acknowledges that as the mapping has been derived from pre-existing products, there may be inaccuracies that have continued from these base layers.

Deep Creek, Tooloombah Creek and Barrack Creek are mapped as 'major' waterways, while a number of smaller waterways within the ML are mapped as 'low' or 'moderate' risk waterways. A single small section of a drainage line (in the Deep Creek catchment) to the south of the highway is mapped as 'high' risk. It is evident, that within the ML, these waterways have been subject to substantial modification.



N

0 1 2 km

Scale @ A4 1:80,000
Date: 01/11/18
Drawn: Gayle B.

Legend

- Wetland (VM Act)
- Wetland Buffer
- Remnant Vegetation (DNRME) RE 11.3.25
- ML 80187
- ML 700022
- Mine infrastructure
- Main Road
- North Coast Rail Line
- Watercourse
- Reservoir
- Dam

Figure 15-26
Mine layout on MSES aquatic values – wetlands, waterways (fish passage) and riparian vegetation

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 15_Supp_Report_Aquatic Ecology\1000111 existing aquatic values_15-11.mxd 11/1/2018

The majority of the Project footprint lies within drainages associated with Deep Creek (i.e. Open cut 1 and 2, Waste Rock Stockpile 1a and 2, and Dam 1) and will be heavily impacted. The mapped waterways lie in a heavily modified landscape including several dammed areas, particularly south of the Bruce Highway where the creek system has been subject to a substantial network of artificial embankments. These drainage features are highly ephemeral and their extent does not extend far beyond the boundary of the ML if at all, resulting in a small catchment area. The potential for fish passage is considered extremely low, or nil, given the lack of connectivity to either Deep or Tooloombah Creeks.

Under the current mapping at least 13.4 km of mapped waterway may be impacted by the Project footprint, excluding upstream sections of the waterways. Central Queensland Coal considers some of these waterways to be incorrectly mapped and have prepared a mapping revision for submission to the DAF limiting the impact area to approximately 7 km of waterway providing potential fish passage in the Project area (refer Appendix A21 for the full waterway revision document). Further discussions with DAF will be ongoing regarding assessment of these water features.

15.7.3 Aquatic Habitat Connectivity

Aquatic habitat connectivity may be disturbed as a result of the Project largely by the potential for obstructing movement of aquatic fauna across Deep Creek and Barrack Creek as a result of the haul road crossing. A minor tributary of Deep Creek within the northern portion of the Project area will be heavily impacted by construction of Dam 1, Waste Rock Stockpile 2 and Open Cut 2 mine area, although it is uncertain whether fish occur in this creek line given it is already heavily disturbed and highly ephemeral. The only water observed in February 2017 was restricted to isolated, small turbid pools. Site observations during dry season sampling in February 2017 confirm the tributaries of the Styx River are ephemeral upstream of the intersection of Deep Creek and Tooloombah Creek. Deep Creek and Barrack Creek are ephemeral due to the relatively small catchment providing inflows. Flowing conditions were observed during surface water quality investigations in May 2017 following heavy rains in the previous month. A subsequent survey in June recorded no flow and a relatively small and shallow pool at the site of the proposed crossing of Deep Creek.

The Project lies on a relatively flat plain. Flood modelling indicates the Project is unlikely to directly or indirectly increase water velocities within waterways or waterway diversions (refer Chapter 9 – Surface Water) to a level that would prevent fish movement through a structure downstream of the Project area.

15.7.4 Direct Fauna Mortality

Direct mortality of aquatic fauna may occur as a result of the Project during construction works associated with creek crossings and clearing of wetlands / dams. Mortality during riparian habitat clearing and instream works will be managed through the presence of a qualified fauna spotter.

15.7.5 Dust

Increased dust resulting from excavations, topsoil stripping, vehicle movement, open-cut mining activities, construction of infrastructure, coal transport (by road and conveyor) and from coal stockpiles has the potential to impact local flora and fauna values within and surrounding the Project area throughout construction and operation.

Coal dust can result in adverse impacts on plant photosynthesis and productivity (Chaston and Doley 2006), changes in soil properties ultimately impacting plant species assemblages' (Farmer 1993; Spencer and Tinnin 1997) and mortality and / or decrease in aquatic health on aquatic communities from the toxicity of poor water quality. Naidoo and Naidoo (2005) found coal dust on mangroves located within 3 km of a coal terminal in South Africa impaired the productivity of two out of four species tested by reducing photosynthetic activity. Only leaves that were 'extensively covered and appeared black' were tested.

The deposition of (unpaved) road dust on nearby freshwater wetlands caused by heavy traffic increases due to energy development projects found minimal impact on water quality or soils (Creuzer et al. 2016). However, the actual impacts on wetlands or wetland vegetation from coal dust deposition, as (opposed to increased atmospheric dust) appear little studied.

The predominant wind directions from the region are as follows: from the north and northeast during spring; north, northeast and southeast during summer; in autumn, the winds are primarily from the southeast; and southerly and southeast winds are more frequent during the winter season. Modelling of potential dust particle deposition resulting from both Project construction and operation activities showed the areas most likely to be impacted were receptor points located to the direct west of the Project (Tooloombah Creek service station) and in the Ogmore area to the north of the Project. However, these impacts were minimal in comparison to the modelled natural background dust concentration and all concentrations were below air quality criteria set by the State under the Environmental Protection (Air) Policy 2008 (refer Chapter 4 – Climate for more information).

As shown on the revised layout for the mine (see Figure 15-26) (detailed in Chapter 3 – Description of the Project) the coal conveyor is no longer located along Deep Creek. Vegetation along Deep Creek in the vicinity of the Project area has potential to be impacted during construction works for infrastructure (such as access roads), the CHPP / MIA 2 area and Dam 1 which is located within 500 m of Deep Creek. Operational Project components located close to creek lines includes Open Cut 1 and Waste Rock Stockpile 1a (200 m to 300 m from Deep Creek), Open Cut 2 (north-west corner adjacent to Tooloombah Creek and south-west corner adjacent to eucalypt woodland), and Waste Rock Stockpile 2 (adjacent to both Tooloombah and Deep Creeks). It is important to note that mining activities in the Open Cut Pits and Stockpile areas will be sequential and will include rehabilitation of mined areas as the Project progresses.

The haul road between MIA 2 and the TLF crosses Deep Creek and Barrack Creek, although there are no large, permanent pools on either creek at, or near, the proposed haul road crossing points. Dust emitted during coal transport may have a minor potential to impact riparian vegetation associated with the creeks where they occur adjacent to the haul road (see EIS Chapter 12 – Air Quality for further information).

The WPA is located approximately 550 m west of Open Cut 1 and Waste Rock Stockpile 1b. An existing screen of trees 150 m wide will remain between the WPA and existing cleared habitat and Project activities. Increased dust deposition may have potential to impact on this wetland although air quality modelling for the Project suggests the effects are likely to be minimal compared to background atmospheric dust.

Chronic exposure to high and localised concentrations of fine coal particles (as associated with bulk coal marine transport spills) have been found to have lethal effects on coral and impact the growth rates of tropical fish and seagrass (Berry et al. 2015). Coal contains contaminants such as metals and polycyclic aromatic hydrocarbons which may pose a risk to aquatic organisms including marine species. However, recent research indicates the risk of these contaminants leaching into seawater is low (Jaffrennou et al. 2007; Lucas and Planner 2012, Berry et al. 2015). The risks of fine coal particles in water are likely to be physical processes where there is a concentrated point source or plume of particles. This may have effects such as the physical smothering of benthic fauna, and attenuation of light inhibiting algae (Jaffrennou et al. 2007) or seagrass growth.

Marine values associated with the GBR area downstream of the mine area include extensive areas of mudflats, saltmarsh flats and mangroves. These habitats support valuable fish breeding areas as well as resident and migratory shorebirds. Coral communities and seagrass meadows do not occur to any great extent in the vicinity of the Styx River (refer Figure 15-4). Given the distance these habitats are away from the Project area, the use of purposely engineered permanent and temporary erosion and sediment control infrastructure and the relatively minor extent of the modelled impacts it is considered that coal dust deposition from Project activities will not impact downstream marine habitats, including those associated with the GBR.

15.7.6 Pests and Weeds

Pest and weeds pose one of the most significant threats to aquatic flora and fauna within and adjacent to the Project area. Much of the riparian habitat associated with the creek lines already contains infestations of introduced weed species, particularly Lantana and Rubber Vine. Olive Hymenachne is a semi-aquatic grass species that may infest and choke wetlands and waterways. The species was observed in a farm dam in February 2017 and within a wetland gilgai in May 2017, and was observed in many wetland areas by January 2018 (although not along any creek line waterholes). Parthenium is toxic to cattle and was observed growing on the bed of Tooloombah Creek at To2. No other infestations of this species were observed within the Project area. These weed species are listed under Queensland’s Biosecurity Act and as Weeds of National Significance.

A total of 28 fish species were recorded during the 2011 survey (including 18 species in the freshwater sites) indicating a relatively diverse native fish fauna. No introduced fauna species were collected during surveys for the Project which indicates that the Styx River catchment may be relatively free of introduced taxa such as Tilapia (*Oreochromis* sp.) and Mosquito fish (*Gambusia* sp.).

Any potential unmitigated introductions of weeds and pests as a result of Project activities may therefore pose a risk to the productive capacity of wetlands / waterways and may impact the local diversity of the resident fish community. The transportation and operation of construction vehicles and equipment has the potential to introduce weeds into the Project area. Project activities are not considered likely to introduce aquatic pest fauna. Weed and pest management measures will be developed and implemented to manage these risks.

15.7.7 Accidental Release of Pollutants

Changes to surface water quality may also occur due to contaminated runoff from the haul road, waste rock stockpile areas, coal stockpiles and other infrastructure elements such as environmental dams. Coal mine water collected in dewatering and sediment dams may contain a range of pollutants (depending on the source material) such as hydrocarbons and heavy metals. The release of pollutants into the surrounding environment and waterways has the potential to cause mortality to aquatic fauna, degrade stream habitat quality near the Project and degrade downstream stream marine water quality in the Broad Sound area. Without mitigation, potential exists for several potential contaminants to enter waterways including: contaminated mine dewatering runoff; contaminated runoff from waste rock stockpiles; aqueous waste streams including oily waste water (from heavy equipment cleaning); contaminated runoff from chemical storage areas; potentially contaminated drainage from fuel oil storage areas; and general washdown water.

Contaminated runoff has the potential to impact potential habitat for Estuarine Crocodile should downstream waterholes on the Styx River be impacted. Contaminated runoff also has the potential to enter the Styx River, temporarily impacting localised MSES values such as mangroves and saltmarsh communities, habitat for migratory shorebirds and fish species. In the unlikely event contaminated run-off entered large marine fauna. However, given the transient nature of such an event (should it occur) and the large tidal regime in Broad Sound and the Styx River, it is considered any contaminated runoff will be diluted by tidal waters and unlikely to cause any significant or lasting impact to these values.

During operations, Deep Creek and Tooloombah Creek are not anticipated to be directly impacted by surface water runoff from Project infrastructure as rainfall runoff will be captured in a number of environmental dams for re-use or treatment specific to each mine component (CHPP 1 and 2, Waste Rock Stockpile 1a and 1b, Waste Rock Stockpile 2 and the TLF).

Deep Creek is located within 200 m of the eastern edge of the Open Cut 1 and Waste Rock Stockpile 1a areas and over 500 m from the south-eastern corner of Open Cut 2. Other potential sources of pollutant inputs into waterways include the CHPP / MIA 2 area which is located approximately 500 m from Deep Creek. Waste Rock Stockpile 2 is located within 300 m of both Deep Creek and Tooloombah Creek (when considered at its full extent) and thereby has potential to release contaminated run-off in the creeks (although for the most part this area drains toward Deep Creek). Surface water run-off from the TLF facility will be diverted into for remediation before discharge into Barrack Creek. All environmental dams will be designed to capture the 1:10 year ARI, 24 hr duration storm event and have been sized in accordance with DES stormwater guidelines (EHP 2014b).

Cattle will be excluded from the majority of Mamelon property including all of ML80178. Vegetation outside of the Project footprint will be allowed to regenerate in previously cleared areas. In the longer term this will create a vegetated buffer reducing sediment and nutrient run-off from the property into the waterways and downstream habitats. Together with Project erosion and sediment controls outlined in Section 15.7.8 it is predicted there will be minimal (if any) impact on surface water runoff, and in the long-term water quality of runoff may improve due to improved land management practises. The proposed detailed design of the water storages and other water infrastructure components associated with the Project is described in detail in Chapter 9 – Surface Water.

15.7.8 Sedimentation of Waterways and Sediment Runoff

During construction and operation of the mine sediment can be mobilised and transported by surface water during rainfall events ultimately discharging into drainage lines which can result in negative impacts on water quality and aquatic habitats. Specifically, increased suspended sediments can reduce light penetration, decreasing photosynthesis of aquatic flora, and decrease dissolved oxygen. This has potential to impact marine taxa such as seagrass and algae beds, and corals.

The potential impacts of erosion and sedimentation from surface water rainfall runoff, if not adequately mitigated, could produce impacts on localised and downstream water quality and aquatic ecosystem EVs.

This may impact downstream refugial pools in Deep Creek and Tooloombah Creek, although for the most part the Project area drains towards Deep Creek. These creeks in turn drain into the Styx River which ultimately drains into Broad Sound and the GBR area. Suspended sediments from runoff will potentially contain elevated nitrogen and phosphorus levels due to the agricultural activities within the surrounding landscape – notwithstanding this already occurs through existing cattle grazing activities and would not be exacerbated by the Project given the Project would not contribute to nitrogen and phosphorous levels in the pools. Surface water quality sampling and observation recorded naturally higher turbidity levels in Deep Creek sites (refer Section 15.6.3.1). The Project has committed to the removal of cattle from much of the property and allow vegetation regeneration in cleared areas, so this could be expected to decrease over time. Increased nutrients can promote algal growth and in extreme cases result in blooms and surface water deoxygenation within low flow situations.

If stormwater runoff is not adequately contained, particularly during the construction of the mine infrastructure components, there is potential for sedimentation and contamination to adversely impact the surface water receiving environments. Erosion and sedimentation during the operation phases is most likely to occur from stormwater runoff from the coal stockpiles, CHPP / MIA areas and ongoing minor earthworks associated with the maintenance of roads and dams.

Impacts to Tooloombah Creek are less likely, as this catchment is isolated from the majority of the Project infrastructure components. Environmental Dam 1b (associated with Waste Rock Stockpile 1b) and Environmental Dam 2a (associated with Waste Rock Stockpile 2) both drain towards Tooloombah Creek.

Baseline water quality monitoring results indicated that existing waterways generally have low to moderate turbidity and suspended sediment loads during flow periods (such as sampled in June 2011 and May 2017). During dry periods when the waterways are reduced to isolated pools high levels of turbidity and suspended sediment loads were recorded consistently in the Deep Creek sites.

The waters of Broad Sound are shallow and subject to a large tidal regime with resulting naturally high turbidity levels. The extensive grazing activities within the Styx catchment and adjoining catchments, including extensive vegetation clearance and un-managed erosion, contribute significantly to the existing high turbidity of the habitat downstream of the Project and more generally the Broad Sound environments. An assessment of the volume of sediment that has potential to be mobilised through cattle grazing on Mamelon is at Chapter 5 – Land.

The currents associated with the tides already leads to constant resuspension of sediment in the water column – attributable to cattle grazing and land clearing activities already occurring in the contributing catchments. The turbidity plume extends outwards from Broad Sound to local islands in the Capricorn area of the GBR (Kleypas 1996). When combined with the extreme tidal range (potentially leaving prolonged exposure of the substrate during low tides) there are few marine habitats supporting MSES fauna directly downstream of the Project (such as coral reefs and seagrass meadows) (refer Figure 15-4). Downstream mangrove communities entrain suspended sediments contributing to the extension of existing mud banks (Furukawa 1996). The release of suspended sediments has potential to extend mangrove habitat thereby creating more breeding habitat for fish species and foraging habitat for threatened shorebirds.

As described previously a number of water diversions and environmental dams will be constructed as part of the Project layout minimising entrained sediments entering the creek lines during heavy rainfall events. The Project lies at least 14 km upstream of the nearest mangrove habitat and given the background occurrence of high turbidity in Broad Sound waters it is considered very unlikely that any accidental (and temporary) release of suspended sediments from Project activities will possibly be of a magnitude that may impact downstream MSES associated with the GBR and other marine EVs.

Several Project components including the site access road and haul road, will traverse a number of drainage features. At these crossings impacts may include riparian vegetation clearing, direct deformation of the bed and banks, and alteration of hydrological flows. Consequential impacts could include decreased instream and riparian habitat, and vegetation removal and earthworks leading to increased erosion and sediment entering downstream waterways. The haul road crosses Deep Creek and Barrack Creek. There are no large waterholes at these crossing points which will require direct disturbance during construction. As a result, no direct impact to aquatic MSES habitat is considered likely.

The potential impacts of erosion and sedimentation from surface runoff, if not adequately mitigated, could produce medium level impacts on localised and downstream water quality and aquatic ecosystem EVs.

15.7.9 Hydrology and Water Flows

The Project activities that may impact surface water hydrology are described in detail in Chapter 9 – Surface Water. The Project will impact on surface water flows as mine infrastructure will decrease the local rainfall catchment area. The Project is largely located within the catchment of Deep Creek. The two major mine pit components (Open Cut 1 and Open Cut 2) will require diversion of two minor drainage lines of Deep Creek (one 1st and one 2nd Order drainage features). Water will be diverted to both Deep Creek and Tooloombah Creek. Diversions will be carried out in a progressive manner as the pits expand. The haul road and other infrastructure will also impact Deep Creek and Barrack Creek including the potential for direct deformation of the stream bed and altering hydraulic flows.

Modelling of local flood levels in Deep Creek and Tooloombah Creek as a result of a reduction in catchment size due to Project activities shows only a very minor reduction in peak flows. Under the 0.1% AEP design flood event there is predicted to be a 2 cm reduction in peak flood level at the confluence of Deep Creek and Tooloombah Creek (the Styx River) downstream of the Project. Flood diversions within the Project infrastructure will lead to a predicted localised rise in peak flood levels in Deep Creek of 7 cm, and Tooloombah Creek of 3 cm. As would be expected, peak velocities are predicted to decrease commensurately. Changes of this magnitude to peak flows is considered unlikely to cause impacts (such as increased scouring / erosional processes) on aquatic EVs, (including downstream) particularly as peak flows only occur for a short duration of time.

Dam 1 is proposed to be built across a 2nd order watercourse to the north of mining activities (within the mine ML) to supply potable water for the life of the Project. As the upstream catchments will be largely removed due to Project construction, water is to be stored in the dam by pumping water from the environmental dams collecting stormwater run-off on the site. This is not expected to impact aquatic downstream EVs due to the highly ephemeral nature of the creek.

Watercourse and creek crossing structures may cause a localised increase in runoff velocity due to construction of culverts and conveyance features that eliminate natural features such as meanders and increase in slope. However, with appropriately designed stormwater and crossing structures this is unlikely to cause more than localised and very minor changes to surface hydrology.

15.7.10 Changes to Groundwater Table and GDE Impacts

Modelling of the potential drawdown effect of the open cut mine operations has been updated based on the collection of further groundwater data since the EIS. This includes the establishment and sampling of 16 Project monitoring bores installed from September 2017 to March 2018. A further 30 Project monitoring bores have been installed in September and October 2018. These have been specifically located to provide greater coverage around the Project (for groundwater heads and quality), especially near to watercourses to assess potential for groundwater and surface water interactions and vertical hydraulic gradients between shallow and deeper hydrostratigraphy.

The Project area is dominated by shallow alluvial aquifers which are intersected by deeply incised ephemeral creeks. Recharge to this system is from direct rainfall, leakage from the creeks during surface flow events and from the underlying units. Surface pools exist within streambeds of

Tooloombah Creek and Deep Creek. The pools in Tooloombah Creek and in the lower reaches of Deep Creek are groundwater fed (i.e. Type 2 GDEs), albeit to a much lesser degree than Tooloombah Creek, during dry periods. A review of groundwater bore information and groundwater dependent ecosystems in the Project area indicates the water table reaches the rooting depth of riparian vegetation along Tooloombah Creek and Deep Creek (RE 11.3.25) and the alluvial community adjacent to Deep Creek (RE 11.3.4) although there is a lack of understanding around the groundwater environmental requirements of these communities. Elsewhere (i.e. away from watercourse), the water table is deeper, generally >10 mbgl and it is unlikely that groundwater forms a large proportion of terrestrial GDEs water requirements, if at all.

15.7.10.1 Groundwater Quantity

The Project area is characterised by local to intermediate groundwater flow systems (i.e. the distance between recharge and discharge zones ranges between less than a few kilometres up to between 10 and 20 km). Groundwater flow analysis shows that, prior to mining, groundwater discharges locally to Tooloombah Creek but only intermittently to the lower sections of Deep Creek. Groundwater also discharges to the Styx River itself, the Broad Sound estuary, and low lying areas closer to the coast. Significant amounts of groundwater are expected to be lost via evapotranspiration (ET), either directly from the water table or from plant transpiration.

Where the water table is close to surface (generally within a few metres), which will be typical along the riparian zone of most stream reaches in the mid to lower catchments of Tooloombah and Deep Creeks, Styx River and the Broad Sound estuary, significant amounts of groundwater will be lost via evapotranspiration, either directly from the water table or from plant transpiration.

Open-cut mining will extend below the water table within the proposed mine lease. As overburden rocks and coal seams below the water table are removed, groundwater will seep into the mine void from the intersected saturated strata. Collection of this water to facilitate dry and safe mining conditions, either via ex-pit dewatering bores or in-pit sumps, will depress groundwater heads immediately surrounding the pit to the approximate elevation of the pit floor and a cone of depression (groundwater drawdown / depressurisation) will extend outwards from the pit void. Surrounding hydrostatic units will depressurise and a zone of groundwater depressurisation that decreases in magnitude with increasing distance from the mine pit will develop. The zone of depressurisation represents depletion of groundwater storage (unconfined and confined).

Once backfilling commences, groundwater storage (and groundwater heads) will commence recovery back toward the pre-mine condition.

Impacts to GDEs may result if they are exposed to a direct effect of mining, primarily altered groundwater quantity (drawdown, head, flux) and altered interactions between groundwater and surface water (and connected systems). The scale of the direct effect, both spatially (i.e. the extent of a GDE exposed to an adverse impact) and temporally, (the length of time the GDE is exposed to that impact) combined with the GDE's capacity to adapt to altered conditions (i.e. its resistance and resilience), determines the level of threat. For example, an ecosystem reliant on surface expression of groundwater that is exposed to a significant reduction in baseflow, even if only for a short period of time may result in a high level of threat, as it may not be resilient to that change. Conversely, a terrestrial vegetation ecosystem that is exposed to a significant drawdown in water table, even for a long period of time (e.g. several years) may result in a low level threat, as they are able to utilise other sources of water e.g. soil reservoir.

The magnitude of drawdown caused by mine dewatering ranges up to >100 mbgl although this is restricted to the pit areas within ML 80187. This occurs within the first five years of mine operation and may persist for up to 20 years post-mining. The cone of depression is initially steep, reflecting the change in geology from Quaternary sediments to the outcropping (Permian) basement units. Further decline in the groundwater levels propagates outwards from the mine pits and particularly to the north-west the north-west creating an oval shaped region of impact that is effectively confined to the Quaternary sediments.

Figure 10-69 to Figure 10-79 in Chapter 10 – Groundwater depict the predicted changes to potentiometric surface drawdown over the life of the mine and following closure. The 0.1 m potentiometric surface drawdown contour extends to a maximum of approximately 5.5 km north-west of the mine (but does not intercept the Styx River). The maximum drawdown extent occurs at 10 years post mining (Figure 15-27) and after 25 years post-mining, the groundwater system begins to recover back to pre-mining conditions, with regional groundwater flow occurring to the north, and local groundwater flow occurring to the watercourses. Fifty years following closure the predicted extent of the 0.1 m and 1 m drawdown contours have begun to contract back towards the decommissioned and back filled pits, and by year 100 following closure the groundwater system is predicted to have fully recovered to the pre-mining status.

15.7.10.2 Groundwater Quality

The potential exists for groundwater quality to be altered in a number of ways, largely in response to changes in groundwater quantity:

- Evaporative concentration of salts in temporarily open mine voids whilst they remain open (noting that all Project voids will be backfilled);
- Possible induced flow of groundwater of different quality towards depressurised parts of the groundwater system associated with dewatering / depressurisation;
- Infiltration of water from Waste Rock Stockpiles and mine water storages (Dams 1 to 4);
- Accidental release of chemicals (such as unintended fuel spill, leakage of sewage effluent, infiltration of stormwater from mine 'contact' areas); and
- Mobilisation of the 'seawater-freshwater' interface at the coast. A nested monitoring bore has been established along the tidal reach of Styx River (WMP29 located 4.2 km downstream of the junction of Tooloombah and Deep Creeks). Hydraulic head and groundwater salinity data for the site indicates the interface is located further downstream toward the coast from the bore site. Groundwater drawdown modelling shows a lack of drawdown in the lower reaches of the tributary catchments (Tooloombah and Deep Creeks) and downstream of the confluence of these creeks (Figure 15-27) indicating the potential for upstream seawater intrusion is negligible.

Waste Rock Leachate

Waste rock characterisation detailed in Chapter 8 – Waste Rock and Rejects. Overall, the risk of acid generation from waste rock and coal reject materials is considered low, with over 98% of samples analysed classified as NAF (RGS Environmental, 2012). An assessment of the potential to generate acidic leachate from waste rock and coal reject material has also been undertaken (RGS Environmental, 2012). The assessment found metal / metalloid concentrations in water extracts were within the same order of magnitude as the assessment criteria, generally consistent across composition samples and, therefore, likely to be consistent with existing concentrations within the regional geology.

Waste rock has been classified as:

- Acid consuming:
  - Will likely remain pH neutral to alkaline following excavation
  - Dissolution of heavy metals in an acidic environment is unlikely
- Having low potential to be potentially acid forming;
- Having moderate saline drainage potential; and
- Potential to be highly sodic.

Leach testing demonstrates there is low potential for generation of acid from waste materials (including coal rejects), and that leachate generated from waste materials is expected to be less saline than baseline surface water and groundwater. However, there is the potential for some metals / metalloids (such as As, Mo, Se and V) to be elevated above aquatic ecosystem criteria (e.g. ANZECC 2000), although many metals / metalloids do naturally occur above these criteria (refer Section 10.5.5.3 of Chapter 10 – Groundwater).

Acid Sulfate Soils

Acid sulphate soils (ASS) contain iron sulphides that have the potential to produce acid when exposed to oxygen, e.g. when drained or excavated. The CSIRO National ASS mapping illustrates that ML 80187 and ML 700022 are described as having a low to extremely low probability of containing ASS. The National ASS mapping (Fitzpatrick et al. 2011) in relation to the proposed mine, and the location of the 10 m AHD contour is shown at Figure 5-14 in Chapter 5 - Land. The Project area straddles the low to extremely low ASS categories and is located beyond the 20 m contour (see Figure 5-14). CSIRO mapping shows only small pockets of high probability of ASS occurrence (e.g. around 7 km downstream of the Project, below Ogmore).

Predicted contours of water table elevation and drawdown (Figure 10-62 to Figure 10-75 in Chapter 10 – Groundwater; also refer Figure 15-27) show there will be little, if any, change to average water table elevations downstream of Ogmore. Consequently, there is little to no risk of the Project causing the onset of ASS conditions.

15.7.10.3 Surface Water and Groundwater Interaction

The quantification of interactions between groundwater and surface water is often constrained by the available topographic data used to represent the ground surface and stream beds in a numerical model, as well as adopted values of stream bed conductance. In this assessment, changes to baseflow (and evapotranspiration) have been semi-quantified, i.e. they are presented as relative changes from the predicted pre-mine (baseline) condition.

The capture of groundwater during mining (to meet Project water demands and / or provide dry and safe mining conditions) can alter the degree and form of interaction between groundwater, and surface water and connected systems. For example:

- If baseflow fed water courses are located within the zone of drawdown influence of mine pits or borefields, it is probable the rate and timing of baseflow will diminish or cease until post-mine recovery occurs;
- If wetlands relying on shallow water tables or surface expression of groundwater are located within the zone of drawdown influence of mine pits or borefields, the wetlands may become disconnected from groundwater until post-mine recovery occurs;

- Water storages and sediment ponds may leak and cause water table mounding beneath the facilities, which may raise water tables near wetlands and terrestrial vegetation to cause water logging, or increase rates of baseflow to nearby water courses; and
- Placement of waste rock on the ground surface has the potential to cause hydraulic loading of shallow aquifers or mounding of the water table beneath the facilities, which can give rise to displacement of water away from Waste Rock Stockpiles, potentially increasing baseflow discharge to watercourses and wetlands.

15.7.10.4 Impacts to Type 1 GDEs (stygofauna)

Groundwater drawdown has potential to impact on the vertical extent of stygofauna habitat. A maximum drawdown of around 13 m is predicted at the location of the bore (STX 093) where stygofauna have been identified (Figure 15-21) between 2036 and 10 years following the end of mining. The predicted rate of drawdown at this location is around 1.5 m/yr. Water is not suddenly removed, allowing stygofauna to move deeper the alluvium water column.

At this location the alluvial aquifer is estimated to have a saturated thickness of around 15 m, corresponding to an approximate maximum 90% loss of vertical habitat for stygofauna. Although, streamflow recharge can be expected to mitigate this loss of habitat to some extent. Full recovery of the water table to pre-mining condition is predicted to occur by around 50 years after mine closure, with a 50% recovery occurring approximately 15 years after closure.

Stygofauna at this site are therefore likely to undergo a substantial decrease in localised habitat availability and may no longer occur in the area. However, it is considered extremely unlikely that the stygofauna taxon found at the single bore (unknown taxa of water mite – Acari) will be restricted to this area or the local catchment. Therefore, no stygofaunal species is restricted to the potential impact area. On the other hand, a sample that does not contain taxa does not necessarily indicate complete absence in that aquifer setting.

Other locations where stygofauna were detected are located over 5 km north of the nearest 0.1 m modelled groundwater drawdown contour (Figure 15-27) and are not likely to be impacted.

15.7.10.5 Impacts to Type 2 GDEs (waterholes)

Groundwater drawdown has potential to impact on baseflow rates (flux) to streams and, consequently, aquatic ecosystem function. Predicted water table contours during mining show groundwater flow is diverted to the mine pit (due to dewatering / depressurisation) impacting the mid-catchment of Tooloombah and Deep Creeks (refer Figure 10-62 to Figure 10-64 of Chapter 10 - Groundwater).

Shallow surface pools exist within streambeds of Tooloombah Creek and Deep Creek which are groundwater fed (i.e. Type 2 GDEs) during dry periods (refer Section 15.6.4). The sources of groundwater supporting the Type 2 GDEs in the catchment include stream losses from surface flow events, discharge from the alluvial aquifer and / or interception of the shallow water table by deep streambeds. Along the length of Tooloombah Creek, Styx River and the lower reach of Deep Creek, the Type 2 GDEs are likely to be supplied by discharge from local groundwater flow systems, and the connection to groundwater is likely to be permanent. In the mid to upper reaches of Deep Creek, the water table is relatively flat, and the connection of Type 2 GDEs to groundwater is likely to be ephemeral / seasonal, dependent on the magnitude of the rise and fall of groundwater levels in response to recharge events.

All watercourses are likely to experience losing conditions during and following high surface flow periods, when the deep-water column within the streams (>5 m) will recharge the adjacent Quaternary sediment aquifer. As the surface flow recedes, gaining conditions can return where bank storage drains back to the stream, a local groundwater flow system drives flow to the stream, or where shallow water tables are intersected by the streambed. A decline in groundwater levels (e.g. from prolonged periods of dry weather with little to no surface flow events, or from drawdown caused by mine dewatering) may result in a reduction in the volume of groundwater discharge (baseflow and evapotranspiration) and may potentially cause disconnection of the Type 2 GDEs from groundwater (and consequently, an adverse impact on aquatic ecosystem function).

Numerical groundwater modelling predicts 0.5 m to 2 m drawdown along the mid-reach of Tooloombah Creek and 1 to 7.5 m drawdown along the mid-reach of Deep Creek until around 50 years post-mining. Although, the maximum predicted drawdown occurs at around 10 years after the cessation of mining (Figure 15-27) with recovery toward pre-mining levels commencing from approximately 25 years post-mining. Predictions indicate that a baseflow reduction (potentially >30%) will occur along the mid-lower reaches of Tooloombah Creek (i.e. downstream of the Bruce Highway) and tributaries during mining. Conditions will return to pre-mining levels after closure with approximately 50% recovery by around 65 years after mine closure, and the remaining 50% occurring within another 20 years.

Groundwater baseflow reduction will occur along the entire reach of Deep Creek and tributaries with the following predicted effects:

- Less than 10% reduction for the upper reach (i.e. upstream of the confluence of Deep Creek and Barrack Creek; refer Figure 15-27) with a slow return to pre-mining levels within around 75 years after closure;
- Upwards of 40% reduction for the middle reach (i.e. between the confluence of Deep Creek and Barrack Creek and the confluence with the tributary that runs through ML 80187 and is impacted by Dam 1; refer Figure 15-27) with a slow return to pre-mining levels after closure (~25% recovery by around 60 years after closure, and the remaining ~75% occurring within another 20 years or so); and
- Less than 10% reduction for the lower reach (from the confluence with the tributary downstream to the confluence of Deep and Tooloombah Creeks; refer Figure 15-27) with flux slowly returning to background within around 75 years after closure.

A low threat of adverse effects are expected along stream reaches supporting permanent pools within the predicted 0.1 m to 0.5 m drawdown contour, while more than 1 m drawdown is expected to cause a moderate to high threat. Based on this classification, mining effects are expected to pose a low threat of adverse impact to 3.4 km of Tooloombah Creek and 3.3 km of Deep Creek, while a moderate to high threat is expected at 2.4 km of Tooloombah Creek and 3.9 km of Deep Creek (Figure 15-27). This is an overestimate of the extent of potential impact area.

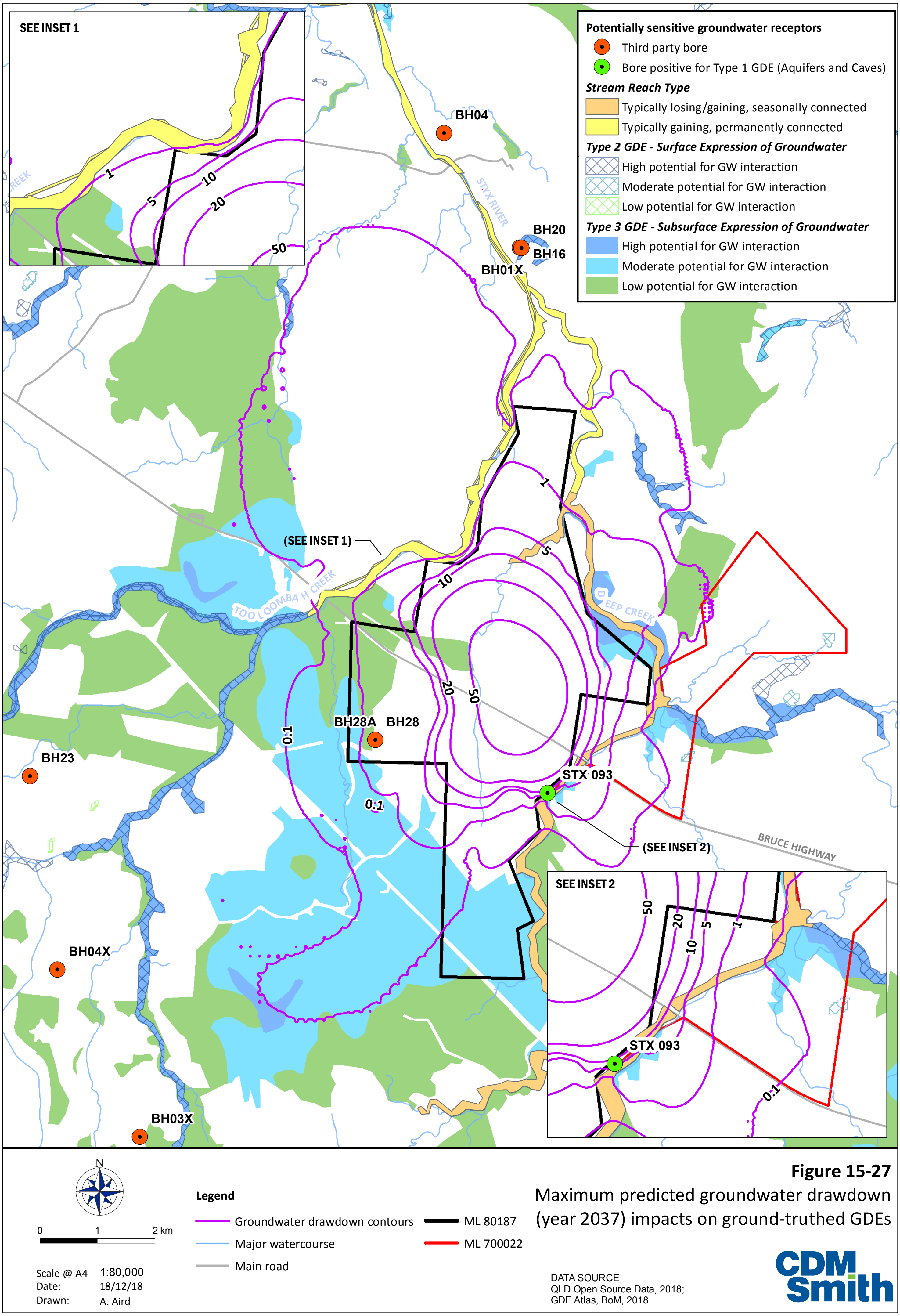


Figure 15-27
Maximum predicted groundwater drawdown (year 2037) impacts on ground-truthed GDEs

DATA SOURCE
QLD Open Source Data, 2018;
GDE Atlas, BoM, 2018

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 16_Supp_Report_MNES\1000111 contour__ground-truthed GDEs.mxd 12/18/2018

15.7.10.6 Impacts to Type 3 GDEs (riparian / terrestrial vegetation)

Type 3 GDEs (including RE 11.3.25 and RE 11.3.4) occur along riparian zones of Tooloombah and Deep Creek. Two wetland areas mapped as Type 3 GDEs (Figure 15-8) are not considered connected to groundwater (refer Section 15.6.4.4) and therefore will not be impacted by groundwater drawdown.

The water requirements of these vegetation communities may include multiple sources of water including soil water stores, seasonal soil water from surface water flow and groundwater. The proportion of water use from each source making up the water requirements will influence the vegetation community's resistance to changes in groundwater. For example, if the predominant source of water use is soil water, then changes to groundwater may be less likely to adversely impact the vegetation community.

The water requirements of GDEs relevant to the Project area is uncertain. It is; however, assumed that vegetation communities along riparian areas, where the depth to groundwater varies from around 10 mbgl along creek banks to 0 mbgl (i.e. at ground surface) within creek beds, are likely to utilise groundwater during dry periods when the soil water reservoir becomes depleted (i.e. seasonally). In terrestrial areas (i.e. away from riparian zones), the depth to groundwater is typically between 10 and 20 mbgl or deeper. Although these observations do not preclude deep-rooted plant species from potentially using underlying groundwater, it is likely that groundwater is only a small component of water use during extended periods of limited soil water availability (i.e. droughts).

A decline in groundwater levels may result in a reduction in the volume of water available to Type 3 GDEs for transpiration and consequently, an adverse impact on riparian and terrestrial ecosystem function. Between 0.1m and 5 m drawdown is predicted beneath riparian GDEs (RE 11.3.25) along Tooloombah Creek. Between 0.1 and 7.5 m drawdown is predicted beneath riparian GDEs (RE 11.3.25) along the majority of Deep Creek. A small section of Deep Creek to the south of the Bruce Highway is predicted to be impacted beyond the 5 m drawdown contour (refer inset Figure 15-27). Between 0.1 m and slightly more than 2 m drawdown is predicted beneath terrestrial Forest Red Gum woodlands on alluvial plains (RE 11.3.4) associated with Deep Creek.

No drawdown is predicted along the lower reaches of Tooloombah and Deep Creeks (immediately upstream of their confluence), or the Styx River and Broad Sound estuary. Less than 1 m of drawdown is predicted on the western side of Tooloombah Creek excepting a small area to the north of open cut pit 2. The eastern side of Deep Creek experiences drawdown of between 0.5 m and 3.5 m along two stretches of the creek to the west of the pits and north-west of open cut pit 2. This impact extends approximately 800 m east of the creek at its maximum extent (Figure 15-27).

Given the limited understanding of the temporal nature of the use of groundwater for Type 3 GDEs relevant to the Project, the impacts have been considered based only on whether or not groundwater is available for use (i.e. the time of exposure to direct effects has not been taken into account) (refer Chapter 10 – Groundwater for further information). Drawdown of between 0.1 m and 1 m in riparian areas is considered to cause a low threat of adverse impacts to Type 3 GDEs while more than 1 m of drawdown is considered a moderate to high threat. Based on this classification and ground-truthed vegetation mapping, mining effects are predicted to pose a low level threat to an area of 40.3 ha of vegetation communities along Tooloombah Creek and 38.3 ha along Deep Creek. A moderate to high threat is predicted in vegetation communities encompassing 8.3 ha along Tooloombah Creek and 34.2 ha along Deep Creek.

In terrestrial areas (i.e RE 11.3.4 located where the water table is less than 10 mbgl), a low to moderate threat is considered to occur if drawdown is between 0.1 m and 5 m while a high level of threat is considered if drawdown exceeds 5 m. Ground-truthed vegetation mapping indicates there

14.25 ha of this community within the 0.1 m to 5 m groundwater drawdown contour. There are no occurrences of this community where the drawdown exceeds 5 m. These potential impacts are summarised in Table 15-17.

Table 15-17 Extent of potential threat on identified Type 3 GDEs from predicted groundwater drawdown

Threat level	Riparian vegetation (RE11.3.25)	Terrestrial vegetation (RE 11.3.4) where water table < 10 mbgl	Terrestrial vegetation (RE 11.3.4) where water table > 10 mbgl
Low to moderate	*Drawdown < 1 m* – Tooloombah Creek – 40.3 ha Deep Creek – 38.3 ha	*Drawdown < 5 m* – 14.25 ha	*Drawdown 5 m to 10 m* – 0 ha
Moderate to high	*Drawdown > 1m* - Tooloombah Creek – 8.3 ha Deep Creek – 34.2 ha	*Drawdown > 5 m* - 0 ha	*Drawdown > 10 m* - 0 ha

The rate at which draw down occurs is expected to influence the extent of adverse impacts. It is expected that a slow rate of draw down will result in a lesser impact as it is expected that root systems will, in part and over time, adjust to the lower water table. Conversely, a sharp and severe reduction in groundwater levels would be expected to result in a greater adverse impact.

15.7.10.7 Summary

Groundwater drawdown may result in long-term (up to 50 years post-mining) impacts to the following MSES:

- Water levels in permanent or ephemerally groundwater-fed waterholes in Tooloombah Creek and Deep Creek may decline in those areas closest to open cut mining, where drawdown of up to 5 m and 7.5 m respectively, and baseflow reductions of more than 30% and 40%, respectively, are predicted to occur. Should drawdown cause changes to water levels this will impact the available habitat for fauna reliant on these waterholes such as freshwater fish species;
- Riparian Forest Red Gum communities in these same areas may also suffer adverse impacts in the long-term if groundwater levels decline below the necessary rooting depth required for tree species within this community. These habitats provide foraging habitat for Koala and Greater Glider (both Vulnerable – NC Act and EPBC Act); and
- Localised impacts to stygofauna which have been identified as present at a single location adjacent to the Project and Deep Creek.

15.7.11 Impacts to Coastal Processes

Potential impacts to coastal processes may manifest as a result of mine site water releases, sedimentation of waterways, and accidental release of pollutants. The potential impacts are summarised below. Groundwater drawdown impacts as identified in the previous section are not predicted to impact the coastal zone or any associated coastal habitats. Figure 15-27 indicates the maximum predicted groundwater drawdown will not impact the Styx River or downstream estuary, and well upstream of the likely 'freshwater-seawater' interface.

Impacts relating to the legislative aspects of coastal processes are summarised in Sections 15.7.11.1 to 15.7.11.4.

Mine Site Water Releases

The release of mine affected water (MAW) is proposed as a contingency measure after water reuse within mine operations. A MAW release strategy has been designed based on minimising the need to release MAW and to mitigate the risk of non-compliant discharges through effective balance of the mine water inventory and by discharging better quality water when possible instead of allowing contaminants to concentrate in storages. Releases of mine affected water may occur as "controlled" release through a piped transfer to Tooloombah or Deep Creek in accordance with EA conditions or as an "uncontrolled" release via flow over a designated spillway during extreme wet weather events. Controlled and uncontrolled releases may occur at the same time, for example, during emergency situations.

Release points (RPs) have been designated for storages containing pit dewater volumes, overburden stockpile runoff and mine process water. Mine affected water dams have piped outlets that transfer water to RPs within Tooloombah Creek, where instream dilution is possible. Environmental dams located within the Deep Creek catchment have piped transfers to RPs within Deep Creek. The open cut pits further provide contingency as MAW storages should conditions require.

The proposed water quality release conditions have been developed based on DES's *Model Water Conditions for Coal Mines in the Fitzroy Basin* (EHP 2013). The proposed releases reside within the adjoining Styx Basin; however, the guidelines for the Fitzroy Basin form current regulatory expectations for mine water management and thus have been adopted as the basis of the release strategy.

Water quality release limits for mine affected water include electrical conductivity (µS/cm), pH, suspended solids (mg/L) and sulphate (mg/L). In addition to the release limits, release contaminant trigger investigation levels also apply. Should the contaminant trigger level be exceeded, further investigation of background levels would be required. Water monitoring will be undertaken at the discharge locations of the environmental dams and mine-affected water dams, and at reference locations both upstream and downstream of the Project area.

The proposed water release strategy is provided in detail in Section 9.9 and 9.10.4 of Chapter 9 - Surface Water.

Sedimentation of waterways

During construction and operation, sediment can be mobilised and transported by surface water during rainfall events, ultimately discharging into Deep Creek drainage lines. This may result in negative impacts on water quality and aquatic habitats downstream. Specifically, increased quantities of suspended sediments can reduce light penetration, decreasing the photosynthesis of aquatic flora and lowering dissolved oxygen concentrations. Due to the ephemeral nature of the drainage features and watercourses, this is unlikely to be an impact in the immediate area but would more likely cause impact downstream and in the Styx River where more permanent refugial pools exist. Suspended sediments from runoff will likely contain elevated nitrogen and phosphorus levels due to the agricultural activities on the Mamelon property. Increased nutrients can promote algal growth and in extreme cases result in blooms and surface water deoxygenation within low flow situations.

Erosion and sedimentation during the operation phases is most likely to occur from stormwater runoff from the coal stockpile, MIA and from ongoing minor earthworks associated with the maintenance of roads and dams. If stormwater runoff is not adequately contained, there is a potential for sedimentation and contamination to adversely impact surface water receiving environments, particularly Deep Creek. Surface water observations taken during no flow periods during the surface water monitoring program undertaken in 2017 and 2018 recorded naturally high turbidity levels in Deep Creek sites.

Impacts to Tooloombah Creek are unlikely, as the majority of the Project area (~85%) drains towards Deep Creek with only ~15% draining towards Tooloombah Creek. The catchment is relatively isolated from most of the Project infrastructure components. The diversion of clean stormwater run-off from upstream of Open Cut 1 western section may mobilise sediments during the operational period.

Baseline water quality monitoring results indicated that existing waterways generally have low to moderate turbidity and suspended sediment loads during and following flow periods. During extended dry periods with no flow (as sampled in February 2017, and November 2017 to April 2018) when the waterways are reduced to isolated pools, high levels of turbidity and suspended sediment loads were recorded predominantly (but not solely) in Deep Creek sites.

The potential impacts of erosion and sedimentation from surface runoff, if not adequately mitigated, could produce moderate impacts on local downstream water quality, and on aquatic ecosystems EVs, including the marine environment (and associated recreational fishing values).

A detailed sediment load assessment is provided as Section 5.6 of Chapter 5 - Land.

Accidental Release of Pollutants

Accidental release of pollutants may adversely impact Deep Creek as the Project area lies within the Deep Creek catchment. Potential sources of pollutants include CHPP / MIA 2 areas, which are located approximately 500 m from Deep Creek. Waste Rock Stockpile 1a and 2 are located approximately 300 m west of Deep Creek representing another potential source of contaminants (refer Project layout in Figure 15-26).

Several items of infrastructure have the potential to accidentally release contaminants to Deep Creek owing to their proximity. These include:

- The waste rock stockpile areas (1a) located to the south and west of Open Cut 1 have potential to release contaminated run-off into Deep Creek;
- Waste Rock Stockpile 2 has the potential of releasing contaminated run-off into Deep Creek and to a minor extent Tooloombah Creek as well; and
- Dam 1 is located onstream, which during the construction of the dam wall has the potential to release construction related contaminants into Deep Creek.

Without mitigation, potential exists for aqueous waste streams to potentially enter waterways. This includes such things as:

- Oily waste water (from heavy equipment cleaning);
- Contaminated runoff from chemical storage areas;
- Contaminated drainage from fuel oil storage areas; and
- General washdown water.

The accidental release of pollutants can result in adverse impacts of flora and fauna (i.e. through coating) or may manifest itself as chronic illness and mortality, via slow and long term release of contaminants.

The EVs for the receiving waters include irrigation, stock watering and human consumption. Accidental release of pollutants and contaminants may adversely impact downstream agricultural operations and prevent use of the water for human consumption.

Potential impacts of accidental pollutant and contaminant releases, if not adequately mitigated, could produce moderate impacts on local and downstream water quality, aquatic ecology, irrigation, farm supply, stock water and cultural EVs. It is unlikely to impact human consumer and drinking water EVs due to the distance between the Project area and downstream extraction points.

15.7.11.1 The Coastal Zone

Mapping for the coastal zone indicates the boundary includes properties on the west side of Tooloombah Creek as well as upstream near Ogmore (Figure 15-28).

The Project lies adjacent to the coastal zone as currently mapped. There will be no direct development impacts to this area as a result of the Project. Conceivable impacts to the coastal zone from Project activities are restricted to dust deposition within the coastal zone, and potential downstream marine water quality impacts. These impacts are considered to be minor at a spatial scale and temporally short in duration as the greatest potential for impact is during the construction phase of the Project. These impacts have been addressed in previous sections.

15.7.11.2 Coastal Management District

The State's Development Assessment Mapping System (coastal protection) indicates the Styx River has been designated as part of the 'coastal management district.' This area pertains to the river itself and not adjacent properties. The 'coastal management district' triggers assessment by the State Assessment Referral Agency where development is proposed within the area including:

- Operational works, such as interfering with quarry material, disposing of dredge spoil or constructing an artificial waterway, removing or interfering with coastal dunes;
- Material change of use of premises;
- Reconfiguring a lot; and
- Buildings seaward of a coastal building line.

There is no proposal as part of the Project for development within or near this area, and the Project is not considered likely to exacerbate impacts resulting from storm tides or coastal erosion as discussed in the following sections. No further assessment is required.

15.7.11.3 Storm Tide Hazard Area

Storm surges are a condition associated with cyclonic weather whereby tidal levels are much higher than normal due to the piling up effect of wind upon the ocean. Little information is available about the potential magnitude of storm surge in the Styx River. It is a relatively small, ungauged catchment, so there is no history of flood heights or frequency and no local tidal data from which surge data could be inferred. Nevertheless, the State's Development Assessment Mapping System indicates sections of Deep Creek and Tooloombah Creek as potentially subject to 'medium' level impacts from storm tide inundation (Figure 15-28).

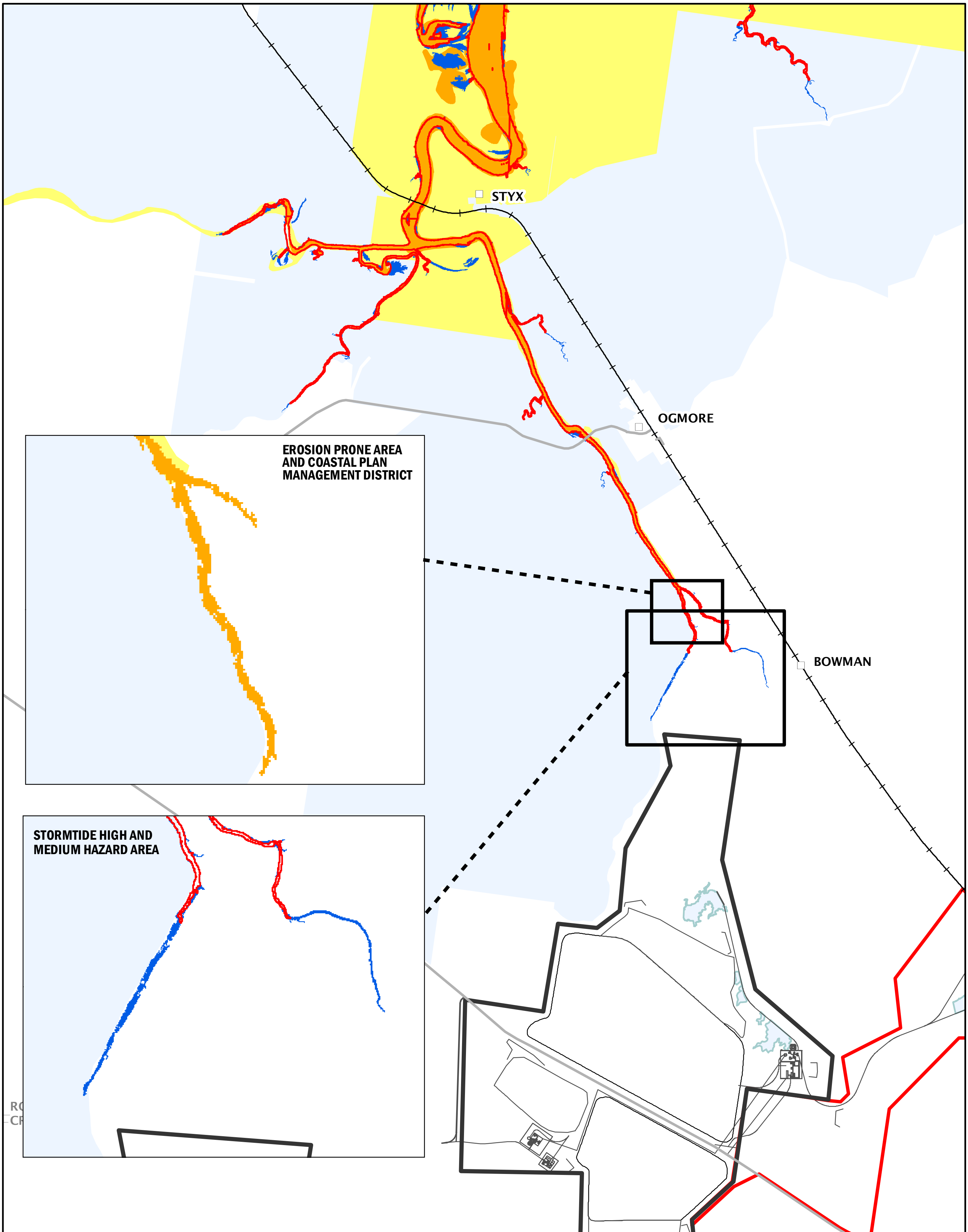


Figure 15-28
Coastal Zone and other development mapping

Legend

- ML 80187
- ML 700022
- Mine infrastructure
- Main Road
- North Coast Rail Line
- Dam
- Storm Tide High Hazard
- Storm Tide Medium Hazard
- Erosion Prone Area
- Coastal Plan Coastal Management District
- Coastal Plan Coastal Zone

0 0.5 1 km

Scale @ A4 1:70,000
Date: 01/11/18
Drawn: Gayle B.

DATA SOURCE
Waratah Coal, 2018
QLD Open Source Data, 2018
State Planning Policy, 2018

CDM Smith

BRUGGEMANNGD \\brbsvr1\PRO\Project\1000111 - Styx SEIS Post submission work\7Work\3GIS\DATA\MXD\Chapter 15_Supp_Report_Aquatic Ecology\1000111 coastal management zones__15-14.mxd 11/1/2018

On-site fieldwork observations indicate the upstream extent of irregular (peak) tidal inundation, as evidenced by the presence of scattered patches of Marine Couch on lower banks, occurs downstream of the confluence of Deep Creek and Tooloombah Creek. Representative creek bed elevation at this location is approximately 5.5 m AHD. This area lies upstream of the river crossings at Ogmore and the North Coast Rail line. At the Bruce Highway bridge over Deep Creek, the representative creek bed elevation is approximately 25 m AHD, almost 20 m higher than the peak tidal level. Whilst it is acknowledged that a storm surge creates tidal inundation (i.e. the storm tide) that travels further inland than regular tides, it would appear highly unlikely that cyclonic conditions could create a surge of this magnitude (Figure 15-29).

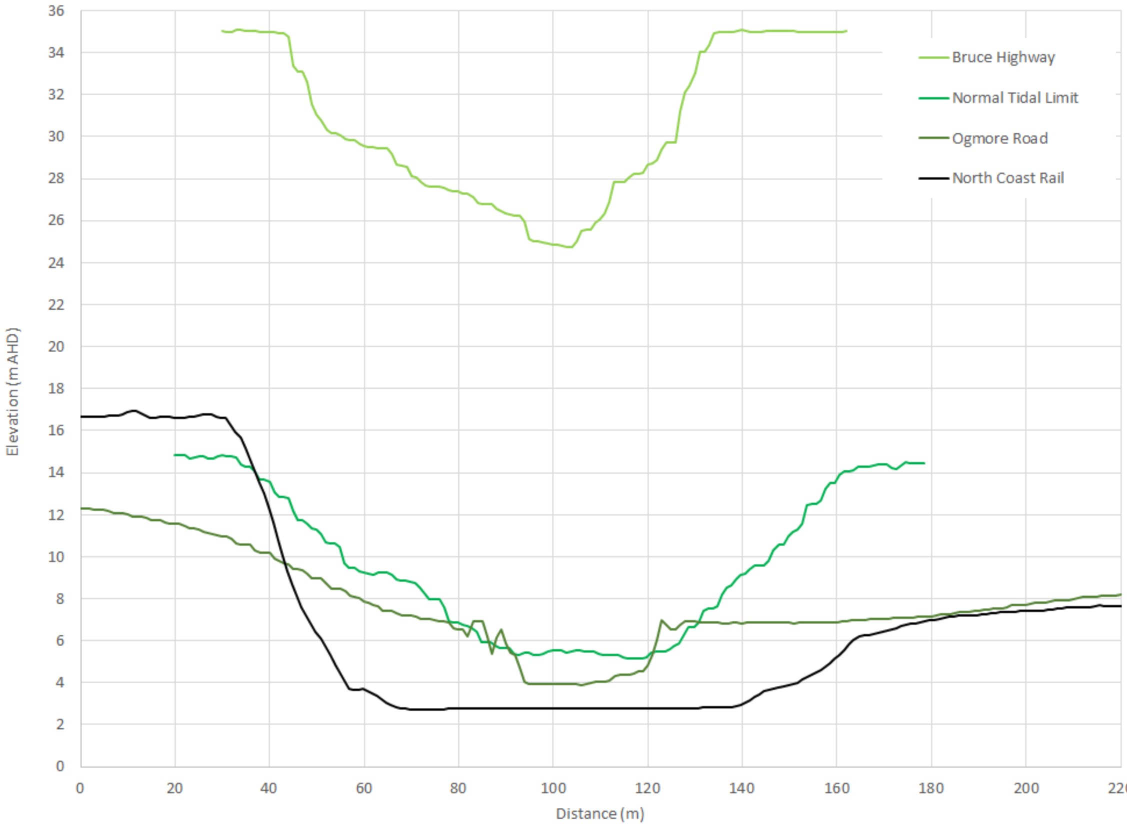


Figure 15-29 Comparative cross-section of watercourse crossings obtained from airborne laser survey

Flooding within the Styx basin is seasonal and is often associated with a cyclonic event. These flooding events occur during the wet season, with the Styx River containing most of the flow within the channel and overbank before overflowing into the floodplain areas downstream of the Project towards the township of Ogmore. In the (low likelihood) event of being coupled with a storm surge flooding events may be exacerbated. Within the vicinity of the Project, Deep Creek and Tooloombah Creek are incised with channel depths of more than 5 m. Tooloombah Creek is well-defined with little evidence of floodplain discharges while Deep Creek demonstrates several locations of floodplain discharges within the Project area evident by the presence of erosion and lack of vegetation on the banks.

Hydrologic models have been developed for the Project and potential flooding of the Project area has been depicted in both the current (undeveloped) scenario, and with development of the mine (see Chapter 9 – Surface Water), including the 0.1% AEP rainfall event (refer Figures 9-11 to 9-33 in Chapter 9 – Surface Water). In the undeveloped scenario the modelling indicates in a 0.1% AEP rain event minor flooding (up to 1.25 m depth) would occur through the centre of the ML with patches of deeper flooding associated with lower lying areas adjacent to Deep Creek to the north of the Bruce Highway (Figure 9-21 in Chapter 9 - Surface Water).

To manage the risks from flooding, a mine water management system has been developed (see Chapter 3 – Description of the Project). A system of flood protection levees and diversion drains has been developed to prevent ingress of clean water runoff to pits for up to and including the 0.1% AEP rainfall event. This provision reduces the volumes of water entering pits and becoming contaminated, and hence reduces the storage requirements of pit dewatering dams. Mine infrastructure (such as CHPP / MIA 2) is located within the lower floodplain of Deep Creek. These areas will sit on a fill pad at an elevation selected to ensure that infrastructure is not inundated under any scenarios up to the 0.1% AEP event.

All regulated dams are conceptualised in accordance with DES guidelines and include storage provisions to reduce the probability of non-controlled discharges of contaminated water from dam failure or overtopping during extreme rainfall events or wet seasons. Water held in pit dewater dams is prioritised for reuse in mine operations, which reduces the net raw water demand from external sources. Environmental dams are located downstream of stockpiles and disturbed areas to reduce sediment loads entering the watercourses and controlled discharges reduced to a contingency measure and subject to Environmental Authority conditions.

The Mine footprint is upstream of the State-mapped storm tide extent. The mine water management system has been developed to withstand the flooding impacts of a 0.1% AEP rainfall event. It is therefore considered unlikely that a storm-tide event will have any measurable impact upon concurrent riverine flood levels throughout the Project area.

15.7.11.4 Erosion Prone Area

The State's Development Assessment Mapping System (coastal protection) indicates minor sections of Deep Creek and Tooloombah Creek upstream of the Styx River are considered 'erosion prone areas' (Figure 15-28). This mapping is based on various factors including estimating potential erosion caused by extreme storm events, channel migration, sediment supply, and future sea level rise.

Based on the hydrological modelling described in Chapter 9 - Surface Water of the SEIS and summarised in Section 15.7.9 it is considered very unlikely that the Project activities would have any additive impact on background coastal erosion issues downstream of the Project.

15.8 Mitigation and Management Measures

Mitigation measures have been developed to minimise impacts associated with construction and operation of the Project. Mitigation strategies have been developed based on the following criteria:

- Avoid potential impacts where possible;
- Minimise the severity and / or duration of the impact; and
- Offset unavoidable impacts.

The potential impacts to aquatic EVs, including impacts to MSES, GDEs, and stygofauna as a result of the activities, and suggested mitigation measures associated with the Project are outlined in the following sections.

15.8.1 Vegetation Clearing

The majority of impacted remnant vegetation is not associated with aquatic habitat. Areas of Least Concern vegetation communities (under the VM Act) associated with riparian habitat (RE 11.3.25) and a single mapped wetland will be impacted by tree / habitat clearing. These communities will be subject to the Project Offsets Delivery Plan (refer Chapter 14 – Terrestrial Ecology).

To ensure the Project does not result in additional unforeseen direct impacts to remnant vegetation, the following mitigation measures will be implemented:

- Prior to construction, Project design may be further altered to avoid or minimise clearing areas of riparian vegetation communities, wetland areas and potential habitat for threatened aquatic species where possible;
- Vegetation located adjacent to the Project construction works will be appropriately marked to avoid unnecessary clearing / vegetation damage;
- Riparian vegetation and creek banks adjacent to culverts that are damaged during construction will be rehabilitated / stabilised; and
- The Project Land Use Management Plan (LUMP) will include monitoring of riparian and HEV wetland vegetation health (including the WPA) and associated remnant vegetation considered at risk to mining activities to identify whether indirect impacts are occurring as a result of dust, erosion and mine run-off contamination.

The Project is located on the Mamelon property. Mamelon encompasses a total area of 6,478 ha of which the Project footprint covers approximately 1,090.8 ha. Central Queensland Coal have proposed destocking the majority of the property and restricting cattle access to already cleared habitat in the south-west and south of the property. This area encompasses approximately 1,000 ha. The remaining area, including the creek lines which lie adjacent to the mine area, will be managed and allowed to regenerate. This measure will in the long-term increase the area of remnant vegetation on the property as well as contributing to local EVs through a reduction in soil erosion on the property (refer Section 15.8.8).

This will provide benefits to aquatic EVs by improving the water quality entering the adjacent creek lines (and potentially Styx River and Broad Sound) during heavy rainfall events through reducing nutrient inputs from cattle dung, reducing soil erosion and mobilisation of sediments and increasing vegetation cover on the site.

15.8.2 Waterway Barrier Works and Fish Passage

Minor waterways on the site are considered necessary for fish passage under the Waterway Barrier Works mapping and are significantly impacted by the location of Project components. However, following a review of the site conditions (as outlined in Section 15.7.2) Central Queensland Coal considers some of these waterways to be incorrectly mapped and have prepared a mapping revision for submission to the DAF (refer Appendix A21 for the full waterway revision document). Subsequently any waterways considered to be suitable for fish passage will be subject to the Project Offsets Management Plan.

The haul road crosses Deep Creek and Barrack Creek. As described in detail in Chapter 9 - Surface Water, Central Queensland Coal commits to undertaking detailed design of the haul road crossings to ensure aquatic habitat connectivity is maintained.

15.8.3 Aquatic Habitat Connectivity

To ensure aquatic habitat connectivity is maintained, Central Queensland Coal commits to undertaking detailed design of the haul road crossings in compliance with:

- Austroads – Guide to Road Design Part 5B – Open Channels, Culverts and Floodways; and
- Design detail requirements of the Code for Self-Assessable Development; Minor Waterway Barrier Works Part 3: Culvert Crossings, Code number: WWWBW01 (April 2013), Department of Agriculture and Fisheries (DAF).

In all cases the following specific conditions will be applied:

- Works will aim to be completed during the dry season;
- This measure eliminates the requirement to construct waterway barriers such as coffer dams to divert water around the construction area;
- Stabilisation of the banks will be done post construction to allow revegetation and reduce scour potential;
- Crossings will have a minimum (combined) culvert aperture width of 2.4 m or span 100% of the main channel width;
- All new and any replacement culvert cells will be installed at or below bed level;
- Internal roof of the culverts will be >300 mm above 'the commence to flow' water level;
- Where the cell is installed at less than 300 mm below bed level, the culvert floor will be roughened throughout to approximately simulate the natural bed form;
- To the extent possible, box culverts will be used to facilitate fish passage at low flow depths. Footings will be considered over base slabs to maintain the natural bed channel through the culverts;
- Apron and stream bed scour protection must be provided in line with the design requirements of the Code; and
- The culvert will be installed at no steeper gradient than the waterway bed gradient.

Waterway crossings will comprise of box culverts located within the main channel. Box culverts allow the most efficient passage of flows and for preferential fish passage conditions. Furthermore, haul trucks can drive directly on the top of box culverts or link slabs with little to no earth fill required and hence the risk of sediment transport through scour is significantly reduced. Where appropriate, the box culvert height will match the depth of the main channel. This serves to minimise haul road filling on the approach to the culvert crossing whilst maintaining the existing bank full discharge conditions. Box or circular culverts will only be located on the overbank areas where filling is required on approach to the main channel crossing (refer to example crossing design in Figure 15-30). Flows that exceed bank full discharge will overtop the culverts and efficiently pass a floodway section, therefore minimising increases to flood levels upstream (flood afflux).

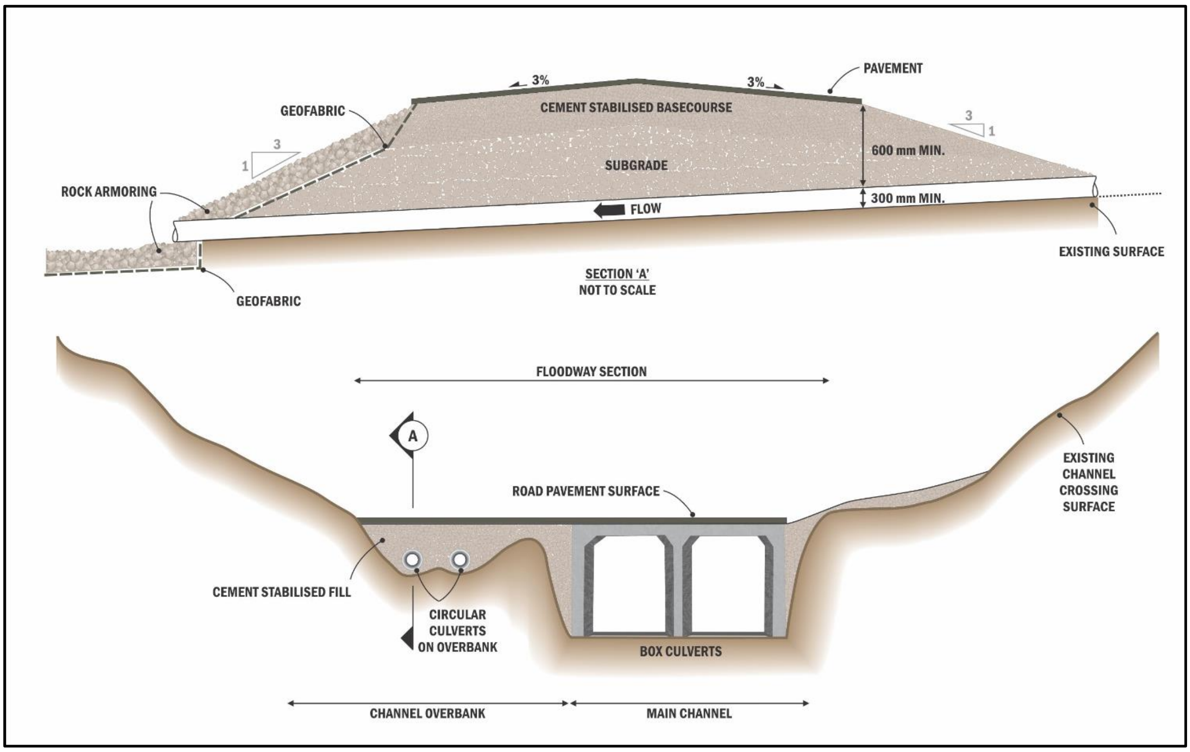


Figure 15-30 Example crossing design

The critical case for flows over the floodway is for events that just overtop the road (i.e. lesser than the 100 year ARI or PMF). This is when the low flow depths result in relatively higher velocities and is where scour potential and hence contamination transport is at its greatest. Scour protection will be designed in accordance with Austroads – Guide to Road Design Part 5B – Open Channels, Culverts and Floodways.

In addition to the above measures it is also important to recognise that all works will be undertaken in the dry season and this will significantly reduce the potential for construction impacts associated with erosion and scour. After construction, the banks will be stabilised and vegetation allowed to establish. There will be no impacts to aquatic connectivity as a result of the Project.

15.8.4 Direct Fauna Mortality

Works will be carried out on creek lines during the construction of the haul road although no permanent water holes are expected to be present at these areas including the crossing at Deep Creek and Barrack Creek.

Fauna management measures will be implemented as part of the Project LUMP and will establish protocols for pre-clearing activities. Prior to emptying any wetland area, a trained ecologist or other qualified environmental specialist will be on site to inspect the wetland and remove aquatic fauna (if required). In the event that fish are trapped by the Project, fish salvage activities in accordance with the 'Fish salvage guidelines' will be applied. These guidelines provide steps for the removal, handling, storing and transport and releasing of fish. They also provide guidance on the steps to take in the event of a fish kill. Aquatic fauna will be transferred to a suitable location as determined prior to the activity occurring. All fauna recorded during pre-clearing surveys will be recorded on a dedicated fauna register.

Significant Species Management Plans will be developed and implemented for those threatened aquatic species known or likely to occur on the site (under the NC Act and EPBC Act). The plan will identify potential impacts on these species (including identified habitat) as a result of Project activities from throughout the life of the Project (construction, operation and decommissioning). The Plans will detail specific management measures to mitigate the potential impacts and will incorporate adaptive management principles to allow for the adoption of new measures where necessary as the Project progresses.

15.8.5 Dust

Dust is not anticipated to significantly impact aquatic habitat in the area surrounding the Project. However, a vegetation monitoring program will be implemented as part of the Project LUMP and will include measures to monitor the health of adjacent riparian vegetation communities on Tooloombah Creek and Deep Creek within close proximity to the mine, haul road and coal conveyor, and the HEV wetland (WPA) to the west of the southern mine pit. These areas may be potentially subject to dust accumulation impacts. Results of the vegetation monitoring will be used to inform adaptive management of mitigation measures where impacts are found to be occurring.

A water quality monitoring program will also be implemented under the Project Receiving Environmental Monitoring Program (REMP). This will include monitoring of sites / waterholes identified as potentially impacted by dust such as the WPA, along Tooloombah Creek and Deep Creek (adjacent to the haul road).

The following measures have been developed to ensure dust levels resulting from the Project are kept to a minimum:

- The coal conveyor (in place from 2028) will be covered (although not fully enclosed) and will incorporate 'spill protectors' along the sides for the entire length of operation in order to minimise fugitive coal dust emission;
- All areas which have the potential to give rise to airborne dust such as unsealed roads, tracks, spoil areas and coal stockpiles will be wetted down regularly using water from environmental dams;
- Speed limits will be implemented throughout the site to minimise dust generated;
- Areas stripped of topsoil for Project construction will be rehabilitated as soon as practicable where not required during operations;
- Regular cleaning of machinery and vehicles tyres to prevent wheel entrained dust emissions;
- Design haul roads to have a less erodible surface, particularly where adjacent wetland habitat occurs, such as using materials with a lower silt content and / or applying chemical dust suppressants or paving used for haul roads; and
- Further dust suppression mitigation measures are discussed in Chapter 12 - Air Quality.

The Project is located on the Mamelon property. Mamelon encompasses a total area of 6,478 ha of which the Project footprint covers approximately 1,090.8 ha. Central Queensland Coal have proposed destocking the majority of the property and restricting cattle access to already cleared habitat in the south-west and south of the property. This area encompasses approximately 1,000 ha. The remaining area, including the cleared lands to the east of the WPA, will be managed and allowed to regenerate. In the long-term this will increase the vegetative buffer between the WPA and Project infrastructure (currently approximately 150 m wide), thereby decreasing the potential for dust settlement impacts on the WPA from Project activities.

15.8.6 Pests and Weeds

Weed and pest management will be an important and integral part of proposed site management activities, and will be detailed in the Project LUMP. This Plan will include measures and monitoring to be developed and managed in accordance with the requirements of the Biosecurity Act, and will include the following measures:

- Implementation of sediment control mechanisms to minimise the risk of weed seed washing into waterways;
- Implement control strategies outlined in the DAF weed and pest animal fact sheets and other relevant government biosecurity management strategies;
- Pre-construction weed mapping should be undertaken to accurately determine the extent of weeds and pests;
- Vehicle wash down procedures;
- Minimise the use of off-road vehicle movements;
- Onsite waste disposal strategies (particularly for food wastes) to be employed that will not encourage the presence of pest fauna;
- Strategies for the storage of construction and operation materials / equipment to be employed that will not encourage the presence of resident pest fauna;
- Regular onsite inspections of site infrastructure / equipment for resident pest fauna and establishment of register for pest sightings; and
- Monitoring and weed and pest inspections particularly in responses to reported outbreaks or from complaints or adjacent property owners.

15.8.7 Accidental Release of Pollutants

The Project design has incorporated the following components as part of the wider Project Water Management Plan (WMP). With these design elements, it is considered the potential impacts from the Project to water quality and hence local aquatic EVs in the vicinity of the site and downstream, are appropriately minimised to the greatest possible extent. A system of dams will be constructed to contain mine groundwater pumped from the open cut pit areas over the life of the Project.

Several environment dams are proposed to capture rainfall runoff from the CHPP / MIA areas, TLF and waste rock stockpile areas (refer Section 9.8.1 of Chapter 9 – Surface Water for detail on the proposed storage dams). The primary function of the environment dams is to capture sediment laden runoff for sediment removal. The environment dams will be designed to contain 1:100 year AEP storm event.

Surface waters will be managed and monitored according to the Project-specific REMP and WMP. A water release strategy will be developed for the Project. Water quality release limits are set for mine affected water across several parameters as to be conditioned under the Project EA conditions and will be in accordance with EPP water quality objectives for the Styx Basin (refer EHP 2014). Release contaminant trigger investigation levels also apply. Ongoing water monitoring will be undertaken at the environmental dams, mine-affected water dams, discharge locations and locations both upstream and downstream of the Project area as part of the Project REMP. Discharge of mine-affected water will be restricted to flow trigger events in the relevant creek catchments and will also be limited by the quality of water to be released. The vast majority of affected mine water will be treated and re-used for on-site Project activities.

Surface water contaminants from industrial pollutants have the potential to impact the local catchment and vegetation communities throughout the Project area. These impacts will be mitigated through:

- All refuelling facilities and the storage and handling of oil and chemicals will comply with relevant Australian Standards (management and mitigation measures for wastewater is discussed in Chapter 7 - Waste Management);
- Bunding of chemical storage facilities and appropriate storage of chemicals according to AS 1940 'The storage and handling of flammable and combustible liquids;
- Appropriate spill control materials including booms and absorbent materials will be onsite at refuelling facilities at all times. These will be used for mitigating and managing events where a substance is spilled into the surrounding waters;
- Locate and design roads and other built infrastructure so that minimal run-off to waterways occurs;
- Retention Basins to allow a pre-treatment of water and wastewater prior to any discharge into the aquatic environment. The discharge of wastewater and stormwater will be similar to water quality of receiving waters and in accordance with EPP water quality objectives for the Styx Basin; and
- Wash-down areas for plant and equipment will be clearly marked to prevent contaminated water from leaching into soils or flowing into nearby watercourses.

Further details relating to surface water management are discussed in Chapter 3 – Description of the Project and Chapter 9 – Surface Water.

The Project REMP will include monitoring of stream and wetland water quality including associated waterbodies considered at risk from contaminated run-off / wastewater releases from Project construction and operation to identify whether impacts are occurring.

15.8.8 Sedimentation of Waterways and Sediment Runoff

The Project is located on the Mamelon property. Mamelon encompasses a total area of 6,478 ha of which the Project footprint covers approximately 1,070 ha. Central Queensland Coal have proposed destocking the majority of the property and restricting cattle access to already cleared habitat in the south-west and south of the property. This area encompasses approximately 1,000 ha. The remaining area, including the creek lines which lie adjacent to the mine area, will be managed and allowed to regenerate. This measure will contribute to localised water quality improvements, and contribute to improving the water quality entering Broad Sound and the GBRWHA through the following:

- The long-term restoration of this habitat, and in particular allowing vegetation to regrow along the riparian zones along Deep Creek and Tooloombah Creek (which are presently mostly cleared), will capture / entrain sediment and nutrient run-off from the property;
- The restoration of cleared areas will also reduce soil erosion on cleared areas of the property, thereby reducing the entrainment of sediments entering creek lines during bouts of heavy rainfall; and

- The removal of cattle from much of the property will also remove a source of long-term nutrient input into creek lines following rainfall.

An assessment of the existing sediment loads on Mamelon property has been carried out under differing stocking regimes (refer Section 5.6.5 of Chapter 5 – Land). The results of the assessment show that for the areas assessed within ML 80187 the estimated annual sediment generation potential ranges between 777 to 3,653 t/ha (dependent on cattle stocking regime). Soil loss estimate calculations undertaken for the site (refer Section 5.11 of Chapter 5 – Land) indicate a maximum soil loss of 217 tonnes per hectare per year, assuming no erosion and sediment controls are implemented as part of Project activities. With the installation, operation and maintenance of sediment basins, at least 95% of sediments would be captured and retained. With the removal of cattle from much of the property, this represents a significant reduction in downstream sedimentation compared with the current grazing regime.

It is expected that the reduction of mobilised sediments will continue post mining as the intention is to set aside the property for nature conservation purposes. A key aspect of the destocking approach will be to allow the vegetation communities within the riparian corridors to regenerate without being subjected to ongoing grazing pressures. As vegetation coverage continues to increase within the riparian corridors and across the property more generally combined with the absence of grazing, the potential for sediments to mobilise reduces and will continue to do so.

Erosion in active construction or development areas cannot be eliminated. However, impacts can be controlled and with proper mitigation measures, adverse effects to surface waters can be avoided or minimised. The following mitigation measures are proposed to avoid potential sedimentation impacts that could occur as a result of construction and operation activities:

- Surface waters will be managed and monitored according to the Project-specific REMP and WMP;
- Preparation of a certified Erosion and Sediment Control Plan (ESCP) prior to construction and implementation during activities. The ESCP is to ensure construction activities are being undertaken in accordance with best management practices and the International Erosion and Control Association (IECA) Guidelines (2008). Management measures that should be detailed within the plan are outlined in Chapter 5 – Land. As a minimum the ESCP will include the following control measures:
    - Installation of sediment fences on the downslope side of any disturbed areas
    - Diversion of clean water around disturbed areas
    - Policies to avoid and minimise the use earthmoving activities during intense rainfall events
    - Installation of erosion control devices diversion drains
    - A construction plan that minimises the area required to be disturbed for operations.
- Land will be surveyed and pegged out prior to clearing to avoid identified areas of significance;
- Vegetation will be preserved with only the minimum amount of land required to operate the Project cleared at any one time;
- Progressive rehabilitation of disturbed areas will be undertaken, where possible; and
- Disturbed land will be returned to pre-existing vegetative habitat condition, including cattle grazing, or native habitat.

Several environmental dams are planned to be constructed during the early site works (see Section 9.8.1 in Chapter 9 – Surface Water). The early construction of these storages will allow for runoff from disturbed areas to be captured and thus provide one of the most effective mitigation measures to minimise potential erosion and sedimentation impacts in relation to the MIA. All site dams, including environmental dams have been and will continue to be designed in accordance with the 'Manual for Assessing Consequence Categories and Hydraulic Performance of Structures' (EHP 2016).

In addition, potential contaminant impacts will be reduced via specifically sized and designed sediment containment dams and a controlled water release policy. The mine water release strategy is presented in detail in Section 9.9 (Chapter 9 – Surface Water) and sets the basic criteria for minimising the effect of mine affected water releases on the receiving environment. In addition, the following mitigating measures are proposed:

- Maintain a site-specific mine water balance to:
  - Assess the net mine water inventory
  - Determine the likely mine water release volumes for oncoming wet seasons
  - Forecast the likelihood of non-compliant discharges
  - Adjust the mine water release strategy based on the above
- Release better quality water as soon as possible to avoid the accumulation of salts and other contaminants; and
- Incorporate suitable monitoring and water infrastructure such as:
  - Automated real-time flow and EC monitoring at point discharge and background monitoring locations to determine the appropriate quality and quantity of mine affected water releases
  - Sufficient mine water dam capacity to reduce non-compliant discharges from overtopping
  - Automated release gates to allow release of mine affected water during wet weather conditions where access is limited
  - Continually assess the release strategy and its impact on the receiving environment.

15.8.9 Hydrology and Water Flows

Surface waters will be managed and monitored according to the Project specific REMP and WMP. The WMP will describe the mine water balance, key water infrastructure (e.g. water storages, water distribution network, drainage system) and flood protection infrastructure. The WMP will address both the construction and operational phases of the Project.

No impacts to hydrological values of adjacent or downstream waterways are expected to result from waterway diversions and / or flood harvesting. If monitoring detects adverse impacts and assesses that replenishment is required, only water that meets the approved release conditions derived from the site specific water quality monitoring will be released. Using water that meets the approved water quality trigger values will minimise or eliminate adverse impacts to the ecological function of the targeted waterways.

15.8.10 Changes to Groundwater Table and GDE Impacts

The proposed open-cut mining method will physically disrupt and drain saturated rocks within the subsurface, resulting in groundwater depressurisation and decline of water table elevation surrounding the open-cut pits during mining. Apart from alteration of the volume of coal resource to be extracted, the magnitude and extent of groundwater depressurisation will be controlled by the hydrogeological properties of the surrounding rocks, with no practical measures available to mitigate these effects.

15.8.10.1 Groundwater Monitoring - REMP

A detailed REMP will be established for the Project (refer Section 10.8 in Chapter 10 – Groundwater for more detail). This will include continued monitoring of established shallow groundwater monitoring bores within the likely zone of mine influence. Based on the information collected during the first few years of mining, a need for expansion or rationalisation of the monitoring network may be identified. In the long term monitoring of these bores will allow for a better understanding of local groundwater conditions and observations regarding actual drawdown caused by mining activity. Data collected from the REMP in the first years of mining will be used to verify the groundwater drawdown model predictions and, if necessary, provide a basis for recalibration of the groundwater model. The REMP will document the proposed groundwater monitoring and evaluation plan, and will include:

- GDE condition monitoring, including vegetation and aquatic surveys;
- Groundwater monitoring, including level gauging, water sampling and laboratory testing program;
- Monitoring of mine water dewatering rates/volumes and produced water laboratory testing program;
- Data evaluation criteria;
- Monitoring frequency and reporting; and
- Requirements for revision of the REMP.

Trigger Action Response Plans (TARPs) (see Chapter 9 – Surface Water) will form part of the REMP and will outline the actions and responses required in the event that operations have or are likely to result in management objectives and approvals conditions not being achieved. TARPs will identify:

- Further investigations to identify EVs and sensitive receptors that may be impacted and to assess level of impact / threat posed to the sensitive receptors, if pre-determined trigger thresholds are reached;
- Of those mitigation measures identified in the REMP, which are appropriate to manage or remove the specific cause or pathway of the impact / threat and what other mitigation measures may be available to improve outcomes (e.g. new technology);
- Implementation of the mitigation plan(s) deemed most appropriate, including providing notification (where necessary) to relevant authorities and stakeholders;
- Reporting (internal and external) to summarise monitoring results, investigation findings and mitigation approaches, with follow up information provided to relevant authorities and stakeholders; and

- Review and update of the REMP to ensure adequate monitoring of detected impacts and mitigation efforts is incorporated, and to re-assess appropriateness of mitigation measures outlined in the plan (i.e. to ensure the mitigation measures will appropriately address the level of impact identified into the future).

Mine water inflow monitoring will consist of daily measurements of rates and/or volumes of all water pumped from the mine pit using a suitable method. Mine produced waters will be subject to quarterly:

- Measurements of field water quality parameters (e.g. TDS, EC, pH); and
- Laboratory analyses of major ions, TDS, EC, dissolved metals (including aluminium, arsenic, selenium and vanadium) and hydrocarbons (TPH, TRH and BTEXN).

Groundwater monitoring (water quantity and quality) will occur on the MLs and off-lease during the construction, operational and post-operational phase of the Project to:

- Determine if an impact has or will likely be realised, which would trigger (based on pre-determined trigger thresholds) implementation of appropriate mitigation measures, including initial review and evaluation; and
- Assess the environmental performance of any adopted management and mitigation measures once implemented, which may require expansion of the monitoring network and analytical program.

The location and configuration of monitoring bores is designed to provide sufficient coverage of identified aquifers and potential GDEs to detect and monitor groundwater effects resulting from the Project and provide a baseline from which management objectives are set. Groundwater monitoring bore locations are described in Chapter 10 – Groundwater.

Monitoring of groundwater drawdown and depressurisation will involve:

- Gauging of hydraulic head in selected groundwater monitoring bores and landholder bores located within the predicted zone of mine influence, as a minimum;
- Automated pressure transducers will be installed at selected monitoring bores to provide daily observations that can be used to distinguish short-term changes, such as seasonal recharge, from potential long-term effects of the Project (dewatering and backfilling); and
- Gauging hydraulic heads at selected locations outside of the predicted area of impact to confirm the extent of impact and to assess baseline conditions away from potential mining effects.

Groundwater quality monitoring will include the following:

- Mine water inflow monitoring will consist of daily measurements of all water pumped from the mine pit;
- Quarterly field measurements of EC and pH of groundwater sampled from monitoring bores located on the mine lease and monthly field measurements of the same parameters for water pumped from the mine;
- Quarterly field measurements of EC and pH of groundwater sampled from compliance monitoring bores located off the mine lease;
- Six monthly sampling (quarterly or more frequently for the first two years of mining, or if trigger is reached) of groundwater sampled from compliance monitoring bores for laboratory

analyses of major ions, TDS, EC, dissolved metals (including aluminium, arsenic, selenium and vanadium) and hydrocarbons (TPH, TRH and BTEXN); and

- Six monthly sampling (quarterly or more frequently if trigger is reached) of groundwater from reference monitoring bores (located outside the predicted zone of drawdown influence) for laboratory analyses of major ions, TDS, EC and dissolved metals.

Groundwater chemistry data will be analysed graphically for trends (e.g. using Piper plots and Stiff patterns) and any correlation with observed groundwater levels, mine inflow and rainfall. Data collected from the recently installed monitoring bores will be assessed and evaluated to allow adjustment of the nominated trigger values for groundwater quality (following 24 months of data collection).

If a monitoring trigger is breached, after review and where required the appropriate mitigation measure will be implemented and the monitoring program appropriately adjusted, e.g. if a water quality trigger is realised, sampling frequency for analysis of water quality may be increased from six monthly to quarterly or more frequently, and additional monitoring locations may be incorporated (i.e. between bores where the trigger is reached and the threatened receptor).

Groundwater compliance reports will be prepared to facilitate the transfer of monitoring data to relevant regulatory authorities. The frequency of reporting will be decided in the relevant Project environmental authority. Issues relating to groundwater samples that are reported by the landholder or mine staff will be recorded and documented in the monitoring report, including corrective actions.

Future improvements to the numerical model will be undertaken as and when new data become available, particularly where there is a divergence of observed groundwater system response from the predicted. New data may require a revision and update of the conceptual (eco-)hydrogeological model prior to updating and recalibrating the numerical model and re-running of predictive scenarios. Where this is deemed necessary, the REMP and WMP may also need to be updated depending on model predictions.

As mining progresses, a need for further model updates will be assessed every two years based on quarterly reviews of groundwater monitoring data and findings of impact verification. It is expected the confidence level of model predictions will increase over time as the model is updated to reflect the observed effects on groundwater from the monitoring program.

Where additional management strategies are required in response to environmental performance, the existing numerical model, or new models depending on the type of impact observed (e.g. density coupled models to simulate seawater intrusion), will be used to test the effectiveness of mitigation measures prior to implementation to improve the outcomes of the proposed measures.

15.8.10.2 GDE Monitoring

Targeted investigations of the hydrological requirements of potential GDEs have been carried out as part of works to inform the updated SEIS (refer Section 15.6.4). Ongoing GDE monitoring will incorporate some of these methods and inform how GDE water requirements can be maintained during and following mining.

GDE monitoring will include the following:

- Type 1 GDEs:
    - Stygofauna collected in November 2011 and March 2012 sampling events have been identified as belonging to Orders / Families that occur in all Australian states (Serov,

2002). To satisfy the ToR, endemism needs to be disproved at the Family or Order level for stygofauna. Any proposed mining activities associated with the Project will not threaten or put at risk the survival of the taxa present at the Order / Family level of taxonomic resolution. Based on these results, no mitigation measures are required

- Stygofauna will be monitored at five-yearly intervals during the life of the mine to increase understanding of coastal stygofauna. Sampling will follow the procedures detailed in DES 2018 and
- Monitoring will seek to identify obligate (groundwater dependent) stygofauna to the lowest possible levels to determine levels of endemicity of the stygofauna community within the aquifers. This community is the most disturbance sensitive environmental indicator for changes in aquifer conditions. Project groundwater bores included in the groundwater monitoring program (see Chapter 10 - Groundwater) will be sampled for stygofauna;

- Type 2 GDEs:
  - Macroinvertebrate surveys to establish the existing distribution, abundance and richness of macroinvertebrate communities, in association with ongoing water quality monitoring and
  - Macroinvertebrate sampling will be conducted in accordance with standards and protocols detailed in the State's Monitoring and Sampling Manual DES (2018) as issued for Queensland waters;
- Type 3 GDEs:
  - Establish permanent vegetation monitoring transects to measure structural characteristics and baseline condition of GDE habitats subject to impact (also including the consideration of the need for control sites)
  - Monitoring transects will provide dedicated sites for structured and repeatable temporal measurements of Foliage Index / Leaf Area Index using canopy photography / hemispherical lenses
  - Temporal measurement of LWP at reference trees when GDE vegetation monitoring sites are established and at subsequent monitoring events, this will provide a direct measure of water stress
  - Capture of high resolution Normalised Differential Vegetation Index (NDVI) imagery over possible impact areas and any control sites, timed to coincide with monitoring events and undertaken biannually for the initial three years to establish a seasonal baseline for ongoing comparison (the data sets provide a measure of all vegetation, rather than selected sites within the transects);
- Comparison of results against observed changes in GDE water budgets to link the cause, if possible, of observed stress to changes in the water budget attributable to the Project, and differentiating other potential factors such as climate change, fire, or introduced plant species. These factors could be as significant as the threats posed to groundwater resource condition by the Project.

15.8.10.3 Further Works

Further works could include collection of samples in the wet and dry season for both environmental and radon isotope analysis from both surface water and groundwater. Shallow in-stream piezometers should be used due to the radon's short half-life (3.82 days). Groundwater samples will also be collected from these piezometers and used for radon analysis to help quantify the groundwater flux. The flux can be calculated using the following equation (Atkinson *et al.*, 2015):

$$I = (Q^*(\delta C_r / \delta x) - w.E.C_r + k.d.w.C_r + \lambda.d.w.C_r) / (C_i - C_r)$$

Where,

I = groundwater inflow ($m^3/m/day$)

C_i = dissolved ^{222}Rn activity of groundwater (Bq/m^3)

C_r = dissolved ^{222}Rn activity of surface water (Bq/m^3)

Q = stream discharge, in m^3/day

w = stream width (m)

d = stream depth (m)

λ = radioactive decay rate (1/day)

E = evaporation rate (m/day)

K = reaeration coefficient, in 1/day (range is from 0.5 to 5 (Atkinson et al., 2015))

15.8.10.4 Preliminary Management and Mitigation Measures

Mitigation measures will be defined to address unacceptable impacts arising on sensitive receptors from reduced groundwater quantity or diminished groundwater quality. The TARPS will form the basis for determining when management and mitigation measures will need to be confirmed and implemented.

It is recognised that GDEs within this landscape will have evolved some resilience, whereby they are able to cope with some degree of change to baseline water regimes (quantity, quality and timing). For example, Type 3 terrestrial GDEs may be able to extend the depth of rooting to access deeper soil water or the capillary fringe, and macro-invertebrates may persist in a surface water pools that are reduced in surface area and depth compared to what may have existed pre-mining. Resilience levels need to be further assessed by ongoing monitoring, but for the purpose of identifying suitable mitigation measures it is conservatively assumed at this stage that sensitive ecosystems have no resilience to changed water regimes (i.e. the temporal nature of environmental water requirements is static / unchanging). In the first instance, mitigation measures are defined on this 'static' basis, but once environmental water requirements are better understood an adaptive mitigation plan will be able to be implemented.

The following sets out examples of groundwater management and impact mitigation measures for the Project. These and other mitigation measures will be further detailed in the REMP, building on from the baseline understanding of receptor water requirements with understandings developed from ongoing studies (see Section 10.8.2.2 of Chapter 10 - Groundwater). It is anticipated that, where an adverse impact is indicated as part of the approved monitoring, evaluation and reporting program, a wide range of management and mitigation approaches will be considered, not only those that may be detailed in the REMP as additional approaches may evolve with time and technology, and new knowledge gained may lead to the development of new approaches that are not identified here. Any new mitigation measures identified as part of this process will require an update of the REMP.

Water Quantity

An approach that will be considered to manage impacts where Type 2 and Type 3 GDE access to groundwater might be compromised due to drawdown arising from mine dewatering involves supplementing environmental flows to waterways and soil water stores so that baseline flow/water availability regimes can be maintained or supported. Table 15-18 summarises the management and mitigation measure with details expanded upon below. For Type 2 GDEs, supplementary water can be provided directly to permanent or ephemeral pools in a manner that provides the minimum required volume and frequency to maintain GDE function, the understanding of which will be improved with ongoing monitoring.

The practice of supplementing surface water flow to maintain the aquatic system and riparian vegetation health is used as a management tool in providing environmental flow requirements to waterways and wetlands across Australia. Examples of where the provision of environmental flows made directly into pools in response to groundwater dewatering include the Collie Basin in south-west Western Australia (DoW 2009) and Fortescue Metals Solomon Iron Ore Project Bore Field in Western Australia (FMG 2016).

Table 15-18 Available management and mitigation measures

Direct effect	Instream habitat	Riparian/terrestrial habitat	Third party bores
Change in groundwater quantity/surface water – groundwater interactions	Supplementary environmental flows provided directly to pools from mine produced water or other groundwater (e.g. pumping bores)	Supplementary environmental flows provided via irrigation from mine produced water or other groundwater (e.g. pumping bores) Land contouring, which will retard surface water run-off and encourage additional recharge to the underlying soils	Lowering of pump/ deepening bore Provision of surplus water from mine dewatering if suitable Provision of an alternative water supply
Change in groundwater quality	Onsite water and hazardous materials management Containment or capture of contaminant/pollutant e.g. cut off walls, pumping bores. Treatment of contaminated/polluted water		

For Type 3 GDEs, supplementary water can be applied to soil water reservoirs (i.e. the root zone) either directly through irrigation or indirectly through leakage from water provided to waterways / wetlands / bunded areas. Contouring of the surface could be considered to encourage ponding of any surface runoff or direct rainfall to encourage additional recharge to the underlying soils. However, the efficacy of this approach also needs to consider impact to creek flow regimes.

The source of supplementary water would ideally be mine produced water, as there would be no associated additional drawdown impacts. Mine water balance modelling, as presented in Chapter 9 – Surface Water, predicts the mine water supply exceeds the mine water demand for the duration of mining almost all of the time, with a predicted minimum available excess in the order of 40 ML in the worst case dry year. This suggests that mine produced water is a likely to be a viable source of water to offset any reduction in groundwater baseflow to the dependent pools, with adequate treatment if necessary.

However, a supply deficit will exist post-closure when mine produced water is no longer available. Alternatively, sourcing the supplementary flows from a groundwater resource is a strategy that may be considered – whilst the Alluvium aquifer would likely not present as a viable long term option (due to drawdown effects), the Styx Coal Measures, which has similar water quality to the Alluvium may provide a suitable source. Modelling has been prepared examining water 'consumption' at a pool near the western boundary of ML 80187 (sample point To2; Figure 15-1) and assessing whether waterhole groundwater requirements can be met via abstraction from pumping wells accessing the Styx Coal Measures. The modelling has shown that the Styx Coal Measures is capable of supplying between 0.1 to 0.2L/s in the long-term, which could sustain around 2,400 to 4,800m^2 of pools, with little additional effect to the predicted drawdown (discussed in detail in Section 15.7.10 and Appendix A6 – Groundwater Technical Report).

Change in Groundwater Quality

There is a low potential for Project-related activities to impact groundwater quality (mining, water storages, waste rock stockpiles, and acid mine drainage) resulting in adverse impacts on GDEs. However, careful management and control measures of potential pollutants and contaminant sources will be maintained to prevent uncontrolled discharge to groundwater. These will include:

- Provision of appropriate spill control materials including booms and absorbent materials at refuelling facilities to contain spills (also refer Section 15.8.7);
- Establish procedures to ensure safe and effective fuel, oil and chemical storage and handling. This includes storing these materials within roofed, bunded areas to contain spills and prevent uncontrolled discharge to the environment; and
- Ensure all refuelling facilities and the storage and handling of oil and chemicals to comply with relevant Australian Standards. Management and mitigation measures for wastewater are discussed in Chapter 7 - Waste Management.

All uncontrolled discharges will be reported to the DES under legislative requirements of the EP Act. If groundwater quality impacts are identified, mitigation measures will include:

- Investigation to identify and rectify any activity / facility that has caused uncontrolled discharge; and
- Containment or interception of the impacted groundwater / pollutant source e.g. cut-off trenches.

Control of surface water discharges and dirty water management systems, including storage of mine dewatering water, are discussed in detail in Chapter 9 – Surface Water.

Environmental Offsets

A key mitigation measure of last resort that is available to deal with unacceptable outcomes that cannot be adequately managed involves committing to Project environmental offsets (refer Section 14.12 of Chapter 14 – Terrestrial Ecology). This would involve undertaking the studies required to understand how GDEs interact with groundwater and implementing management approaches, such as provision of supplementary water. Should all mitigation methods be unsuccessful these habitats / vegetation communities will be subject to the Project Offsets Management Plan (refer Appendix 18A).

15.8.11 Impacts to Coastal Processes

Mitigation measures to minimise impacts to coastal processes as a result of the Project construction and operation are summarised below. These are management measures proposed to protect water values both in waterways directly affected by the Project, but also indirect impacts downstream of the Project.

A detailed water monitoring program is proposed to be implemented during Project construction and operation.

15.8.11.1 Mine Site Water Releases

The mine water release strategy presented in Chapter 9 – Surface Water sets the basic criteria to minimising the effect of mine affected water releases on the receiving environment. In addition, the following mitigating measures are proposed:

- Maintain a site-specific mine water balance to:
  - Assess the net mine water inventory
  - Determine the likely mine water release volumes for oncoming wet seasons
  - Forecast the likelihood of non-compliant discharges
  - Adjust the mine water release strategy based on the above
- Release better quality water as soon as possible to avoid the accumulation of salts and other contaminants; and
- Incorporate suitable monitoring and water infrastructure such as:
  - Automated real-time flow and EC monitoring at point discharge and background monitoring locations to determine the appropriate quality and quantity of mine affected water releases
  - Sufficient mine dewater dam capacity to reduce non-compliant discharges from overtopping
  - Automated release gates to allow release of mine affected water during wet weather conditions where access is limited
  - Continually assess the release strategy and its impact on the receiving environment.

15.8.11.2 Sedimentation of Waterways

The Project is located on the Mamelon property. Mamelon encompasses a total area of 6,478 ha of which the Project footprint covers approximately 1,090.8 ha. Central Queensland Coal have proposed destocking the majority of the property and restricting cattle access to already cleared habitat in the south-west and south of the property. This area encompasses approximately 1,000 ha. The remaining area, including the creek lines which lie adjacent to the mine area, will be managed and allowed to regenerate. This measure will contribute to localised water quality improvements, and contribute to improving the water quality entering Broad Sound and the GBRWHA through the following:

- The long-term restoration of this habitat, and in particular allowing vegetation to regrow along the riparian zones along Deep Creek and Tooloombah Creek (which are presently mostly cleared), will capture / entrain sediment and nutrient run-off from the property;
- The restoration of cleared areas will also reduce soil erosion on cleared areas of the property, thereby reducing the entrainment of sediments entering creek lines during bouts of heavy rainfall; and
- The removal of cattle from much of the property will also remove a source of long-term nutrient input into creek lines following rainfall.

An assessment of the existing sediment loads on Mamelon property has been carried out under differing stocking regimes (refer Section 5.6.5 of Chapter 5 – Land). The results of the assessment show that for the areas assessed within ML 80187 the estimated annual sediment generation potential ranges between 777 to 3,653 t/ha (dependent on cattle stocking regime). Soil loss estimate calculations undertaken for the site (refer Section 5.11 of Chapter 5 – Land) indicate a maximum soil loss of 217 tonnes per hectare per year, assuming no erosion and sediment controls are implemented as part of Project activities. With the installation, operation and maintenance of sediment basins, at least 90% of sediments would be captured and retained. With the removal of cattle from much of the property, this represents a significant reduction in downstream sedimentation compared with the current grazing regime.

It is expected that the reduction of mobilised sediments will continue post mining as the intention is to set aside the property for nature conservation purposes. A key aspect of the destocking approach will be to allow the vegetation communities within the riparian corridors to regenerate without being subjected to ongoing grazing pressures. As vegetation coverage continues to increase within the riparian corridors and across the property more generally combined with the absence of grazing, the potential for sediments to mobilise reduces and will continue to do so.

Erosion in active construction or development areas cannot be eliminated. However, impacts can be controlled and with proper mitigation measures, adverse effects to surface waters can be avoided or minimised. The following mitigation measures are proposed to avoid potential sedimentation impacts that could occur as a result of construction and operation activities:

- Surface waters will be managed and monitored according to the Project-specific REMP and WMP;
- Preparation of a certified Erosion and Sediment Control Plan (ESCP) prior to construction and implementation during activities. The ESCP is to ensure construction activities are being undertaken in accordance with best management practices and the International Erosion and Control Association (IECA) Guidelines (2008). Management measures that should be detailed within the plan are outlined in Chapter 5 – Land. Sat a minimum the ESCP will include the following control measures:
  - Installation of sediment fences on the downslope side of any disturbed areas
  - Diversion of clean water around disturbed areas
  - Policies to avoid and minimise the use earthmoving activities during intense rainfall events
  - Installation of erosion control devices diversion drains
  - A construction plan that minimises the area required to be disturbed for operations.
- Land will be surveyed and pegged out prior to clearing to avoid identified areas of significance;
- Vegetation will be preserved with only the minimum amount of land required to operate the Project cleared at any one time;
- Progressive rehabilitation of disturbed areas will be undertaken, where possible; and
- Disturbed land will be returned to pre-existing vegetative habitat condition, including cattle grazing, or native habitat.

Several environmental dams are planned to be constructed during the early site works (see Section 9.8.1 in Chapter 9 – Surface Water). The early construction of these storages will allow for runoff from disturbed areas to be captured and thus provide one of the most effective mitigation measures to minimise potential erosion and sedimentation impacts in relation to the MIA. All site dams, including environmental dams have been and will continue to be designed in accordance with the 'Manual for Assessing Consequence Categories and Hydraulic Performance of Structures' (EHP 2016).

In addition, potential contaminant impacts will be reduced via specifically sized and designed sediment containment dams and a controlled water release policy. The mine water release strategy is presented in detail in Section 9.9 (Chapter 9 – Surface Water) and sets the basic criteria for minimising the effect of mine affected water releases on the receiving environment. In addition, the following mitigating measures are proposed:

- Maintain a site-specific mine water balance to:
    - Assess the net mine water inventory
    - Determine the likely mine water release volumes for oncoming wet seasons
    - Forecast the likelihood of non-compliant discharges
    - Adjust the mine water release strategy based on the above
- Release better quality water as soon as possible to avoid the accumulation of salts and other contaminants; and
- Incorporate suitable monitoring and water infrastructure such as:
    - Automated real-time flow and EC monitoring at point discharge and background monitoring locations to determine the appropriate quality and quantity of mine affected water releases
    - Sufficient mine water dam capacity to reduce non-compliant discharges from overtopping
    - Automated release gates to allow release of mine affected water during wet weather conditions where access is limited and
    - Continually assess the release strategy and its impact on the receiving environment.

15.8.11.3 Accidental Release of Pollutants

All contaminated water on-site will be collected using site environmental dams, preventing the water from entering local waterways. The Project will include five environmental dams. These dams will collect water from the MIA, CHPP, waste rock storage, coal stockpile and the TLF and store contaminated rainfall runoff across the site. This water will be used to supplement the demands for stockpile dust suppression, washdown and CHPP demand.

In addition to the installation of environmental dams, the following management measures will be implemented to minimise the risk of pollutants and contaminants entering local water ways:

- Appropriate spill control materials including booms and absorbent materials will be onsite at refuelling facilities at all times. These will be used for mitigating and managing events where a substance is spilled into the surrounding waters;

- All refuelling facilities and the storage and handling of oil and chemicals will comply with relevant Australian Standards (management and mitigation measures for wastewater is discussed in Chapter 7 - Waste Management);
- Procedures will be established at the mine for safe and effective fuel, oil and chemical storage and handling. This includes storing these materials within roofed, bunded areas with a storage capacity of 100% of the largest vessel and 10% of the second largest vessel. The bunding will have floors and walls that are lined with an impermeable material to prevent leaching and spills; and
- Wash-down areas for plant and equipment will be clearly marked to prevent contaminated water from leaching into soils or flowing into nearby watercourses.

15.9 Cumulative Impacts

The area the Project is located within is relatively small. The Tooloombah Creek catchment comprises approximately 36,000 ha and Deep Creek comprises a further 29,000 ha. For the purposes of this cumulative impact assessment on aquatic values we have chosen to restrict the assessment to the overall Styx River catchment as it is inconceivable the Project will have impacts beyond this area. The ranges to the west and south of the Project catchment areas drain into the Fitzroy Basin which remains separate from the Styx River catchment.

The nature of the Styx River catchment is rural with approximately 78% of lands occupied by agriculture dominated by cattle grazing. A review of the latest publicly available information regarding development in the region found no large-scale industrial or mining developments proposed for the catchment other than the Central Queensland Coal Project.

The only major development known from the wider area is the proposed expansion of the Shoalwater Bay Training Area by the Department of Defence. This area lies largely within the adjacent Shoalwater catchment which also drains into Broad Sound to the northeast of the Project area. The original proposal identified a 'likely expansion area' stretching west from the existing training area to the approximate east bank of the Styx River located to the north of the Project. Based on opposition from local communities it has been recently assessed that a reduced expansion area is 'achievable' (DoD 2017). As such, the extent of the proposed expansion and the potential changes to land use are unknown at this stage.

Given there are no other large projects currently known to have identified lands within the Styx River catchment, the Project impacts to aquatic ecology will only add to those impacts that are a result of current land use in the catchment. These background land use impacts are already characterised within this chapter through the identification of local water quality values and aquatic ecology monitoring results. There are no other projects in the catchment or surrounds which the potential Project impacts to aquatic ecology subject to this assessment could conceivably add to.

15.10 Qualitative Risk Assessment

Potential impacts resulting from the current Project on ecological values have been assessed utilising the risk assessment framework outlined in Chapter 1 – Introduction.

For the purposes of risk associated with aquatic EVs risk levels are defined as follows:

- Extreme – Works must not proceed until suitable mitigation measures have been adopted to minimise the risk;
- High – Works should not proceed until suitable mitigation measures have been adopted to minimise the risk;
- Medium – Acceptable with formal review. Documented action plan to manage risk is required; and
- Low - Acceptable with review.

A qualitative risk assessment that outlines the potential impacts, the initial risk, control measures and the residual risk following the implementation of the control measures detailed in the previous sections is shown in Table 15-19.

Table 15-19 Qualitative risk assessment

Issue	Potential Impacts	Potential Risk	Control Measures	Residual Risk
Vegetation and wetland clearing	▪ Clearing of wetlands, aquatic habitat and associated vegetation; ▪ Degradation of receiving water quality and adverse effect on supported ecosystems; and ▪ Bank instability and associated follow-on impacts such as further riparian degradation.	Extreme	▪ Avoidance of riparian / wetland habitat in Project design; ▪ Avoid unnecessary clearing; ▪ Rehabilitate riparian habitat and creek banks adjacent to construction works on creek crossings; and ▪ Revegetation works on Mamelon property as part of Project ODP.	High
Aquatic habitat connectivity	▪ Road crossings causing loss of connectivity along creek lines preventing fish movements and changing water flows; and ▪ Increased flow velocities in creeks due to Project-associated water diversions.	High	▪ Appropriately designed culverts informed by DAF guidelines installed at all creek crossings; and ▪ Project water diversions designed to minimise flow velocities in creeks.	Medium
Direct fauna mortality	▪ Mortality of aquatic fauna including threatened species during clearing of artificial wetlands (farm dams) and instream works.	High	▪ Where necessary trained ecologist / fauna spotter will inspect waterholes and remove aquatic fauna from ponded areas prior to Project disturbance.	Low
Dust	▪ Impacts of construction-operation related dust settlement on riparian vegetation and wetland habitat; and ▪ Operational impacts of coal dust settlement on riparian vegetation and instream habitat.	High	▪ Incorporate monitoring program to encompass at risk riparian / wetland vegetation within Project LUMP; ▪ Implement water quality monitoring program including sites identified as potentially impacted by dust settlement; ▪ Project mine water to be recycled and used for dust suppression across site; ▪ Vehicle speed limits and regular maintenance enforced to reduce dust emissions; ▪ Coal conveyor designed to minimise fugitive dust emissions (covered and spill collectors featured in design); ▪ Areas stripped of topsoil during construction to be rehabilitated as soon as practical; and ▪ Haul road design to incorporate dust suppression techniques.	Low

Issue	Potential Impacts	Potential Risk	Control Measures	Residual Risk
Pests and weeds	▪ Degradation of aquatic habitats through weed invasion.	High	▪ Pest and weed management measures incorporated within Project LUMP; ▪ Carry out pre-construction weed mapping of Project site and implement control strategies as per DAF fact sheets; ▪ Implement weed wash-down procedures and minimise off-road vehicle movements across site; ▪ Implement appropriate strategies to reduce pest occurrence on-site; ▪ Implement regular weed and pest monitoring regime; and ▪ Establish complaints register to report outbreaks on neighbouring lands.	Medium
Accidental release of pollutants	▪ Degradation of instream habitat / water quality including downstream HEV estuarine habitat in the Styx River; and ▪ Fish mortality events.	High	▪ Design and implement Project Receiving Environment Monitoring Program and Water Management Plan; ▪ Controlled release of better quality water in accordance with licensed EA conditions; ▪ Maintenance of Design Storage Allowance on the onset of the wet season to minimise the likelihood of uncontrolled discharges; ▪ Pipeline connectivity between storages to allow water transfer to where there is available capacity; ▪ Establish measures to minimise / control Project-associated chemical spills; ▪ Project design will locate infrastructure to minimise stormwater run-off; and ▪ All waters discharged into adjacent waterways will be treated in retention basins and similar in quality to receiving waters.	Medium
Sedimentation of Waterways and Sediment Runoff	▪ Degradation of instream habitat / water quality including downstream HEV estuarine habitat in the Styx River.	High	▪ Design and implement Project ESCP; ▪ Surface waters managed and monitored under Project REMP; ▪ Minimise unnecessary disturbance to vegetated lands; ▪ Progressive rehabilitation of disturbed areas will be undertaken; ▪ Appropriately designed water management system including sediment containment dams; and ▪ Destocking and revegetation of Mamelon property as part of Project management and Project ODP.	Low
Hydrology and water flows	▪ Reduction of inflows to creek lines and consequent reduction in long-term habitat persistence (large waterholes).	Medium	▪ Design and implement Project REMP and WMP; and ▪ Project design to ensure surface water flows into creeks maintained as close to natural conditions as practical.	Low

Issue	Potential Impacts	Potential Risk	Control Measures	Residual Risk
Changes to groundwater table and GDE impacts (including stygofauna)	▪ Drawdown of groundwater impacting local stygofauna (Type 1 GDEs); ▪ Drawdown of groundwater impacting long-term habitat persistence in creeks (large waterholes) (Type 2 GDEs); and ▪ Drawdown of groundwater impacting adjacent riparian and alluvial vegetation communities (Type 3 GDEs).	High	▪ Design and implement Project REMP and WMP; ▪ Ongoing assessment and monitoring to address knowledge gaps and allow a greater understanding of GDE function; ▪ Regular monitoring of groundwater levels and quality, and riparian /wetland vegetation health at areas considered at risk of drawdown impacts; ▪ Conduct a stygofauna survey every five years during operations of the mine in accordance with the Department of Science, Information Technology and Innovation's *Guideline for the Environmental Assessment of Subterranean Aquatic Fauna*; ▪ REMP to include measures to replenish large waterholes in the event of identified impacts; and ▪ Implementation of the Project Biodiversity ODP as a last resort.	Medium

Note: R=Rare, UL= Unlikely, P=Possible, L=Likely, AC=Almost Certain

15.11 MSES Impact Assessment

The assessment has identified potential impacts to MNES fauna and other MNES values associated with the wider area downstream of the Project area, including values associated with the Great Barrier Reef World Heritage Area. Impacts to MNES are addressed in Chapter 16 – MNES.

The MSES that are applicable to aquatic EVs associated with the Project as described are compiled in Table 15-20. Where the identified impacts are considered as 'significant residual impacts' requiring the application of environmental offsets these are discussed further in Section 14.13 of Chapter 14 - Terrestrial Ecology.

Table 15-20 MSES as they apply to the Project

Category	Description	Project applicability
Protected area estates	Includes all classes of protected area (except nature refuges and coordinated conservation areas).	Tooloombah Creek Conservation Park is located 750 m west of the westernmost boundary of the ML. Bukkula Conservation Park and Marlborough State Forest are located 17 km east of the ML boundaries. Mitigation measures will be implemented to prevent potential offsite impacts such as dust settlement. **No significant residual impacts are expected.**
Marine Parks	Includes 'highly protected areas' of State marine park zones. These zones include: ▪ Preservation zones; ▪ Marine National Park zones; ▪ Scientific research zones; ▪ Buffer zones; and ▪ Conservation Park zones.	The boundary of the Great Barrier Reef Coast Marine Park is located approximately 8 km north of the Project in the middle estuary of the Styx River. The downstream section of the park closest to the Project is identified as a 'general use zone' and therefore not identified as a 'highly protected area.' The Marine National Park zone is located approximately 40 km downstream of the Project by which time the Styx River opens into a broad shallow estuary. The Project will release treated mine water only during flow events. Water quality of released water will be strictly controlled under the Project EA conditions. Other potential impacts resulting from Project activities include sedimentation and uncontrolled releases of pollutants. Mitigation measures to control for such events are described in Section 15.8.9 and in detail in Chapter 9 – Surface Water. **No significant residual impacts expected.**
Fish Habitat Areas	Includes areas declared as FHA Management A, or FHA Management B under the Fisheries Act.	The Project area is located 8 km south of the boundary of Broad Sound which is listed as declared FHA (Management A). Works are considered to result in a significant residual impact to a declared FHA or highly protected zones of marine parks if: ▪ The works are not for a purpose or a structure type listed below; and ▪ The works will result in a residual disturbance footprint within the declared FHA and/or highly protected marine park zone of $40m^2$ or greater in area. The Project does not require any works within the boundary of the FHA and no downstream impacts are predicted from Project activities. There will be no direct or indirect disturbance to fish habitat areas as a result of the Project.

Category	Description	Project applicability
		Impacts and mitigations will be the same as that described under 'Marine Parks.' **No significant residual impacts expected.**
Waterway fish passage	Includes any part of a waterway that provides for passage of fish. Applies to any structure that may create a barrier or otherwise impact fish habitat quality.	The mine haul road will cross Deep Creek and Barrack Creek. Deep Creek is likely to be used for fish passage when flows occur. Barrack Creek is largely an ephemeral waterbody with highly intermittent flows. With appropriate crossing construction including culverts no impacts are anticipated at this crossing point. Several minor waterways (tributaries of Deep Creek) occur throughout the ML. Large sections of these waterways will be impacted by the Project layout i.e they occur within the footprint of the mine pits and infrastructure. However, some of these waterways are highly ephemeral and modified and are not considered to provide passage for fish (refer Section 15.7.2). There is potential for waterholes along Tooloombah and Deep Creek (mapped as a 'major' waterway) to be impacted by groundwater drawdown. These creeks will be subject to water quality and height monitoring under the Project REMP. Where impacts are detected the Project will establish a waterhole supplementary replenishment program (refer Section 15.8.9). **Significant residual impacts expected in areas within the ML where development will occur. Discussions with DAF required to confirm outcome of application to amend the waterway mapping.**
Regulated vegetation	Includes: ▪ REs classified as 'endangered' or 'of concern'; ▪ REs classified as 'watercourse'; ▪ Habitat mapped as 'essential habitat'; and ▪ Wetlands on the VM Act map.	Under ground-truthed vegetation mapping there are two REs classified as Of Concern and regulated vegetation intersecting a watercourse that may be directly impacted by the Project, thereby triggering offsets. A total of 3.53 km or 7.78 ha of lands mapped as 'watercourse vegetation' will be impacted by clearing for Waste Rock Stockpile 2, Dam 1, and for the haul road (refer Section 14.12.2 of Chapter 14 – Terrestrial Ecology for further detail). There is potential for groundwater drawdown to impact sensitive vegetation communities requiring access to shallow groundwater including Least Concern watercourse vegetation (RE 11.3.25), Of Concern (RE 11.3.4) and a wetland mapped under the VM Act (11.3.12). These communities will be subject to vegetation health monitoring and mitigation actions where impacts are detected (refer Section 15.8.10). The wetland will be subject to groundwater height monitoring through a site specific bore. Where mitigations are unsuccessful these areas will be subject to significant residual impacts. **Significant residual impacts expected in areas subject to clearing only (refer Section 15.7.1). Potential significant residual impacts from groundwater drawdown.**
Protected wildlife habitat	Includes flora and fauna species listed as Special Least Concern, Vulnerable, or Endangered under the NC Act and includes habitat	There are several terrestrial fauna and flora species listed as Endangered, Vulnerable or Special Least Concern that occur or have potential to occur in the study area.

Category	Description	Project applicability
	that supports a listed fauna species (e.g. foraging roosting or breeding habitat).	One threatened aquatic species is likely to occur in the waters downstream of the Project area boundary – Estuarine Crocodile. Several threatened marine species may occur in downstream waters associated with the Styx River estuary / Broad Sound area. No significant residual impacts to habitat supporting these species are expected. Several threatened marine species (marine turtles and inshore dolphin species) may occur in downstream waters associated with the Styx River estuary / Broad Sound area. However suitable habitat for marine species is not considered likely to occur close to the Project area due to the impact of the large tidal regime in the area (much of the river is very shallow and narrow at low tide). Suitable habitat for these species is not considered likely to occur upstream of Rosewood Island (approximately 30 km downstream of the Project boundary). There is potential for groundwater drawdown to impact sensitive vegetation communities that provide habitat for Koala and likely require access to shallow groundwater (RE 11.3.4 and RE 11.3.25). These communities will be subject to vegetation health monitoring and mitigation actions where impacts are detected (refer Section 15.8.10). Where mitigations are unsuccessful these areas will be subject to significant residual impacts. **Significant residual impacts to habitat for threatened terrestrial fauna only expected in cleared areas. Potential significant residual impacts from groundwater drawdown (refer Chapter 14 – Terrestrial Ecology).**
Connectivity	Includes all remnant vegetation.	The landscape Project impacts to the extent of remnant vegetation in the area have been analysed using EHPs 'landscape fragmentation and connectivity' tool. Refer Appendix A9g – Results of Landscape Fragmentation and Connectivity of the EIS. **No significant residual impacts expected**.
Designated precinct in a strategic environmental area	Includes areas designated under the *Regional Planning Interests Regulation 2014*	No strategic environmental area is designated within or near the Project area. **Not applicable.**
High conservation value wetlands and watercourses	Includes: ▪ Wetlands assessed as 'High Ecological Significance' on the map of referable wetlands; or ▪ High Ecological Value (HEV) freshwater and estuarine areas declared under the Environmental Protection (water) Policy 2009 [EPP (water)].	**Land based wetlands** There is a single HEV wetland considered as a 'WPA' on the map of referable wetlands located in the western portion of the ML. Project mine infrastructure does not intersect the 500 m buffer area applied to the WPA. The indicative access road for the CHPP / MIA 1 area and Mount Bison Road is currently proposed to intersect the 500 m buffer area (refer Section 15.7.1). Central Queensland Coal will configure the final design / route for the access road in such a way as to avoid impacts to the WPA. **No significant residual impacts expected**. **Refer Section 15.11.1.4.** **Marine wetlands**

Category	Description	Project applicability
		The middle estuary of the Styx River is mapped as HEV under the EPP (water) approximately 8 km north and downstream of the Project area. **No significant residual impacts expected**. **Refer Section 15.11.1.4.**
Marine Plants	Protected marine plants as regulated under the *Fisheries Act 1994.*	Marine Couch was identified along the edge of the Styx River approximately 2.5 km downstream of the Project boundary and is considered a marine plant. Extensive stands of saltmarsh and mangrove species occur downstream of the Project (14 km and 21 km downstream respectively) along the margins of the Styx River and Broad Sound. There are no marine plants within the Project area. There will be no direct impact on marine plants from the Project. The Project will not result in indirect damage to marine plants, changes to the marine plant community composition, or cause fragmentation of an ecological community. **No significant residual impacts expected. Refer Section 15.11.1.5.**
Legally secured offset areas	Includes offset areas legally secured under a registered covenant, easement, conservation agreement or development approval condition.	There are no secured offset areas on or near the Project area. **Not applicable.**

Project impacts to MSES requiring offsetting under the *Environmental Offsets Act 2014* are based on current DNRME vegetation mapping. A 'Regional Ecosystem assessment request' including vegetation data, GIS data (ESRI shapefiles), and site photographs has been lodged with DES regarding amendments to the vegetation mapping associated with the Property the Project is located on – Mamelon (refer Appendix A19 for request letter and site data). The impacts to regulated vegetation and habitat for MSES fauna species discussed below are based on updated vegetation mapping associated with the assessment request.

Significant residual impacts to aquatic MSES that cannot be reasonably avoided or mitigated will be subject environmental offsets. Refer Section 14.13 (Biodiversity Offsets) of Chapter 14 - Terrestrial Ecology for further detail.

15.11.1 Potential Impacts to MSES and EVNT Fauna

15.11.1.1 Waterway Fish Passage

Approximately 13.4 km of waterways mapped under the Waterway Barrier Works for Fish Passage mapping layer occurs within the Project area, much of which will be heavily impacted by components of the Project. Central Queensland Coal considers these waterways to be incorrectly mapped as discussed in Section 15.7.2. Should DAF require further assessment and / or consider these areas to be used for fish passage then the extent of area required to be considered for Environmental Offsets (upon discussions with DAF / DES) will be included in the Project Offsets Delivery Plan. Refer Section 14.12 (Biodiversity Offsets) of Chapter 14 - Terrestrial Ecology for further detail.

Tooloombah Creek and Deep Creek are waterways mapped as 'major' under the Waterway Barrier Works for Fish Passage mapping layer. Sections of these waterways lie within the predicted area of groundwater drawdown as discussed in Section 15.7.2. This includes a low to moderate threat of adverse impact to 4 km of Tooloombah Creek and almost 6 km of Deep Creek, while a high threat is expected at 1.2 km of Tooloombah Creek and 3.7 km of Deep Creek. Waterholes in these waterways will be monitored and subject to supplementary replenishment where drawdown impacts are expected.

15.11.1.2 Regulated Vegetation

The Project will impact watercourse vegetation (Criteria 8e) i.e. vegetation along a watercourse mapped as Least Concern. A total of 3.74 km of lands mapped as 'watercourse vegetation' will be impacted by clearing for Waste Rock Stockpile 2 (2.64 km or 5.38 ha of 2nd order watercourse), dam 1 (800 m or 1.6 ha of 2nd order watercourse) and for the haul road (70 m or 0.55 ha across 3rd / 4th order watercourses – Barrack Creek, and 25 m or 0.25 ha across 5th order watercourse – Deep Creek) (Figure 15-26).

There is potential in the long-term for remnant vegetation classified as Least Concern watercourse vegetation to be adversely impacted by groundwater drawdown in the vicinity of open cut mining operations. Where this community occurs within the predicted zone of groundwater drawdown impact these areas will be subject to vegetation health monitoring as part of the Project LUMP and REMP. Areas mapped as RE 11.3.25 have a low to moderate threat of being impacted where groundwater drawdown is less than 1 m. Above this level there is a moderate to high threat (Figure 15-27). Areas mapped as RE 11.3.4 are located within the predicted 5 m drawdown contour where a low to moderate threat has potential to occur. In the event that impacts have been found to occur and mitigation actions are unsuccessful these areas will also be subject to the Project's environmental OMP. Refer Section 14.12 (Biodiversity Offsets) of Chapter 14 - Terrestrial Ecology for further detail.

15.11.1.3 EVNT Aquatic Fauna

The Project may result in direct and indirect impacts to a single threatened freshwater fauna species considered known or likely to occur: Estuarine Crocodile (Vulnerable – NC Act). The species is only likely to utilise large permanent pools in the Styx River downstream of the Project. The waterholes in Tooloombah Creek and Deep Creek are unlikely to provide sufficient habitat value to support the species presence. Potential impacts most applicable to these species are pollutant and sediment releases which may impact habitat quality.

An impact assessment for threatened aquatic fauna relevant to the Project is carried out in Section 15.11.2. The results of the significant impact assessment for Estuarine Crocodile are not considered to be significant and there is no change in that assessment for the SEIS.

15.11.1.4 High Conservation Value Wetlands and Watercourses

There is a single WPA located within the MLs and near the eastern boundary. No Project mine infrastructure will enter the 500 m buffer area located around this ephemeral wetland.

The indicative access road for the CHPP / MIA 1 area and Mount Bison Road is currently proposed to intersect the 500 m buffer area approximately 120 m from the WPA itself. This has the potential to impact 1.66 ha of remnant vegetation within the buffer area. Mount Bison Road and a minor access track (south and west of the WPA respectively) are both located within the WPA buffer area already. Central Queensland Coal will configure the final design / route for the access road in such a way as to avoid significant residual impacts to the WPA.

The waters of Broad Sound are prescribed as HEV marine waters starting 8 km downstream of the Project boundary.

DES's *Significant Impact Residual Guideline* (EHP 2014a) details the significant impact criteria regarding wetlands and watercourses. The two identified wetland areas are assessed against the criteria in Table 15-21. No significant impacts are predicted on either wetland.

Table 15-21 Assessment against MSES significant impact criteria for prescribed 'wetlands and watercourses'

Assessment criterion	HEV wetland (WPA)	Downstream waters
Areas of the wetland or watercourse being destroyed or artificially modified	Wetland is not within the Project infrastructure footprint	The Project area is located 8 km south of the prescribed marine wetland area and it will not be destroyed or artificially modified
A measurable change in water quality of the wetland or watercourse	Several environment dams are proposed to capture rainfall runoff from the CHPP / MIA areas, TLF and waste rock stockpile areas. The primary function of the environment dams is to capture sediment laden runoff for sediment removal. Mitigation measures detailed in Section 15.8.7 and 15.8.8.	Potential water quality impacts to Broad Sound are discussed in Section 15.7.7and 15.7.8, and Chapter 9 – Surface Water of the EIS. Potential impacts resulting from the Project are restricted to water quality issues resulting from accidental releases of sediment laden water, chemical spills or mine water. It is considered that with appropriate monitoring and mitigation measures as detailed in Section 15.8 these potential impacts can be minimised or eliminated.
The habitat or lifecycle of native species, including invertebrate fauna and fish species, dependent upon the wetland being seriously affected	The Project will not directly impact the wetland and the wetland is highly ephemeral. No fish species occur in the wetland. Indirect impacts are restricted to potential dust settlement and groundwater drawdown impacting woody vegetation in the wetland. However, the reliance of these trees on groundwater remains uncertain and may only occur during very dry conditions (refer Section 15.6.4). Wetland health will be monitored under the Project REMP.	The single potential impact resulting from the Project is from the release of sediment laden and / or polluted waters impacting downstream habitat. The Project has incorporated a number of dams designed to capture mine water and mine-affected rainfall run-off. A number of industry standard mitigation measures will be strictly applied to Project activities to reduce the potential for entrained sediments and chemical pollutants to enter waterways (and hence downstream habitat) during heavy rainfall events (refer Section 15.8.7 and 15.8.8). Proposed erosion and sediment control measures are estimated as capturing 90% of the sediments potentially emanating from the Project site. The Project is considered very unlikely to adversely affect habitat downstream in Broad Sound.
A substantial and measurable change in the hydrological regime or recharge zones of the wetland	There will be no impacts to either surface recharge or quality as a result of the Project. There is a minor chance groundwater drawdown impacting woody vegetation in the wetland. However, the reliance of these trees on groundwater remains uncertain and may only occur during very dry conditions (refer Section 15.6.4). Wetland health will be monitored under the Project REMP.	The hydrological impact of the Project on surface water flows has been summarised in 15.7.9. Impacts are minimal at worst and only occurring during the worst modelled flood events. Impacts due to groundwater drawdown are not expected to have any impact on groundwater inputs associated with the Styx River including downstream HEV waters
An invasive species that is harmful to the environmental values of the wetland being established (or an existing invasive species being spread) in the wetland	Weed and pest control will be incorporated into the Project Land Use Management Plan to control the introduction and spread of weeds and pests in the Project area. The wetland is noted as being currently impacted by Olive Hymenachne.	The Project LUMP will incorporate the management of invasive species which will assist in the prevention of pest plant introduction and associated diseases resulting from Project activities. Project equipment sourced from overseas will be quarantined as required under State and Commonwealth legislation. The Project is not conceivably likely to introduce an invasive species to marine waters.

Assessment criterion	HEV wetland (WPA)	Downstream waters
Assessment of potential for significant residual impacts	No significant residual impacts are considered likely to occur.	No significant residual impacts are considered likely to occur.

15.11.1.5 Marine Plants

Marine Couch was identified along the edge of the Styx River approximately 2.5 km downstream of the Project boundary and is considered a marine plant. Extensive stands of saltmarsh and mangrove species occur downstream of the Project (14 km and 21 km downstream respectively) along the margins of the Styx River and Broad Sound.

DES's *Significant Impact Residual Guideline* (EHP 2014a) details the significant impact criteria regarding wetlands and watercourses.

An action is likely to have a significant residual impact on marine plants where the impacts of the development shall result in private infrastructure works impacting more than 17 m^2 of fish habitat or public infrastructure works impacting more than 25 m^2 of fish habitat; and:

- Temporary impacts are expected to take five years or more for the impact area to be restored to its predevelopment condition; or
- A proposed reduction in the extent of marine plants through removal, destruction or damage of marine plants; or
- Fragmentation or increased fragmentation of a marine ecological community; or
- Adverse changes affecting survival of marine plants through modifying or destroying abiotic (non-living) factors (such as water, nutrients, or soil) necessary for a marine plant's survival; or
- Alteration in the species composition of marine plants in an ecological community, that causes a decline or loss of functionally important species; or
- Interference with the natural recovery of marine plant communities.

There will be no direct impact on marine plants from the Project. The only potential impact to downstream marine plants from Project activities are from releases of chemical pollutant / sediment laden waters. Water quality of released water will be strictly controlled under the Project EA conditions and will only occur during flow events. Mitigation measures to control for accidental events are described in Sections 15.8.7 and 15.8.8, and Chapter 9 – Surface Water of the EIS.

The Project is considered unlikely to impact downstream marine plants.

15.11.1.6 Impacts to MSES

The potential impacts identified on aquatic MSES including EVNT fauna are those associated with wetland vegetation clearing, water quality impacts (sediment and pollutants), potential groundwater drawdown of permanent waterholes and impacting sensitive vegetation communities, and potential dust settlement impacts on wetland health.

Project impacts associated with the Styx River and downstream MSES (including impacts to threatened marine fauna, Broad Sound, HEV marine waters and the GBRCMP) are impacts from uncontrolled release of contaminated and / or sediment-laden waters from Project activities. Mitigations applicable to both of these impacts have already been considered in previous sections (refer Chapter 9 - Surface Water and Sections 15.8.7 and 15.8.8). These impacts will be mitigated against during the detailed Project design and WMP and REMP will incorporate measures and monitoring that minimise any impacts to the identified values. The FHA and GBRCMP are located well downstream of the Project and no significant residual impacts are predicted on downstream aquatic values.

15.11.2 Impact Assessment for Threatened Aquatic Fauna

Section 15.6.3.4 describes the likelihood of occurrence of threatened (listed under the NC Act and / or EPBC Act) fauna. Species that are considered unlikely or with potential to occur are not considered further and will not be subject to significant residual impacts from Project activities. There is one aquatic fauna species listed as threatened under the NC Act which is considered as likely to occur immediately downstream of the Project area in the Styx River: Estuarine Crocodile. The species may potentially occur in larger waterholes in Tooloombah Creek and Deep Creek, although these areas appear much less suitable than further downstream.

There are potential long-term impacts to EVNT fauna or likely habitat (large permanent pools) for Estuarine Crocodile. Initial modelling of a reduction in groundwater levels in the vicinity of open cut mining operations may reduce the level of localised permanent waterholes in the area.

Hydrological impacts resulting from Project activities such as water diversions and flood harvesting are considered very unlikely to impact water levels in habitat in either Deep Creek or Tooloombah Creek (refer Section 15.7.9). Mitigation measures relating to 'Accidental Release of Pollutants,' 'Sedimentation of Waterways and Sediment Runoff' and 'Changes to Groundwater Table and GDEs' are detailed in the Sections 15.8.7, Section 15.8.8 and Section 15.8.10 respectively and are considered largely applicable to potential impacts on water quality and levels in the same areas.

Under the Queensland Environmental Offsets Policy: Significant Residual Impact Guideline (SoQ, 2014) the residual impact criteria for assessing the potential impact of a project's activities are essentially the same as that for Vulnerable MNES fauna under the EPBC Act Significant Impact Guidelines 1.1 (DotE, 2013) (refer Chapter 16 – MNES). The significant impact criteria assessment for each of the threatened species listed above is presented in the following table (Table 15-22).

Table 15-22 Assessment against MSES significant impact criteria for threatened species identified

Assessment criterion	Estuarine Crocodile – assessment against significance criteria
Lead to a long-term decrease in the size of a local population of the species	Anecdotal evidence suggests species occurs although the extent of occurrence upstream of the Styx River is uncertain. No direct construction impacts on suitable habitat (large pools) are proposed. Impacts to habitat values that may directly impact individuals or prey species (such as sedimentation and pollutants causing water quality / habitat degradation) will have mitigation measures applied. Hydrologic inflows to likely habitat will not be impacted. Groundwater drawdown may impact permanent waterholes in the vicinity of mining operations but these areas are likely to be of very limited value to this species. Unlikely to lead to a decrease of a local population.
Reduce the area of occurrence of the species	Species occurs across much of coastal Queensland. Uncertain if species utilises freshwater habitats adjacent to the Project more than occasionally. The Project will not reduce the area of occurrence.
Fragment an existing population	Overall population is widely dispersed and no subpopulations are recognised. Uncertain if species utilises freshwater habitats adjacent to the Project more than occasionally. The Project is unlikely to fragment an existing population should the species occur upstream of Project activities.

Assessment criterion	Estuarine Crocodile – assessment against significance criteria
Result in genetically distinct populations forming as a result of habitat isolation	Project design and location within surrounding landscape is unlikely to result in habitat isolation of any species.
Result in invasive species that are harmful to a vulnerable species becoming established in the species habitat	The LUMP will incorporate weed and pest measures to control the introduction and spread of weed species across the Project area. The LUMP will be in place for the life of the Project, and will minimise the potential for weed invasion and may in the long-term improve habitat condition within vegetation communities located adjacent to Project infrastructure. The Project is considered very unlikely to result in invasive species becoming established in the Project area to the detriment of any threatened species' habitat.
Introduce disease that may cause the population to decline	The LUMP will incorporate the management of invasive species which will assist in the prevention of pest plant introduction and associated diseases resulting from Project activities. Project equipment sourced from overseas will be quarantined as required under State and Commonwealth legislation. The Project is considered unlikely to introduce disease that may cause a population of threatened species to decline.
Interfere with the recovery of the species	The extent of the Project area is relatively small and no individuals of any of either species have been found within the Project site itself. With mitigation of potential Project impacts through surface water management and measures incorporated within the LUMP and REMP, any potential impact on a threatened species, should it occur in the Project area, will be minor and is considered unlikely to interfere with the recovery of the species.
Cause disruption to ecologically significant locations (breeding, feeding, nesting, migration or resting sites) of a species	There will be no direct impacts to suitable habitat and indirect impacts will be mitigated. It is unlikely to cause disruption to ecologically significant locations.
Assessment of potential for significant residual impacts	No significant residual impacts are considered likely to occur.

From the significant impact assessment guidelines for habitat for MSES fauna and flora, no threatened aquatic species are considered to have significant residual impact as a result of Project activities and as a result will not be subject to a biodiversity offsets plan.

15.12 Conclusion

The Project is located within the Styx River basin occupying the lower catchments of two major creek lines – Deep Creek and Tooloombah Creek. The region has experienced a long history of human disturbance largely due to grazing activities which occupies 78% of the Styx River catchment. Deep Creek and Tooloombah Creek lie adjacent to the east and west boundaries of the Project. These creeks are ephemeral, merging two kilometres north of the Project area whereupon it becomes the Styx River. The Styx River is subject to tidal influence almost to the confluence of the two creeks.

The Styx River widens into a large estuary that is located within the wider Broad Sound area 10 km downstream of the Project. Broad Sound is listed as a FHA, is on the DIWA, and is part of the GBRCMP and GBRWHA.

Aquatic habitats sampled in the area appear to be in good condition when surveyed during flow events despite the impact of cattle grazing in the wider area. Riparian cover along Tooloombah Creek and Deep Creek is largely continuous. Water quality across the catchment recorded generally high values of nutrients including ammonia, nitrogen and phosphorus. Deep Creek was recorded as having significant turbidity levels during no flow conditions. Macroinvertebrate assemblages within survey sites were diverse and representative of healthy aquatic systems when creeks were flowing.

No listed aquatic flora was recorded during the surveys. Observations during wet and dry season surveys across the wider area recorded a number of sedge / wetland plants associated with ephemeral wetlands including Swamp Lily, *Eleocharis blakeana* and *Juncus polyanthemus.* A total of 28 fish species were recorded during a detailed site survey in 2011 which included the Styx River. The species recorded are generally typical of what would be expected to occur in a Central Queensland coastal catchment. There are no records of introduced fish species from either desktop information or field surveys indicating the catchment may be relatively free of introduced fish taxa.

One threatened aquatic species has potential to occur in the waters adjacent to the Project and is likely to occur downstream. Anecdotal evidence indicates that Estuarine Crocodile (listed as Vulnerable – NC Act) occurs in the Styx River. Four species of large marine fauna (all considered Vulnerable under the NC Act) are considered likely to occur downstream of the Project in the waters of Broad Sound: Green Turtle, Flatback Turtle, Australian Hump-backed Dolphin, and Australian Snubfin Dolphin. The nearest available habitat for these species is considered to be in the waters of the lower estuary of the Styx River adjacent to Rosewood Island.

Stygofauna communities were recorded during a comprehensive (seasonal) study sampling from groundwater bores located within the mine lease boundary and the wider area. Five species were identified to the north of the Project. Only a single species was located on the eastern boundary of the mine lease. This species was found within the predicted groundwater drawdown impact area resulting from mine activities. It is considered highly unlikely this species is restricted to the localised area of Project groundwater impact. Therefore, no stygofauna species is considered restricted to the potential impact area and there will be no significant impacts.

Predicted groundwater drawdown impacts close to open cut mining activities have the potential to cause long-term impacts to localised habitat for fish species (and to a lesser extent Estuarine Crocodile) through reduction of water levels in permanent waterholes. This effect is predicted to pose a low threat of adverse impact (< 0.5 m drawdown) to 3.4 km of Tooloombah Creek and 3.3 km of Deep Creek, while a moderate to high threat (> 0.5 m drawdown) is expected along 2.4 km of Tooloombah Creek and 3.9 km of Deep Creek (Figure 15-27). This is an overestimate of the extent of potential impact area as waterholes do not occur along the entirety of this impact area.

Groundwater drawdown may also have long-term impacts on adjacent riparian vegetation. Based on ground-truthed vegetation mapping, mining effects are predicted to pose a low level threat (< 1 m drawdown) to areas of riparian Forest Red Gum vegetation (RE 11.3.25) along Tooloombah Creek (40.3 ha) and Deep Creek (62.4 ha). A moderate to high threat (> 1 m drawdown) is predicted in vegetation communities encompassing 8.3 ha along Tooloombah Creek and 34.2 ha along Deep Creek.

Estuarine crocodile will be subject to a Significant Species Management Plan. No impacts from groundwater drawdown are expected to downstream aquatic values of the GBRCMP (including habitat for MNES - aquatic fauna or shorebird species).

The mitigation measures proposed as part of the Project will minimise additional indirect impacts to aquatic EVs within, surrounding or downstream of the Project area from construction and operational activities. These measures include monitoring and management measures under the REMP and WMP, to monitor the health of wetlands, streams and riparian vegetation adjacent to the Project for indirect impacts such as water level reductions (in permanent waterholes), dust and surface water contamination. Management measures will include provisions of replenishment in permanent waterholes should water level reductions be detected. With control measures in place indirect impacts to aquatic EVs and aquatic fauna are not expected to be significant.

15.13 Commitments

Table 15-23 Commitments - aquatic ecology

Commitment
Develop and implement a LUMP which will establish a vegetation monitoring program, identify pest and weed management controls, fire management measures and principles for managing fauna.
Develop and implement Significant Species Management Plans for managing those threatened species known or likely to occur on the site.
Develop and implement a series of dust mitigation and monitoring measures.
Develop and implement a REMP detailing the monitoring and management measures for surface water and groundwater in accordance with DES Guidelines and periodically update as required throughout the life of the Project.
Fish passage will be maintained at haul road crossing points along Deep Creek and Barrack Creek through incorporating box culvert construction designs, using guidelines for fish passage.
In the event that fish are trapped by the Project, fish salvage activities in accordance with the Fish salvage guidelines will be applied.
Design and implement a Project ESCP to be certified by a suitably qualified person, prior to construction.
The health of riparian vegetation adjacent to creek crossings will be monitored at least annually throughout construction, operation and decommissioning to identify impacts (such as coal dust accumulation, bank destabilisation and erosion and sediment issues) to environmental values
To further the understanding of coastal stygofauna, Central Queensland Coal will implement a program to survey stygofauna at five year intervals during the life of the mine.

15.14 ToR Cross-reference Table

Table 15-24 ToR cross-reference

Terms of Reference	Section of the EIS
8.7 Flora and Fauna	
Describe the potential direct and indirect impacts on the biodiversity and natural environmental values of affected areas arising from the construction, operation and decommissioning of the project.	Section 15.7
Consider any proposed avoidance and/or mitigation measures.	Section 15.8
The EIS should provide information based on relevant guidelines, including but not limited to DES's EIS information guidelines that cover flora and fauna, aquatic ecology, coastal issues, ground-dependent ecosystems, water, matters of national environmental significance, and biosecurity.	Noted
The assessment should include the following key elements: • identification of all significant ecological species and communities, including MSES and MNES, listed flora and fauna species, and regional ecosystems, on the project's site and in its vicinity	Section 15.6 and Chapters 14 – Terrestrial Ecology and 16 - MNES
• terrestrial and aquatic ecosystems (including groundwater-dependent ecosystems) and their interactions • biological diversity	Section 15.6 and Chapters 10 – Groundwater and 14 – Terrestrial Ecology
• the integrity of ecological processes, including habitats of listed threatened, near threatened or special least-concern species	Section 15.6 and Chapters 10 – Groundwater, 14 – Terrestrial Ecology, and 16 - MNES
• connectivity of habitats and ecosystems	Sections 15.6, 15.7.2, 15.7.3, 15.8.2 and 15.8.3

Terms of Reference	Section of the EIS
• the integrity of landscapes and places, including wilderness and similar natural places	Chapter 14 – Terrestrial Ecology
• chronic, low-level exposure to contaminants or the bio-accumulation of contaminants	Sections 15.7.7, 15.8.7 and 15.10 and Chapters 9 – Surface Water, 10 – Groundwater, 14 – Terrestrial Ecology and 16 - MNES
• impacts (direct or indirect) on terrestrial and aquatic species and ecosystems whether due to: vegetation clearing; hydrological changes; discharges of contaminants to water, air or land; noise; etc.	Section 15.7 and Chapters 9 – Surface Water, 10 – Groundwater, 14 – Terrestrial Ecology and 16 - MNES
• impacts of waterway barriers on fish passage in all waterways mapped on the Queensland Waterways for Waterway Barrier Works spatial data layer.	Sections 15.7.2 and 15.11
Describe any actions of the project that require an authority under the *Nature Conservation Act 1992*, and/or would be assessable development for the purposes of the *Vegetation Management Act 1999*[3], the *Regional Planning Interests Act 2014,* the *Fisheries Act 1994* and the *Planning Act 2016.* Features to consider include regional ecosystems, environmentally sensitive areas, wetlands, nature refuges, protected areas and strategic environmental areas.	Section 15.2
Propose practical measures to avoid, minimise, mitigate and/or offset direct or indirect impacts on ecological environmental values.	Sections 15.8, 15.10 and 15.12 and Chapters 10 – Groundwater, 14 – Terrestrial Ecology, and 16 - MNES
Assess how the nominated quantitative indicators and standards may be achieved for nature conservation management.	Section 15.8
Address measures to protect or preserve any listed threatened, near-threatened or special least concern species.	Section 15.8 and Chapter 14 – Terrestrial Ecology
Propose measures that would avoid the need for waterway barriers, or propose measures to mitigate the impacts of their construction and operation.	Section 15.8.2
Assess the need for buffer zones and the retention, rehabilitation or planting of movement corridors. The assessment should take account of the role of buffer zones in maintaining and enhancing riparian vegetation to enhance water quality and habitat connectivity.	Sections 15.7.1 and Chapter 14 – Terrestrial Ecology
Propose rehabilitation success criteria, in relation to natural values, that would be used to measure the progressive rehabilitation of disturbed areas. Describe how the achievement of the objectives would be monitored and audited, and how corrective actions would be managed. Proposals for the rehabilitation of disturbed areas should incorporate, in suitable habitat, provision of nest hollows and ground litter.	Chapter 11 – Rehabilitation and Decommissioning

[3] This is notwithstanding that the Vegetation Management Act 1999 does not apply to mining projects. Refer also to https://www.qld.gov.au/environment/land/vegetation/clearing/

Terms of Reference	Section of the EIS
Specifically address any obligations imposed by State or Commonwealth legislation or policy or international treaty obligations, such as the China–Australia Migratory Bird Agreement, Japan–Australia Migratory Bird Agreement, or Republic of Korea–Australia Migratory Bird Agreement.	Chapter 16 - MNES
8.7.1 Offsets	
For any significant residual impacts, propose offsets that are consistent with the following requirements as set out in applicable State and Commonwealth legislation or policies: • Where a significant residual impact will occur on a prescribed environmental matter as outlined in the Environmental Offsets Regulation 2014, the offset proposal(s) must be consistent with the requirements of Queensland's *Environmental Offsets Act 2014* and the latest version of the Queensland Environmental Offsets Policy[4].	Section 15.11 and Chapter 14 – Terrestrial Ecology
• Where the Commonwealth offset policy requires an offset for significant impacts on a MNES, the offset proposal(s) must be consistent with the requirements of the EPBC Act Environmental Offsets Policy (October 2012), the *Offsets Assessment Guide* and relevant guidelines[5] (refer to also Appendix 3 of this TOR).	Chapter 16 - MNES
8.8 Coastal environment	
Conduct impact assessment in accordance with the DES's *EIS information guideline—Coastal*.	Section 15.7.11
Provide illustrated details of the existing coastal zone that is potentially affected by the project, and describe and illustrate any proposed works in the coastal zone, including a schedule of ongoing maintenance requirements. The description should at least address the following matters: • State or Commonwealth marine parks in the region of the project's site	Section 15.6.2
• separately mention marine plants and any fish habitat areas protected under the *Fisheries Act 1994*	Sections 15.6.2.4, 15.6.2.5 and 15.6.2.10
Assess the potential impacts of the project's activities in the coastal zone.	Section 15.7
Propose measures to avoid or minimise the potential impacts of the project's activities in the coastal zone. If acid sulfate soils would be disturbed, describe measures to avoid oxidation of the sulfides or to treat and neutralise the acid if it forms.	Section 15.8 and Chapter 5 - Land
Detail any residual impacts that cannot be avoided, and propose measures to offset the residual loss.	Section 15.11
Develop and describe suitable indicators for measuring coastal resources and values, and set objectives to protect them in accordance with relevant State Planning Policy July 2014, guidelines and legislation. Refer to DES's guidelines on coastal development.	Section 15.8
Detail a monitoring program that would audit the success of mitigation measures, measure whether objectives have been met, and describe corrective actions to be used if monitoring shows that objectives are not being met.	Section 15.8

[4] https://www.qld.gov.au/environment/pollution/management/offsets/

[5] http://www.environment.gov.au/epbc/publications/epbc-act-environmental-offsets-policy