Vulcan South Project

Aquatic Ecology Study

Prepared for:

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Summary

frc environmental was commissioned by METServe Pty. Ltd. on behalf of Vitrinite Pty. Ltd., owner of Qld Coal Aust No.1 Pty. Ltd. and Queensland Coking Coal Pty. Ltd. (Vitrinite), to assess the potential impacts to aquatic ecological values of waterways and wetlands within and surrounding the Project Area of the proposed Vulcan South Project (the Project), to support the Project mining lease and environmental application approvals processes.

The scope of this aquatic ecology study is to:

- describe the aquatic ecological values of waterways and sensitive aquatic environmental receptors of the Broader Study Area
- assess the potential Project impacts on aquatic ecological values, and
- present mitigating measures for avoiding or reducing significant potential Project impacts on aquatic ecological values.

The assessment of aquatic ecological value using the AquaBAMM criteria showed:

- low to moderate aquatic and catchment naturalness
- low diversity of common aquatic species (with no threatened or priority aquatic species)
- no threatened, priority or special habitat or geomorphic features present
- limited and temporary hydrological connectivity, and
- an absence of unique or representative aquatic ecosystems.

The assessment of aquatic ecological value based on regulatory instruments indicated that the:

- headwaters of Plumtree Creek have high aquatic ecological due to the presence of endangered wetland Regional Ecosystem (RE) 11.4.9 in riparian areas
- mainstems of Hughes, Boomerang and Barrett Creeks have moderate aquatic ecological value because these waterways provide suitable habitat for common species of turtle, fish, and macroinvertebrate in some wet seasons, are possibly important corridors for fish passage in some wet seasons, and have of-concern wetland RE 11.3.2 and RE 11.3.25 in their riparian zones
- other waterways of the specific Project Area have potentially moderate aquatic ecological value because these waterways possibly provide suitable habitat for

common species of turtle, fish and macroinvertebrate in some wet seasons, but are unlikely to provide important corridors for fish passage because hydrological connectivity is very limited (several days a year, with no hydrological connectivity on some years) and these systems do not contain or link key breeding, foraging or refugial habitat for fish.

Threatened aquatic fauna are highly unlikely to occur, there are no High Ecological Value (HEV) waters, declared fish habitat areas, or category B or C regulated vegetation classes in the riparian zone.

No sensitive aquatic environmental receptors are likely to occur in waterways in the Broader Study Area.

The following potential sources of impact on aquatic ecological values associated with the Project were identified:

- discharge of mine-affected water to waterways
- localised sedimentation of waterways
- localised increases in turbidity and total suspended solids
- localised contamination of waterways
- waterway crossings
- cumulative impacts with other nearby mining projects
- introduction of aquatic weeds to waterways, and
- disturbance of endangered riparian vegetation types.

All identified potential sources of impact were assessed as having a low risk of adverse impact to aquatic ecological values.

The two aquatic MNES species known from the broader Fitzroy River Basin are highly unlikely to occur in waterways of the Broader Study Area or the Project Area, with the nearest suitable habitat for both species (i.e. white throated snapping turtle and Fitzroy River turtle) some 115 km downstream from the Project Area. Thus, populations of these MNES species are sufficiently displaced from the Project Area to have no risk of direct or indirect impact from the Project.

1 Introduction

frc environmental was commissioned by Vitrinite Pty Ltd (Vitrinite) to assess the potential impacts to aquatic ecological values of waterways and wetlands within and surrounding the Project Area of the proposed Vulcan South Project (the Project), to support the Project mining lease and environmental application approvals processes.

The scope of this aquatic ecology study is to:

- describe the aquatic ecological values of waterways and sensitive aquatic environmental receptors of the Broader Study Area
- assess the potential Project impacts on aquatic ecological values, and
- present mitigating measures for avoiding or reducing significant potential Project impacts on aquatic ecological values.

As part of project planning and feasibility assessment, Vitrinite has completed environmental assessments of a considerably larger study area than the proposed mining lease application (MLA). Baseline data has been collected within this larger study area and has been used in the assessment of the Project, for context, as required. Subject to further project planning, Vitrinite may in future, utilise this baseline information to assess the potential impacts of additional project development opportunities with the Broader Study Area.

Consequently, in this report:

- ‘Project Area’ is the proposed Vulcan South Project MLA area (refer to Map 2.1); and
- ‘Broader Study Area’ encompasses the Project Area and surrounding areas (refer to Map 4.1).

2 Project Description

Vitrinite have proposed the Vulcan South Project, located north of Dysart and approximately 35 kilometres (km) south of Moranbah in Queensland's Bowen Basin (Map 2.1). The Project lies to the immediate west of several established mining operations including BHP's Peak Downs and Saraji mines.

The Project is located immediately to the south of Vitrinite's initial mining Project, the Vulcan Coal Mine (VCM), located on ML700060. The proposed Project mining lease application area abuts ML700060; however, proposed activities will be implemented separately.

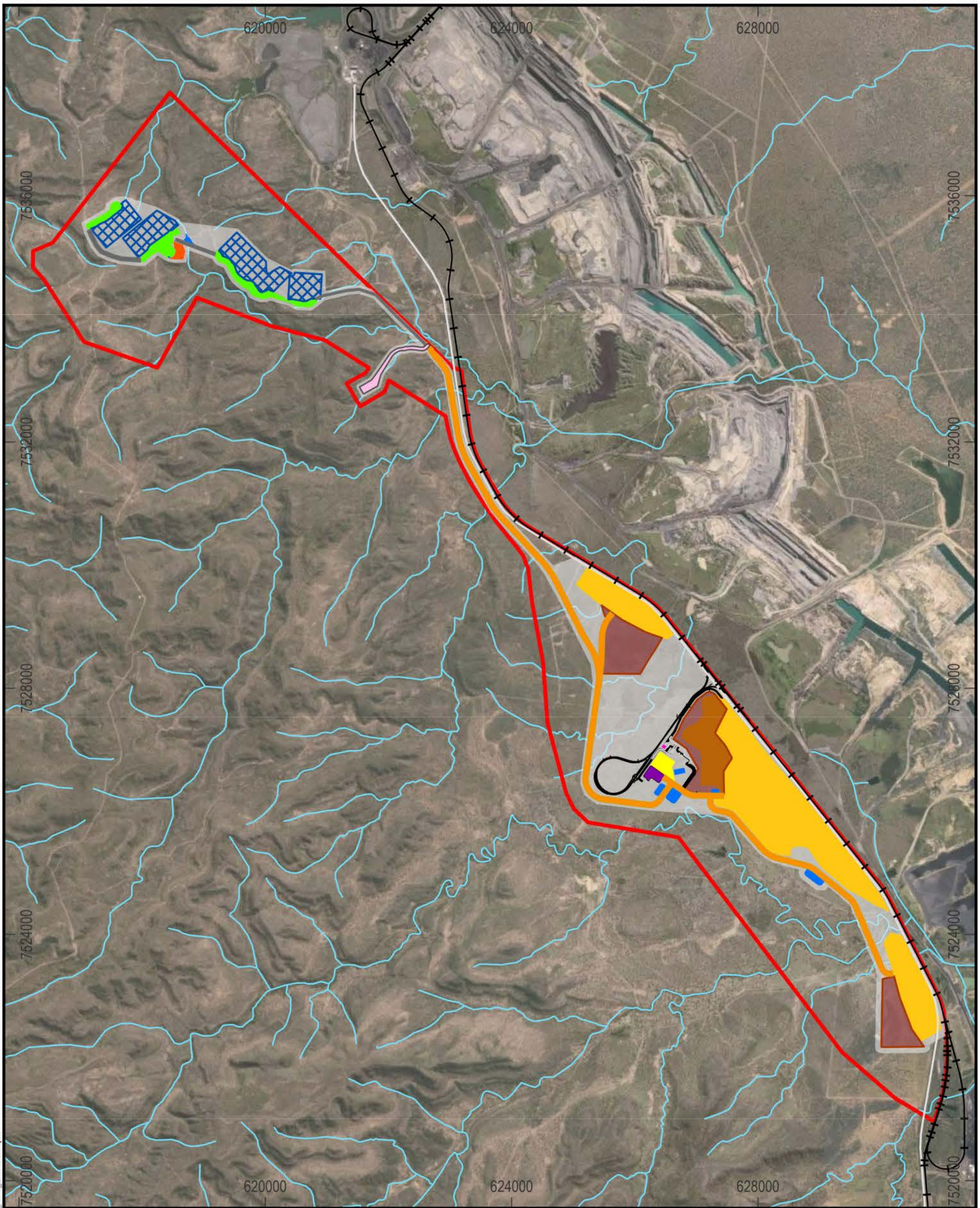
The Vulcan hard coking coal target has been defined and selected for open cut development via three separate open cut pits that form the primary mining focus of the Project. The Project will operate for approximately nine years, including a two-year initial construction period, with primary rehabilitation works undertaken in year 9. The operation will extract approximately 13.5 Megatonne per annum (Mtpa) of run of mine (ROM) coal consisting predominately of hard coking coal with an incidental thermal secondary product, at a rate of up to 1.95 Mtpa. The Project will target the Alex and multiple Dysart Lower coal seams. Truck and shovel mining operations will be employed to develop the pits. A mine infrastructure area (MIA) will be established along with a modular coal handling and preparation plant (CHPP), rail loop and train load-out facility (TLO) at a location between the northern and central pits. The CHPP will include solid bowl centrifuges to maximise water recycling and to produce a dry tailings waste product for permanent storage within active waste rock dumps.

Out-of-pit waste rock dumps will be established prior to commencing in-pit dumping activities that will continue for the life of the operation. Ancillary infrastructure, including a Run of Mine (ROM) pad, offices, roads, and surface water management infrastructure will be established to support the operation.

A realignment of the existing Saraji Road and services infrastructure to the eastern boundary of the proposed MLA area, adjacent to the existing rail easement, is also proposed in several locations. The re-alignment will occur within the MLA area.

In-pit dumping will fill most of the pit volumes during operations with the remaining final voids to be backfilled upon cessation of mining, resulting in the establishment of low waste rock dump landforms over the former pit areas. Following backfill of the final voids, the remaining material stored in the initial out-of-pit waste rock dumps will be rehabilitated in-situ.

The Project includes a small-scale highwall mining trial program in the north of the MLA. The trial will involve the establishment of four highwall mining benches across several hillsides to facilitate extraction of coal utilising a CAT HW300 highwall miner. The highwall mining trial will target up to 750 kilotonne (kt) of coal which will be transported by truck to the Project CHPP via a dedicated haul road within the MLA area. The trial is scheduled to be completed within the first year of mining operations.



Legend

- Railway
- Saraji Road
- Mine Access Road
- Rail Loop and Mine Roads
- Drainage Lines
- Highwall Mining Haul Road
- CHPP
- Magazine
- MIA
- Dams
- Office
- Haul Road and Drainage Infrastructure
- Ex-pit Dump
- In-pit Dump
- Highwall Mining Bench
- Highwall Rock Dump
- Highwall Plunge
- Vulcan South Maximum Disturbance Footprint
- MLA Boundary

Source: State of Queensland (Department of Resources) 2021, Vitrinite 2020-2022, METServe 2022, Earthstar Geographics.

Vulcan South Project

Proposed Project Layout

0 1.5 3
Kilometers
Scale: 1:90,000 (A4)

11/02/2022

Datum: GDA94
Projection: MGA55

Map 2.1

VITRINITE BRIGHTER COAL
METSERVE Mining & Energy Technical Services Pty Ltd

3 Key Legislation and Policy

3.1 Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides the legal framework for the protection and management of matters of national environmental significance (MNES). The 9 MNES to which the EPBC Act applies are (DAWE 2013):

- world heritage properties
- national heritage places
- wetlands of international importance (often called 'Ramsar' wetlands after the international treaty under which such wetlands are listed)
- nationally threatened species and ecological communities
- migratory species
- Commonwealth marine areas
- the Great Barrier Reef Marine Park
- nuclear actions (including uranium mining)
- a water resource, in relation to coal seam gas development and large coal mining development.

The EPBC Act provides protection for threatened flora, fauna, and ecological communities by:

- identifying and listing of species and ecological communities as threatened
- developing conservation advice and recovery plans for listed species and ecological communities
- developing a register of critical habitat
- recognising key threatening processes
- where appropriate, reducing the impacts of these processes through threat abatement plans and non-statutory threat abatement advice, and by
- requiring approval for certain actions or activities that will, or are likely to, have a significant impact on an MNES or other protected matter.

Under the EPBC Act, if an action has, will have, or is likely to have, a significant impact on a MNES, approval is required from the Australian Government Environment Minister (the Minister). The MNES Significant Impact Guidelines (DoTE 2013) outline a 'self-assessment' process to assist in determining whether an action is likely to have a significant impact on a MNES. If this process determines there may be a significant impact to a MNES, a referral should be submitted to the Minister for a decision on whether assessment and approval is required under the EPBC Act.

The Minister can make one of three decisions regarding a proposal (DAWE 2020):

- Not a controlled action: if the proposed action is not likely to be significant, approval is not required if the action is taken in accordance with the referral. Consequently the action can proceed subject to any state, territory, or local government requirements
- Not a controlled action – 'particular manner': if the proposed action is not likely to be significant if done in a particular manner
- Controlled action: if the proposed action is likely to be significant, it is called a 'controlled action'. The matters which the proposed action may have a significant impact on (e.g. Ramsar wetlands or threatened species) are known as the controlling provisions. Controlled actions require approval and are subject to further assessment processes.

Once a controlled action is assessed, it can be approved, approved subject to constraints, or refused.

3.2 Queensland *Environmental Protection Act 1994*

The Queensland *Environmental Protection Act 1994* (EP Act) provides the legislative framework for ecologically sustainable development in Queensland, requiring people, companies, and government to take all reasonable and practical steps to protect Environmental Values (EVs) (i.e. avoid harm to the environment). The EP Act provides a range of mechanisms to achieve the objective of the Act, including establishing Environmental Protection Policies that present strategies for protecting EVs.

The Environmental Protection Regulation 2019 (EP Regulation), pursuant to the EP Act, specifies Environmentally Relevant Activities (ERAs) that are considered to have the potential to cause environmental harm. Mining (e.g. for coal, metal ores, etc) is an ERA under the EP Regulation. ERAs may require an environmental assessment to be prepared as part of the development application process.

3.3 The Environmental Protection Policy (Water and Wetland Biodiversity) 2019

The quality of Queensland waters is protected under the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP (Water and Wetland Biodiversity)). The purpose of the EPP (Water and Wetland Biodiversity) is to achieve the object of the EP Act in relation to waters and wetlands.

The purpose of the EPP (Water and Wetland Biodiversity) is achieved by:

- identifying EVs for waters and wetlands to be enhanced or protected, and
- identifying management goals for waters, and
- stating water quality guidelines (WQG) and water quality objectives (WQO) for enhancing or protecting the environmental values of waters, and
- providing a framework for making consistent, equitable and informed decisions about waters, and by
- monitoring and reporting on the condition of waters.

The EPP (Water and Wetland Biodiversity) defines:

- EVs for waters, including for high ecological value (HEV), slightly disturbed, moderately disturbed, and highly disturbed waters
- EVs for wetlands
- indicators and WQG for EVs for waters, and provides:
- a framework for assessment
- management goals for waters
- water quality objectives for waters, and
- guidance for monitoring and reporting.

EVs for Queensland waters includes the protection of aquatic ecosystems.

Schedule 1 of this EPP lists waters that have defined EVs and WQO, and lists the documents these are published in. For waters not listed in Schedule 1 the EPP provides a process for defining EVs and WQO.

3.4 Queensland *Nature Conservation Act 1992*

The *Nature Conservation Act 1992* (NC Act) provides for the conservation of Queensland's nature by declaring and managing a protected area network, protecting threatened species (wildlife) and their habitats, regulating the taking of wildlife and co-ordinating nature conservation with Traditional Owners and other landowners. Several freshwater species are protected wildlife under the NC Act.

Protected wildlife listed under the NC Act must be protected from threatening processes, and critical habitat for protected wildlife is required to be protected to the greatest extent possible.

3.5 Queensland *Vegetation Management Act 1999*

The *Vegetation Management Act* 1999 (VM Act), as updated by the *Vegetation Management and Other Legislation Amendment Act 2018*, regulates the clearing of vegetation to conserve threatened REs, protect biodiversity, and maintain ecological processes, amongst other purposes.

The VM Act provides for the chief executive to certify various classes of regulated vegetation maps, with regulated vegetation as Matters of State Environmental Significance (MSES). Classes of vegetation under the VM Act include vegetation that is remnant and / or threatened (category B), high value regrowth vegetation (category C) or regrowth vegetation in a wetland, waterway, or drainage feature area within a Great Barrier Reef catchment (category R). Vegetation in wetland areas and vegetation intersecting a waterway is also regulated vegetation under the VM Act. Vegetation clearing and development is regulated for Category R vegetation areas, and Riverine Protection Permits are required to clear vegetation in waterways.

3.6 Queensland *Fisheries Act 1994*

The *Fisheries Act 1994* provides for the management and protection of fisheries resources, including regulating development that might impact declared fish habitat areas, and fish passage. Several fish species of special interest are listed as 'no take' species under the *Fisheries Act 1994*, including the Australian lungfish.

Fisheries resources, including declared fish habitat areas, also contribute to the EVs of waterways and wetlands.

3.7 Queensland State Planning Policy

Under the Queensland State Planning Policy, some aquatic ecological matters protected under Queensland legislation (Sections 3.2 to 3.6) are declared as MSES. Aquatic MSES relevant to fresh waters comprise:

- protected areas (including all classes of protected area except coordinated conservation areas) under the NC Act
- areas within declared fish habitat areas that are management A or B areas under the Fisheries Regulation 2008
- designated precincts, in a strategic environmental area under the Regional Planning Interests Regulation 2014, schedule 2, part 5, s15(3)
- wetlands in a Wetland Protection Area and wetlands of High Ecological Significance (HES) as shown on the map of referable wetlands under the EP Regulation 2019, pursuant to the EP Act. Wetlands of General Ecological Significance (GES) are not MSES.
  - HES wetlands are those wetlands that are assessed as having high ecological value using the AquaBAMM methodology (Clayton et al. 2006).
- wetlands and watercourses in HEV waters identified in the EPP (Water and Wetland Biodiversity)
- legally secured aquatic offset areas as defined under the *Environmental Offsets Act 2004*
- threatened aquatic wildlife under the NC Act, and special least concern animals under the Nature Conservation (Wildlife) Regulation 2006
- waterways that provide for fish passage under the *Fisheries Act 1994*, excluding waterways providing for fish passage in an urban area, and
- habitat for an aquatic animal that is endangered wildlife or vulnerable wildlife under the NC Act.

3.8 Queensland *Biosecurity Act 2014*

The *Biosecurity Act 2014* seeks to manage risks associated with exotic pests (plants and animals, including noxious and invasive species) and diseases that impact plant and animal industries including aquaculture and wild capture fisheries, tourism, infrastructure including water supply, shipping, biodiversity, and the natural environment.

The Biosecurity Act achieves its objective in several ways, including but not limited to:

- defining biosecurity matters (e.g. prohibited and restricted matters)
- establishing a general biosecurity obligation (GBO)
- establishing obligations in relation to prohibited and restricted matters
- specifying what are notifiable incidents, and
- providing for mechanisms to manage emergency biosecurity events.

Prohibited biosecurity matters are species that are not yet present in Queensland, while restricted biosecurity matters are known to be present in one or more region in Queensland.

The GBO states that individuals and other entities are obliged to:

- take all reasonable and practical measures to minimise the likelihood of causing a biosecurity risk; and / or
- do whatever is reasonably required to minimise the adverse effects of dealing with a biosecurity matter.

4 Methods

4.1 Desktop Approach

A desktop approach was used to provide a description of the aquatic ecological values of the Broader Study Area. This included review of:

- aquatic MNES under the Commonwealth's EPBC Act
- aquatic matters protected under Queensland legislation, including:
  - threatened freshwater species under the NC Act
  - features that support fisheries resources (e.g. waterway barrier risk layer), pursuant to the *Fisheries Act 1994*
  - wetland protection areas as shown on the map of Referable Wetlands under the *Environmental Protection Regulation* 2008
  - High Ecological Value waters as defined under the EPP (Water and Wetland Biodiversity)
  - freshwater-dependent regulated vegetation, listed under the VM Act
- mapped aquatic ecological features, including floodplains, wetlands, and surface-expression ground-water dependent ecosystems
- hydrological data recorded at Queensland Government gauging station 130410A (Isaac River at Deverill)
- relevant literature, including published and unpublished technical reports, scientific papers, and conservation advice statements for any MNES identified; and
- data contained in frc environmental's in-house bio-physical database.

4.2 Field Survey

4.2.1 Survey Design

The field survey was completed in the post-wet season, 10 – 12 April 2019, with notable rainfall recorded in the region in late March 2019, shortly prior to the survey (Figure 4.1). The rainfall recorded in early April 2019, prior to the field survey, was the highest rainfall recorded since the 2018 wet season. Thus, the field survey timing reflected typical wet season conditions. A dry season survey was not implemented because these waterways are highly ephemeral and at maximum hydrological condition and biological productivity during the wet season. The aquatic ecological values of the Project Area and Broader

Study Area are well studied, and it is considered that the survey design yielded a characteristic representation of the aquatic ecological values known for the region.

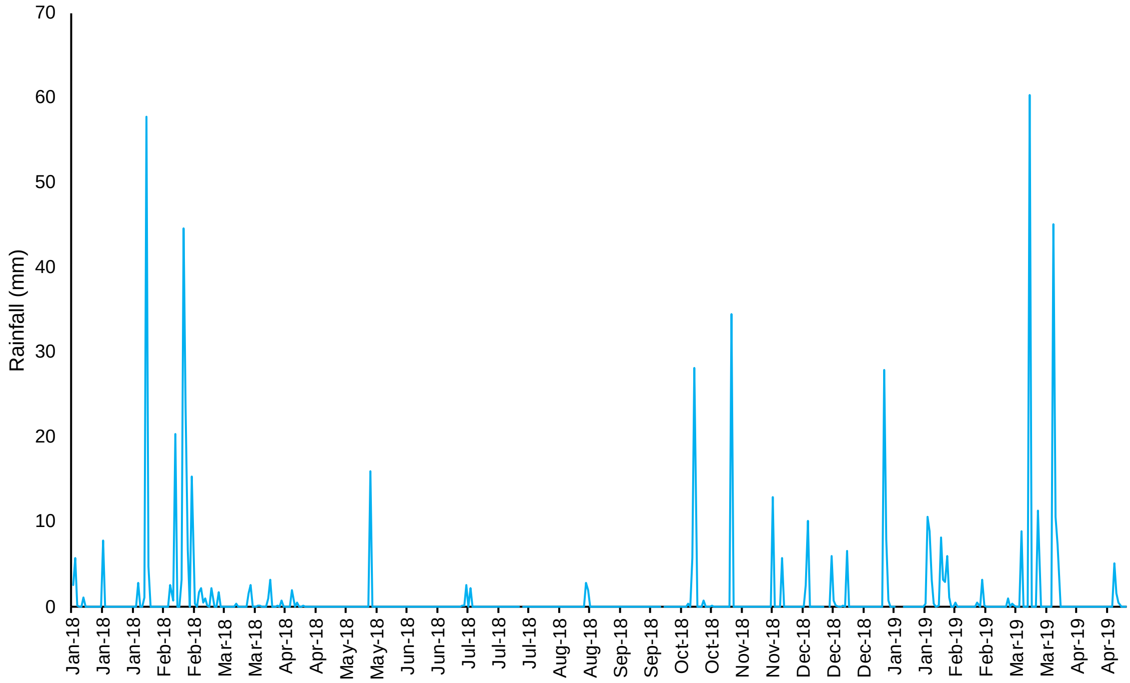


Figure 4.1 Rainfall January 2018 to April 2019 at BOM weather station 34035 at Moranbah Airport.

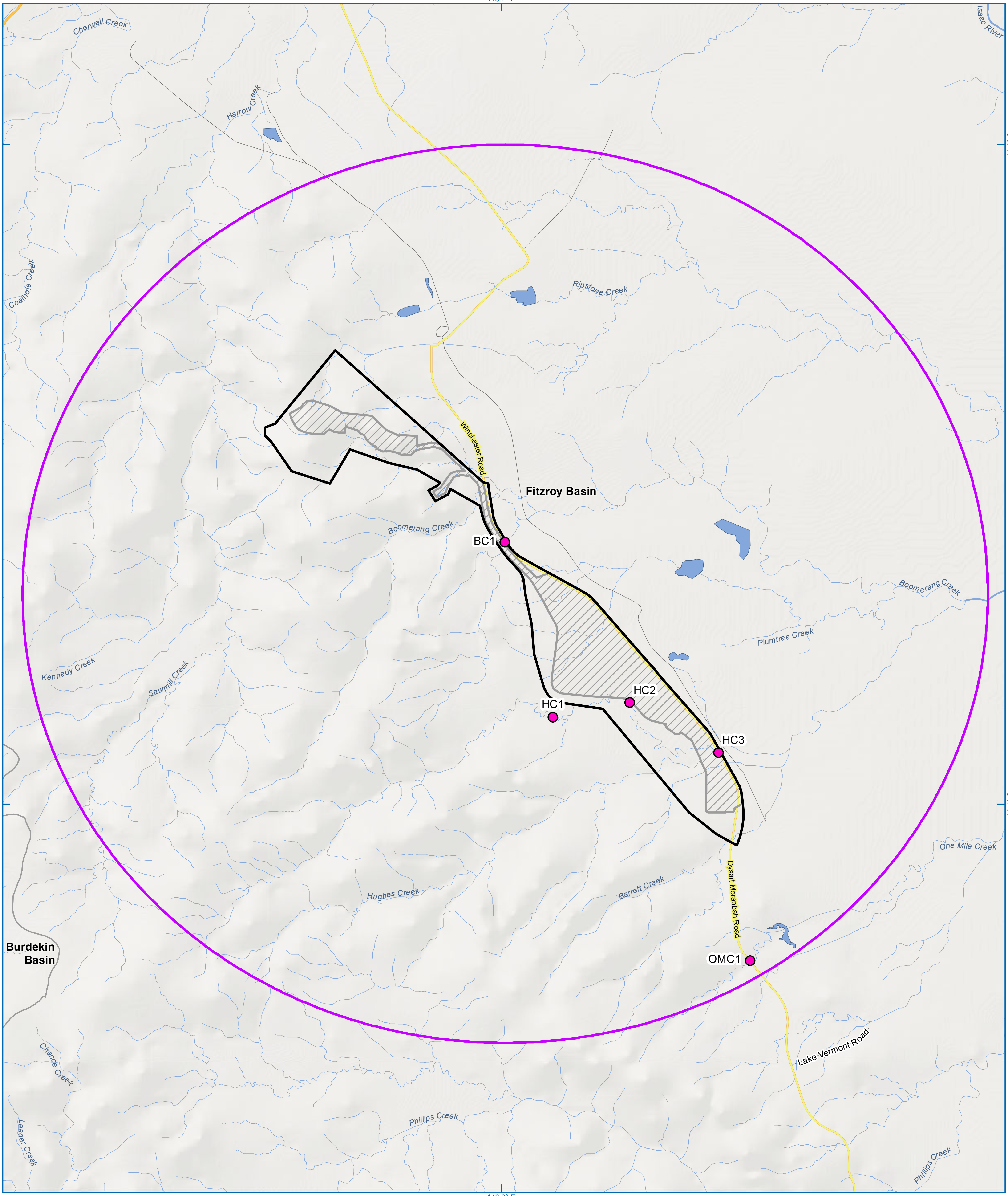
The following aquatic ecological components were assessed at five representative sites in the Broader Study Area (Map 4.1; Table 4.1):

- water quality measured in situ
- aquatic habitat
- aquatic plants
- macroinvertebrates
- fish, and
- turtles.

The survey sites were representative of waterways throughout the full extent of the Broader Study Area, including the specific Project Area considered in this study and its associated receiving waters. The sites were representative of maximum aquatic ecological productivity at the time of the survey as they were holding water (albeit small, isolated pools), in otherwise dry waterways. The breadth of sampling is considered to provide a conservative assessment of the ecological values of the specific Project Area and the Broader Study Area, which is understood well and has been studied considerably over the course of multiple projects in the region.

Table 4.1 Aquatic ecology survey sites.

Site	Site description	Latitude	Longitude
HC1	Tributary of Hughes Creek upstream	-22.373694	148.215594
HC2	Tributary of Hughes Creek mid-site	-22.36926704	148.238943
HC3	Hughes Creek downstream	-22.38438497	148.265843
BC1	Tributary of Boomerang Creek	-22.320614	148.201079
OMC1	One Mile Creek	-22.44749702	148.275431



Vulcan South Project: Aquatic Ecology Study

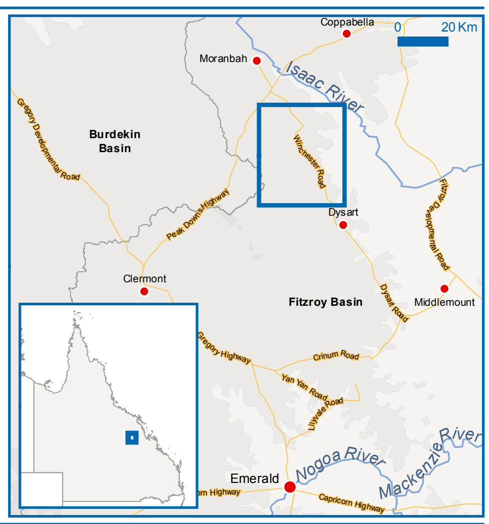
Map 4.1
Aquatic Ecology Survey Site Map

LEGEND

- Aquatic ecology survey sites
- Broader Study Area
- Mining Lease Application Boundary
- Conservative Disturbance Footprint

Road Network

- Highway
- Main Road
- Local Road
- Watercourse



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SOURCES

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4.2.2 Survey Methods

Water Quality

Water quality is assessed in detail in the Vulcan South Surface Water Assessment (WRM 2022). However, for the purposes of supporting the aquatic ecology assessment, field measurements of water quality were taken during the field survey at survey sites holding water.

Water quality was sampled in accordance with the Queensland Monitoring and Sampling Manual (DES 2018). Water temperature (°C), pH, dissolved oxygen, and electrical conductivity (µS/cm) were measured in-situ approximately 0.3 m below the water's surface using an In-Situ smarTROLL multi-parameter water quality meter. The meter was calibrated on the first day of survey in accordance with OEM specifications. Turbidity (NTU) was measured approximately 0.3 m below the water's surface using a calibrated HACH 2100Q portable turbidity meter, with calibration occurring on the first day of the survey.

Water quality results were compared to Water Quality Objectives (WQO) for moderately disturbed waters in the upper Isaac River catchment (EHP 2009):

- electrical conductivity: < 720 µS/cm (baseflow), < 250 µS/cm (high flow)
- pH: 6.5 – 8.5
- dissolved oxygen: 85 – 110 % saturation, and
- turbidity: < 50 NTU.

Aquatic Habitat

The in-stream habitat attributes and condition were assessed using a method based on the Australian River Assessment System (AUSRIVAS) protocol described in the Queensland AUSRIVAS Sampling and Processing Manual (DNRM 2001a). The following parameters were assessed:

- channel shape and pattern
- bank slope, composition, stability, and vegetative cover
- bed substrate composition and stability
- in-stream habitat features, including submerged or emergent aquatic plants, large woody debris, undercut banks, boulders
- water velocity, depth, and width, and

- riparian vegetation composition, extent and condition.

A Riverine Bioassessment Score (DNRM (2001b) was calculated for each site where macroinvertebrates were collected. This score is a numerical index of aquatic habitat complexity and suitability for supporting diverse macroinvertebrate communities that enables a direct comparison of habitat quality between sites. The method scores habitat complexity and suitability for macroinvertebrates for each of the following nine criteria:

- substrate or available cover
- embeddedness
- water velocity and depth
- channel alteration
- bed scouring and deposition
- pool:riffle and run:bend ratio
- bank stability
- bank vegetative stability, and
- streamside vegetation cover.

The sum of the scores for each criterion gives the overall habitat score. This was used to allocate sites to one of four defined categories of habitat complexity and suitability for supporting diverse macroinvertebrate communities (refer Table 4.2):

- excellent (overall score >110)
- good (overall score 75 to 110)
- moderate (overall score 39 to 74), and
- poor (overall score ≤38).

Existing disturbances to riparian vegetation, bed and bank stability, flow and instream habitat were noted, including the presence of any existing barriers to fish passage.

Photographs of aquatic habitat were taken to establish a record of current condition.

Table 4.2 River habitat bioassessment scores used to derive overall habitat condition categories.

Habitat Category	Category Score Range			
	Excellent	Good	Moderate	Poor
Bed substrate or available cover	16–20	11–15	6–10	0–5
Embeddedness	16–20	11–15	6–10	0–5
Water velocity and depth	16–20	11–15	6–10	0–5
Channel alteration	12–15	8–11	4–7	0–3
Bed scouring & deposition	12–15	8–11	4–7	0–3
Pool:riffle and run:bend ratio	12–15	8–11	4–7	0–3
Bank stability	9–10	6–8	3–5	0–2
Bank vegetative stability	9–10	6–8	3–5	0–2
Streamside vegetation cover	9–10	6–8	3–5	0–2
Total (Habitat Bioassessment Score for the Site)	**111–135**	**75–110**	**39–74**	**0–38**

Aquatic Plants

Aquatic plants were surveyed at each site using a timed meander survey (i.e. 15 – 20 minutes per site) across in-stream and riparian habitats, as recommended in the Department of Environment and Science’s (DES 2020a) *Flora Survey Guidelines – Protected Plants*. Plants were identified to species level if they were flowering, otherwise they were identified to genus. It was noted if plants were growing in the water, in the dry in-stream or in riparian areas. The growth form of plants growing in water was recorded (Table 4.3).

There are no published biological objectives for aquatic plants to compare results against.

Table 4.3 Growth forms of aquatic plants growing in water.

Growth Form	Description
Submerged	Submerged aquatic plants are rooted in the bed of the stream or wetland, with leaves totally covered by water most of the time. Some species may have underwater flowers, whereas other species may require water levels to decrease to trigger flowering and have flowers above the water level.
Attached floating	Attached floating aquatic plants are rooted in the bed of the stream or wetland, with leaves typically floating on top of the water. Flowers are usually above the water.
Free floating	Free floating plants float on top of the water, or in the water column, with roots trailing into the water column. Flowers are typically above the water.
Emergent	Emergent plants are rooted in the bed of the stream or wetland, with leaves and flowers above the water.

Macroinvertebrates

Macroinvertebrates were sampled from bed and edge habitat at each site that was holding water during the field survey using the AUSRIVAS sampling method as described in the AUSRIVAS manual (DNRM 2001a) and the Monitoring and Sampling Manual (DES 2018). Samples were collected by disturbing a 10 m long section of bed or edge habitat with a standard triangular-framed dip net (250 μm mesh size), preserved using ethanol, and transported to frc environmental's biological laboratory.

In the laboratory, samples were sorted, identified to the lowest practical taxonomic level (in most instances family) and counted in accordance with Chessman (2003). For QA/QC procedures, macroinvertebrates in 10% of the samples were re-identified and re-counted and 10% of the data was re-entered by an ecologist other than the one who completed the original identifications and data entry. If any errors were found, then this process was repeated until no errors were found or they were within the accepted range (< 5% DES 2018; final error rates in our laboratory are consistently < 2%).

Standard freshwater macroinvertebrate indices were calculated for macroinvertebrate communities in bed habitat: taxonomic richness, PET (Plecoptera / Ephemeroptera / Trichoptera) richness, and SIGNAL 2 (Stream Invertebrate Grade Number – Average Level) scores.

The macroinvertebrate indices were compared to the biological objectives for moderately disturbed waters in the upper Isaac River (EHP 2009) (Table 4.4).

Table 4.4 Default biological guidelines for macroinvertebrates.

Index	Composite [a] Habitat	Edge Habitat
Taxonomic richness	12 – 21	23 – 33
PET richness	2 – 5	2 – 5
SIGNAL-2 scores	3.33 – 3.85	3.31 – 4.20

[a] composite habitat includes both bed and riffle / run habitat types

Fish

Fish were surveyed using seine netting in accordance with recommendations in the Commonwealth Government's *Survey Guidelines for Australia's Threatened Fish* (DSEWPC 2011). Water was too shallow to set fyke nets as planned, noting that the seine nets were dragged through the full expanse of the isolated pools that were present at the sites holding water; thus, providing a thorough assessment of fish at those sites. Fishes were sampled under General Fisheries Permit No. 199434 and Animal Ethics Approval No. CA 2018/08/1224 held by frc environmental.

Fish were identified to species level and counted, with native species released unharmed at the place of capture and pest species euthanised using methods approved under our animal ethics approval.

There is no biological objective for fish in the upper Isaac River.

Raw fish data was tabulated, and the migration pattern of each species noted.

Turtles

No sites held sufficient water that enabled cathedral traps or fyke nets to be set as planned. However, if turtles were present in the isolated pools at the sites holding water, they would have been caught in the seine net hauls (described above for fish), which is a sampling method that reliably catches turtles in small shallow isolated pools.

There are no published biological objectives for turtles.

4.3 Assessment of Aquatic Ecological Values

There are a range of recognised methodologies available to assess the conservation value of aquatic ecosystems in Queensland, including (see SKM 2007):

- the declaration of fish habitat areas
- wetland mapping
- establishing HEV waterways under the EPP (Water and Wetland Biodiversity)
- identification of threatened wetland REs in riparian zones, and
- identification of conservation values using the AquaBAMM framework.

Most of the approaches listed above relate to components of aquatic ecosystems that are protected or have designated conservation value in legislation and policy. AquaBAMM is a complementary approach that systematically integrates criteria relating to the naturalness, diversity, uniqueness, connectivity and representativeness of aquatic ecosystems (Clayton et al. 2006).

Therefore, the aquatic ecological values in and surrounding the Project study area were assessed using:

- the criteria in Table 4.5 which integrates the components of aquatic ecosystems that are protected or have conservation value in legislation and policy, and
- relevant AquaBAMM criteria.

Table 4.5 Criteria used to assess aquatic ecological value of each site.

Aquatic Ecological Value	Criteria / Description
High	Known or likely occurrence of aquatic MNES and / or threatened aquatic species protected under the NC Act and / or HEV Waters under the EPP (Water and Wetland Biodiversity) and / or declared fish habitat areas and / or regulated vegetation types composed of endangered wetland REs in riparian zone (directly abutting top bank)
Moderate	Aquatic MNES, threatened aquatic species protected under the NC Act and HEV waters unlikely to occur, but suitable habitat for non-listed aquatic species of turtles and fish is present. Regulated vegetation types composed of of-concern wetland REs may be present in the riparian zone (i.e. directly abutting to bank), and waterway are important for fish passage under the *Queensland Fisheries Act 1994* (mapped as having higher than low risk of impact to fish passage by waterway barriers)

Aquatic Ecological Value	Criteria / Description
Low	Aquatic MNES, threatened aquatic species protected under the NC Act and HEV waters do not occur, and suitable habitat for non-listed aquatic species of turtles and fish is absent. Threatened RE or category B or C regulated vegetation types do not occur in the riparian zone. Waterways have only low risk / importance for fish passage.

4.4 Impact Assessment

The assessment of potential impacts comprised a risk-based assessment, with the level of risk being an outcome of the consequence and likelihood of the potential impact (Table 4.6 to Table 4.8). The 5 x 3 risk matrix (Table 4.8) gives risk scores ranging between one and 15, with risk being:

- low, when the score is <5
- medium, when the score is >5 but <10, and
- high, when the score is >10.

Assessment of potential impacts to aquatic MNES was guided by the Significant Impact Guidelines 1.1 (DoTE 2013).

To determine the applicable aquatic MNES species and ecological communities, the EPBC Act Protected Matters database was searched (Appendix A), and the following aquatic MNES were listed as potentially occurring in and surrounding the Project area:

- white-throated snapping turtle (*Elseya albagula*) (critically endangered), and
- Fitzroy River turtle (*Rheodytes leukops*) (vulnerable).

All other MNES that the EPBC search identified were considered to be outside the scope of this study (i.e. not aquatic species).

Table 4.6 Ratings used to assess the likelihood of potential impacts.

Rating	Likelihood of occurrence
Very high (5)	Almost certain to occur frequently
High (4)	Probably would happen sometimes to frequently
Moderate (3)	Could happen sometimes
Low (2)	Remote possibility of occurring or not expected to occur
Very low (1)	Would not happen at all

Table 4.7 Ratings used to assess the consequence of potential impacts.

Rating	Consequence of potential impacts
High	Catastrophic, irreversible, or critical long term environmental harm or loss; significant harm or loss of sensitive components of the environment; significant harm or loss of protected components of the environment, such as protected wetlands or MNES.
Moderate	Significant short-term but reversible harm of the environment; minor environmental harm to sensitive or protected components of the environment, such as protected wetlands or MNES.
Low	Minimal impact with no material harm to the environment, with no harm to sensitive or protected components of the environment.

Table 4.8 Environmental risk matrix.

		Likelihood				
		Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
Consequence	Low (1)	1	2	3	4	5
	Moderate (2)	2	4	6	8	10
	High (3)	3	6	9	12	15

5 Aquatic Ecological Values of the Broader Study Area

5.1 Aquatic Matters of National Environmental Significance

5.1.1 White-throated Snapping Turtle and Fitzroy River Turtle

The white-throated snapping turtle is listed as critically endangered under the EPBC Act and endangered under the NC Act. This species is restricted to the Fitzroy, Burnett and Mary Basins, and adjacent coastal basins (e.g. Kolan and Gregory-Burrum systems) (Todd et al. 2013). It is reported that this species is a habitat specialist, preferring permanent, flowing, clear and well oxygenated water with moderate to high cover of aquatic habitat (i.e. large woody debris and undercut banks) (Hamann et al. 2007; Limpus et al. 2007; Limpus et al. 2011; Todd et al. 2013). A full description of white-throated snapping turtle is presented in Appendix B.

The Fitzroy River turtle is listed as vulnerable under the EPBC Act and vulnerable under the NC Act. This species is restricted to the Fitzroy River, with records of the species showing the centre of this species' distribution is the Fitzroy River (main stem) from the tidal barrage to the township of Emerald, the Dawson River and the Connors River (ALA 2020). It is reported that this species prefers permanent freshwater reaches of these rivers where there are large deep pools with rocky, gravelly or sandy substrates, connected by shallow riffles (Cogger et al. 1993), but has also been found in isolated permanent waterholes on the Connors River (frc environmental 2010; Limpus et al. 2007). However, the species is not known to inhabit farm dams or ephemeral waterways (Limpus et al. 2007). A full description of Fitzroy River turtle is presented in Appendix C.

The nearest confirmed records of these two species of turtle to the Project Study area (i.e. Connors River north of Lotus Creek, ALA 2020) is over 115 kilometres (km) (straight-line distance) from the Project study area, with no records of these species from the Isaac River (ALA 2020) or in close proximity to the Project study area (DES 2020b). In the Fitzroy River, records of white throated snapping turtle and Fitzroy River turtle are concentrated in the main stem of the Fitzroy River between the barrage and Emerald, the Dawson River and Connors River, with an isolated record of white-throated snapping turtle at Callide Dam (ALA 2020).

It is likely that flow regime has a strong influence of the distribution of these two species in the Fitzroy River basin, given the degree of their specialisation for flow-dominated habitats (Cogger et al. 1993; Todd et al. 2013). Comparison of flow durations at gauging stations on the Fitzroy River, Dawson River, Connors River and Isaac River (Table 5.1; Map 5.1), indicate that the Isaac River at Deverill and Goonyella, in close proximity to the Project Study area, has significantly shorter duration of flows compared to flow durations recorded in the Fitzroy River, Dawson River and Connors River from where these two species of turtle are known. Thus, the distribution records in ALA (2020) that indicate these species do not occur in the Isaac River near the Project study area align with the reported habitat (i.e. hydrological) preferences of the species (i.e. near-permanent, flow-dominated river reaches).

The reach of the Isaac River east of the Broader Study Area does not provide suitable habitat (i.e. unsuitable flow regime) for white-throated snapping turtle and Fitzroy River turtle (see also Section 5.5). The smaller waterways of the Broader Study Area would have higher ephemerality than the Isaac River at Deverill; thus; there is low probability of occurrence of these species in or near the Broader Study Area. It is likely that the Isaac River at Yatton is the nearest location that has potentially suitable hydrological characteristics for white-throated snapping turtle and Fitzroy River turtle, with this location being some 150 km downstream of the Broader Study Area.

Table 5.1 Comparison of flow durations (i.e. percentage of time flows are recorded) in the Fitzroy River (main stem), Dawson River and Isaac River.

DNRME gauging station	Location	% time flows are recorded
130003B	Fitzroy River at Riverslea	89
130005A	Fitzroy River at The Gap	85
130302A	Dawson River at Taroom	97
130317B	Dawson River at Woodleigh	92
130322A	Dawson River at Beckers	68
130324A	Dawson River at Utopia Downs	100
130374A	Dawson River at Bindaree	72
130403A	Connors River at Mount Bridget	75
130404A	Connor River at Pink Lagoon	80
130401A	Isaac River at Yatton	85
130410A	Isaac River at Deverill	26
130414A	Isaac River at Goonyella	21

Source of data: The State of Queensland (2021)

Blue shading indicates reaches within the Fitzroy River Basin from which white-throated snapping turtle and Fitzroy River turtle have been recorded, with flows recorded 72 – 100 % of the time at these locations.

Grey shading indicates reaches of the Isaac River from which white-throated snapping turtle and Fitzroy River turtle have not been recorded, and where flow duration is significantly lower (i.e. 21 – 26 % of the time) than reaches where these species have been recorded, noting the Project Study area is located adjacent to the reach of the Isaac River between these two gauging stations.

Green shading indicates a reach of the lower Isaac River, approximately 150 km downstream of the Project Study area, from which white-throated snapping turtle and Fitzroy River turtle have not been recorded, but where flow duration is similar (i.e. 85 %) to other reaches from where these species are known. This location (i.e. Isaac River at Yatton) is considered the location of the nearest potentially suitable habitat for these turtle species to the Project Study area.

5.2 State-level Protected Matters Relevant to Aquatic Ecology

5.2.1 Protected Areas and Fish Habitat Areas

There are no declared protected aquatic areas or Fish Habitat Areas in or near the Broader Study Area, and none in or near the specific Project Area.

5.2.2 Wetlands of High Ecological Significance as Shown on the Map of Referrable Wetlands, and Wetlands and Watercourses in High Ecological Value Waters

Mapped High Ecological Value waters (wetlands and watercourses) and mapped High Ecological Significance wetlands do not occur in the Broader Study Area, or in or near the specific Project Area (Map 5.1).

5.2.3 Ecological Offsets Relevant to Aquatic Ecology

There are no legally secured ecological offsets in or near the Broader Study Area, or in or near the specific Project Area.

5.2.4 Threatened Aquatic Species

White-throated snapping turtle and Fitzroy River turtle are threatened species, protected under the NC Act, that occur in the wider Fitzroy River Basin. However, as discussed in Section 5.1, it is highly unlikely that these species occur near the Broader Study Area (or in or near the specific Project Area), as the Isaac River at Goonyella and Deverill have unsuitable flow regime to support the occurrence of these species. The flow regime of waterways of the Broader Study Area, and specific Project Area, have even less suitable flows (i.e. flows are recorded <5% of the time; see Section 5.5).

5.2.5 Waterways that Provide for Fish Passage

Waterways of the specific Project Area include Boomerang Creek and tributaries of Boomerang Creek, Hughes Creek and tributaries of Hughes Creek, upper reaches of Plumtree Creek, and a small section of Barrett Creek. Boomerang Creek and Hughes Creek east (downstream) of the specific Project Area are mapped as major (purple) risk of impact to fish passage by waterway barrier works; Boomerang Creek, Hughes Creek and Barrett Creek within the specific Project Area are mapped as high (red) risk of impact to fish passage by waterway barrier works; unnamed tributaries of Boomerang Creek, Plumtree Creek and Barrett Creek within the specific Project Area are mapped as moderate (amber) risk of impact to fish passage by waterway barrier works, and several unnamed tributaries of Boomerang Creek and Plumtree Creek within the specific Project Area are mapped as low (green) risk of impact to fish passage by waterway barrier (Map 5.2).

5.2.6 Habitat for an Aquatic Animal that is Endangered Wildlife or Vulnerable Wildlife

The likelihood of endangered or vulnerable aquatic wildlife occurring in or near the Broader Study Area, or in or near the specific Project Area, is low (see Section 5.1), and consequently there is unlikely to be aquatic habitat for an endangered or vulnerable animal.

5.2.7 Vegetation Types Relevant to Aquatic Ecology

Regulated vegetation types relevant to aquatic ecology (i.e. in riparian zones) that occur in the specific Project Area are (Map 5.3):

- regulated vegetation intersecting a waterway; and
- small sections of category R vegetation (regrowth vegetation on waterways and drainage features in Great Barrier Reef catchments).

There is no category B or C regulated vegetation types in the Project Area. A small area of vegetation 100 m from a wetland is west (upstream) of the specific Project Area adjacent to a small tributary of Hughes Creek.

The following REs occur in riparian zones within the specific Project Area (Map 5.4; Table 5.2), including two of-concern and one endangered REs:

- 11.3.25 / 11.3.2
- 11.5.9b / 11.4.9 (note 11.5.9b is not a wetland RE)

- 11.3.2 / 11.3.7 / 11.3.25 (note 11.3.7 is not a wetland RE)
- 11.4.9.

While RE 11.4.8 occurs in the specific Project Area, it is not located in the riparian zone of mapped watercourses; thus, is assessed in the Terrestrial Ecology Assessment (METServe 2022). Similar, there is a second patch of RE 11.4.9 near the Hughes Creek headwaters that does not occur in riparian areas; this vegetation is assessed in the Terrestrial Ecology Assessment. All regulated vegetation types listed under the VM Act, and REs, are described and assessed in the Terrestrial Ecology Assessment.

Table 5.2 Description of Wetland Regional Ecosystems occurring in Riparian Zones within the Specific Project Area.

Regional Ecosystem	Description	Conservation Status
11.3.2	*Eucalyptus populnea* woodland on alluvial plains; contains palustrine wetlands in swales	of concern
11.3.25	*Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines; riverine wetland or fringing riverine wetland	of concern
11.4.9	*Acacia harpophylla* shrubby woodland with *Terminalia oblongata* on Cainozoic clay plains; contains palustrine wetlands in swales	endangered

5.2.8 Listed No-take Species Under the *Fisheries Act 1994*

No no-take fish species occur in or near the Broader Study Area, or in or near the specific Project Area.

5.2.9 Aquatic Biosecurity Matters

The Queensland *Biosecurity Act 2014* lists:

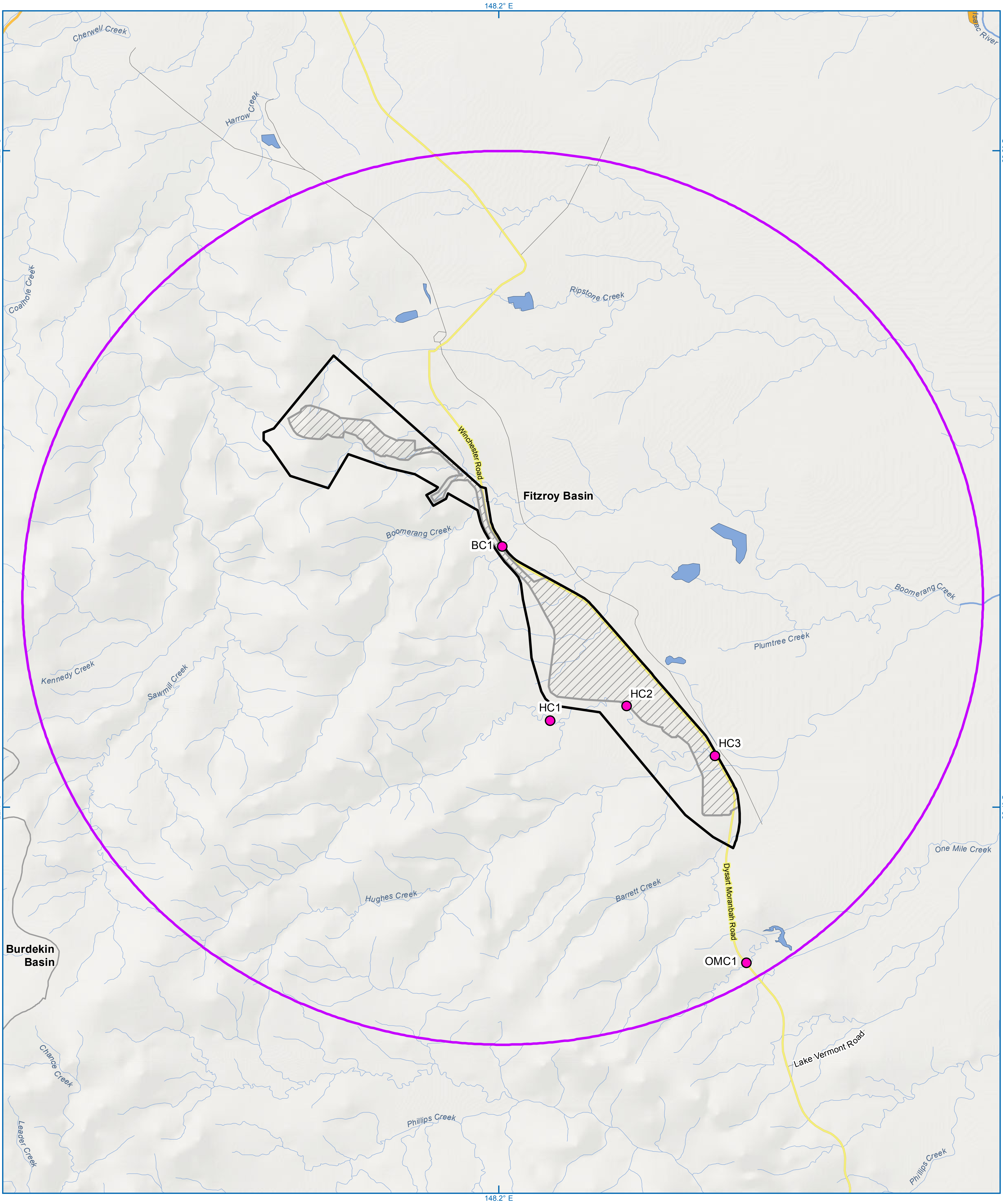
- species that are not yet known from Queensland but are regarded as a likely threat to human health, agriculture and / or the environment in Queensland (Prohibited Matter); and
- species that are known from Queensland and are known to adversely impact agriculture and / or the environment in Queensland (Restricted Matter).

Only Restricted Matters are relevant to this study, with seven categories of Restricted Matter recognised under the Act:

- Category 1: must be reported to DAF inspector within 24 hours of becoming aware of presence, to enable Biosecurity Queensland to take action to contain and eradicate the biosecurity matter
- Category 2: must be reported to DAF inspector within 24 hours of becoming aware of presence, to enable Biosecurity Queensland to take action to reduce, control or contain the biosecurity matter
- Category 3: must not distribute the biosecurity matter, including disposal of the biosecurity matter where disposal leads to distribution of biosecurity matter
- Category 4: must not move the biosecurity matter and ensure that it does not spread to other parts of Queensland
- Category 5: must not keep or possess the biosecurity matter
- Category 6: must not feed the biosecurity matter; and
- Category 7: If you have these noxious fish in your possession, you must kill them and dispose of the carcass by burying the whole carcass (no parts removed) in the ground above the high tide water mark or placing it in a waste disposal receptacle.

Review of Atlas of Living Australia (ALA 2020), Wildlife Online (DES 2020b) and the Isaac Regional Council Biosecurity Plan 2020-2023 indicates the following restricted aquatic biosecurity Matters may occur in the Broader Study Area:

- noxious fish
  - tilapia (*Oreochromis mossambicus*) (categories 3, 5, 6 and 7)
  - eastern Gambusia (*Gambusia holbrooki*) (categories 3, 5, 6 and 7)
- aquatic weeds
  - Salvinia (*Salvinia molesta*) (category 3)
  - water lettuce (*Pistia stratiotes*) (category 3), and
  - Hymenachne (*Hymenachne amplexicaulis*) (category 3).



Vulcan South Project: Aquatic Ecology Study

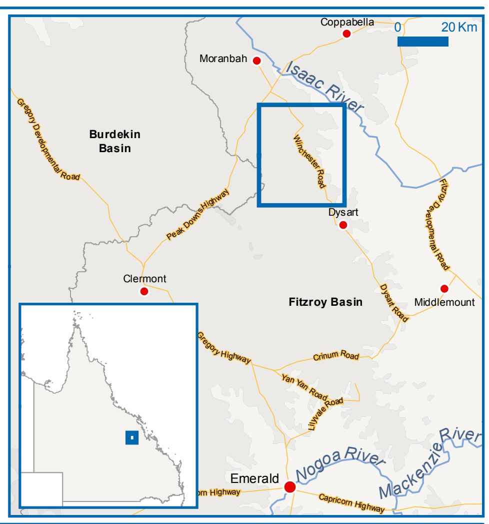
Map 5.1
Mapped High Ecological Value waters (wetlands and watercoures) and mapped High Ecological Significance wetlands.

LEGEND

- Aquatic ecology survey sites
- Broader Study Area
- Mining Lease Application Boundary
- Conservative Disturbance Footprint
- MSES High ecological significance wetlands

Road Network

- Highway
- Main Road
- Local Road
- Watercourse



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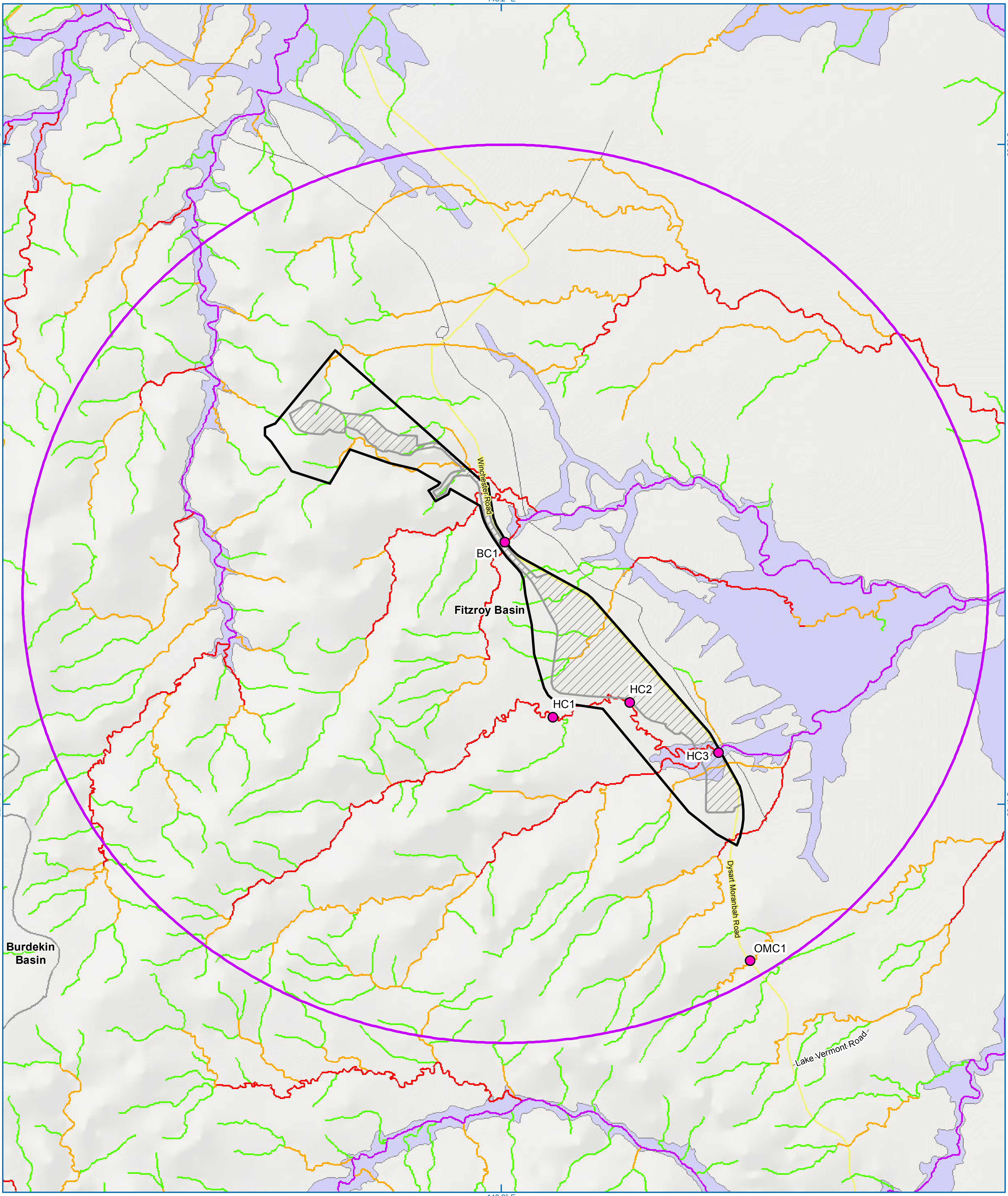


Vulcan South Project: Aquatic Ecology Study

Map 5.2
Waterway Barrier Works Risk Layer
and Mapped Floodplains

LEGEND

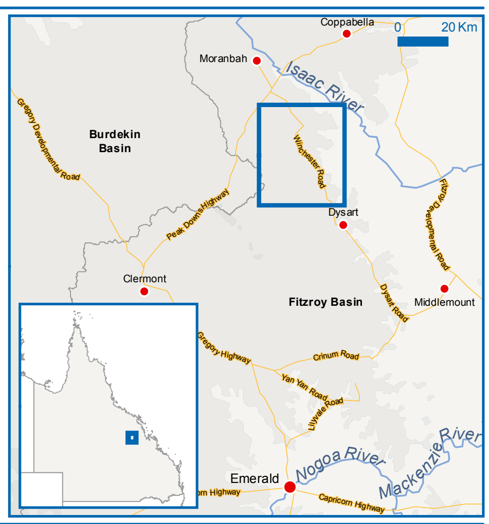
- Broader Study Area
- Aquatic ecology survey sites
- Mining Lease Application Boundary
- Conservative Disturbance Footprint
- Floodplain assessment overlay

Waterway Barrier Works Risk Layer

- 1 - Low
- 2 - Moderate
- 3 - High
- 4 - Major

Road Network

- Highway
- Main Road
- Local Road



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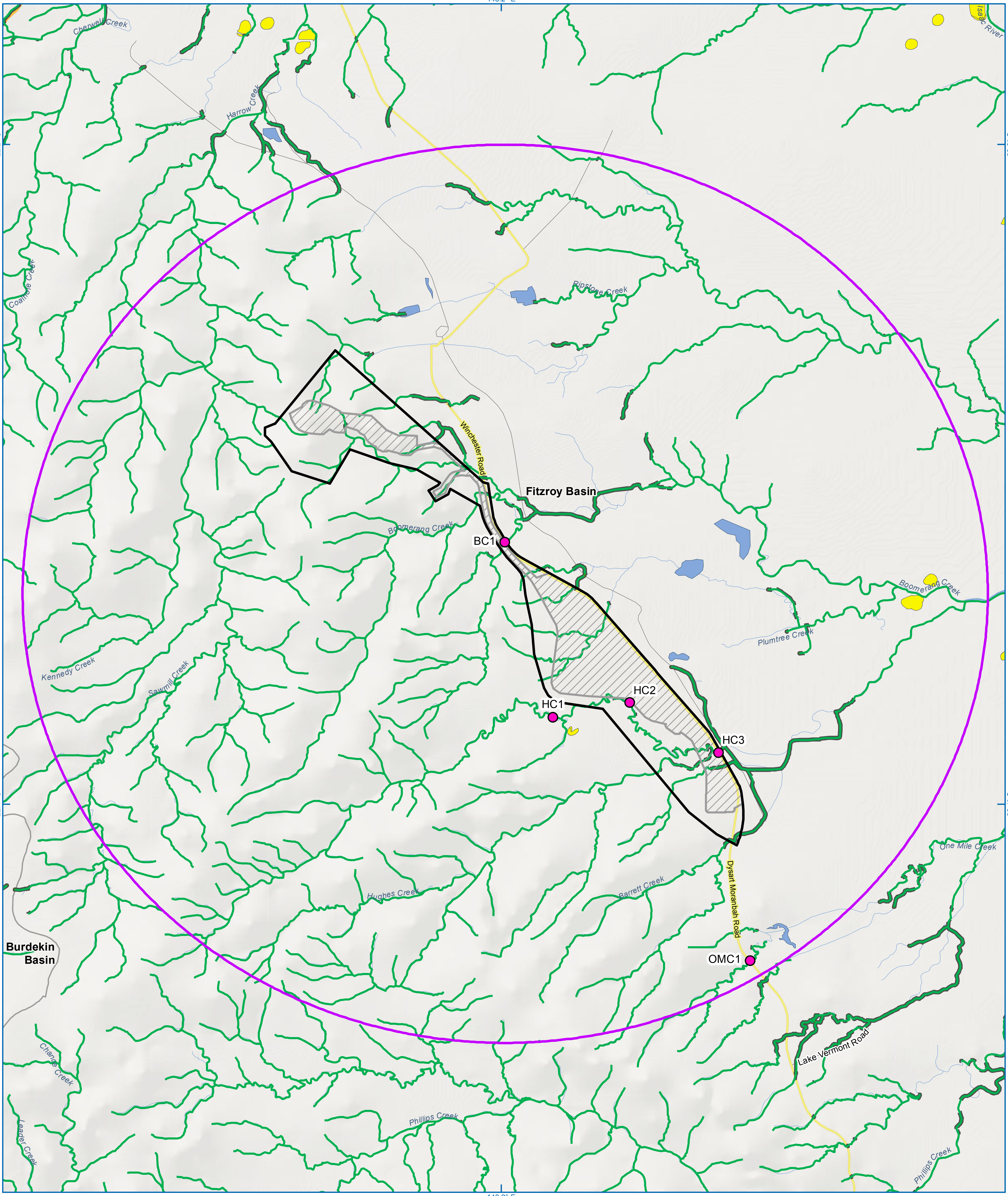


Vulcan South Project: Aquatic Ecology Study

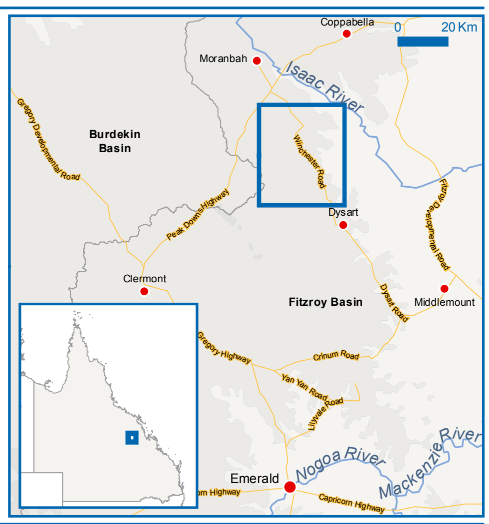
Map 5.3
Regulated Vegetation Types

LEGEND

- Broader Study Area
- Aquatic ecology survey sites
- Mining Lease Application Boundary
- Conservative Disturbance Footprint
- Regulated vegetation intersecting a watercourse
- Regulated vegetation category R
- Regulated vegetation 100m from wetland

Road Network

- Highway
- Main Road
- Local Road
- Watercourse



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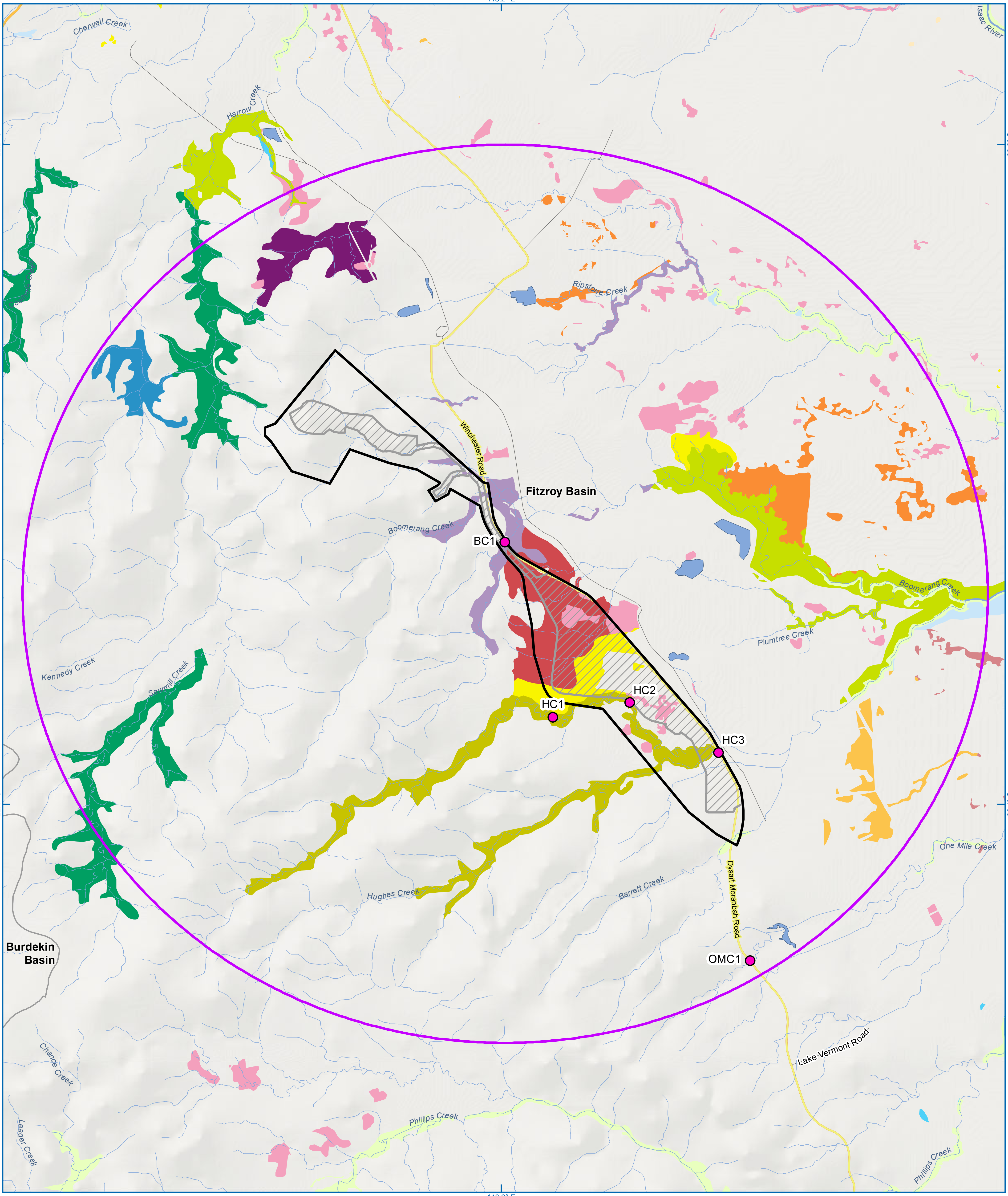


Vulcan South Project: Aquatic Ecology Study

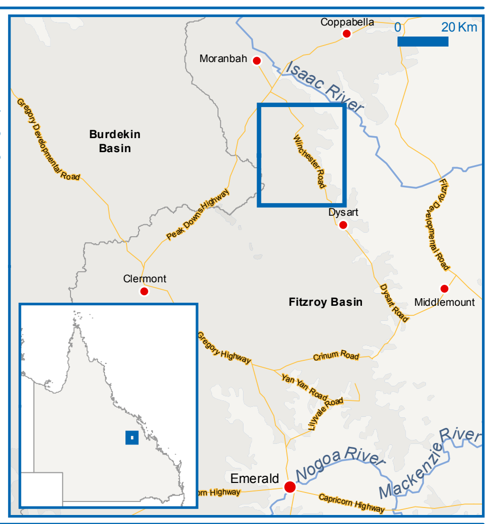
Map 5.4
Wetland Regional Ecosystems

LEGEND

- Broader Study Area
- Aquatic ecology survey sites
- Mining Lease Application Boundary
- Conservative Disturbance Footprint

Road Network
- Highway
- Main Road
- Local Road
- Watercourse

Wetland Regional Ecosystem
- 11.10.1/11.3.2
- 11.3.2
- 11.3.2/11.3.25
- 11.3.2/11.3.25/11.3.1
- 11.3.2/11.3.7/11.3.25
- 11.3.2/11.4.9
- 11.3.25
- 11.3.25/11.3.2
- 11.4.8
- 11.4.9
- 11.4.9/11.4.8
- 11.4.9/11.4.8/11.4.4
- 11.4.9/11.4.8/11.5.3
- 11.4.9/11.5.3/11.4.8
- 11.5.17
- 11.5.9b/11.4.9



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5.3 Water Quality

Water quality is assessed in detail in the Surface Water Assessment (WRM 2022).

Water quality was measured in situ within the scope of this aquatic ecology study at sites in the Broader Study Area to support aquatic habitat assessments. Results show that for sites holding water (Table 5.3):

- the pH of water complied with the default WQO at each site
- electrical conductivity complied with the default WQO at each site, except site HC3
- the percent saturation of dissolved oxygen in water was lower than the default WQO at each site, with water at site HC3 being hypoxic (i.e. <2 mg/L), and
- the turbidity of water was higher than the default WQO at sites HC2 and OMC1.

There are no default WQOs for water temperature or concentration of dissolved oxygen.

Water quality measured in situ at representative sites across the Broader Study Area indicated that at times when the ephemeral waterways of the specific Project Area hold water, the water quality will likely have:

- pH within the default guideline range
- electrical conductivity and turbidity often within the guideline range, but with occasional exceedances, indicating that water quality with respect to these parameters would only sometimes support diverse biological communities, and
- dissolved oxygen being consistently below the default guideline range, and occasionally of very low concentration, indicating that water quality with respect to dissolved oxygen would not support diverse biological communities.

Table 5.3 Results for water quality measured in-situ.

Site	Temperature (°C)	pH (unit)	Electrical conductivity (µS/cm)	Dissolved oxygen (mg/L)	Dissolved oxygen (% saturation)	Turbidity (NTU)
WQO	**–**	**6.5 – 8.5**	**720**	**–**	**85 – 110**	**50**
HC1	25.4	8.0	295	5.2	65	38
HC2	23.2	7.6	476	3.8	46	131
HC3	21.4	6.9	776	0.2	2	32
BC1	27.2	7.4	501	5.5	71	43
OMC1	23.9	7.9	138	2.3	28	98

grey shading indicates results that do not achieve the default WQO.

5.4 Aquatic Habitat

5.4.1 Mapped Habitat Features

There are mapped floodplains within the broader Project study area, including on lower reaches of Boomerang Creek, but not within the Project area (Map 5.2). Waterways of the broader Project Area have well-defined channels that follow an irregular sinuous pattern, while those of the Project area have reaches with both well-defined channels and some reaches with only moderately defined channels (Map 5.1).

Land use surrounding the Project area is dominated by low intensity dryland cattle grazing, with native catchment and riparian vegetation moderately cleared for pasture grasses. Cattle access to waterways contributes to bank erosion in the region.

5.4.2 Field Survey Results

Detailed habitat descriptions are presented in Appendix D, with a summary of aquatic habitat features of the Broader Study Area including:

- well-defined channels, with stream beds dominated by sand with some patches with silt and clay, and stream banks also comprising sand, silt and clay
- waterways were mostly totally dry, with some sites having small, isolated pools generated by notable rainfall leading up to the survey
- low cover of physical habitat (e.g. large wood debris [i.e. logs, branches], fine organic matter [i.e. twigs and leaves], undercut banks, trailing vegetation, aquatic plants)
- riparian vegetation was in low to moderate condition at most sites
- riverine bioassessment scores were mostly ‘poor’, with site OMC1 in the low end of ‘moderate’, with low scores (i.e. 25% or less of possible score) for criteria relating to substrate embeddedness, water velocity and depth and pool:riffle:run ration at most sites (Table 5.4), indicating that aquatic habitat was generally not suitable for supporting diverse macroinvertebrate communities.

The habitat assessment results for representative sites across the Broader Study Area indicate that the specific waterways of the Project Area are characterised by well-defined channels with dry stream beds, substrate dominated by sand with some clay, and streambanks dominated by clay with some sand. Waterways of the Project Area have low to very low cover of aquatic habitat elements, and riparian vegetation condition was in low to moderate condition. Riverine bioassessment scores cannot be calculated for dry waterways, but the score would be low at the rare times that hydrological habitat is present, indicating that even during brief periods that water is present at these sites the habitat features would not support diverse biological communities.

Table 5.4 Riverine Bioassessment Scores.

Habitat Category	Maximum Score Possible	Sites				
		HC1	HC2	HC3	BC1	OMC1
Bed substrate or available cover	20	1	2	2	2	5
Embeddedness	20	1	1	2	2	3
Water velocity and depth	20	1	1	1	1	2
Channel alteration	15	3	3	5	5	7
Bed scouring & deposition	15	2	2	2	6	7
Pool:riffle and run:bend ratio	15	4	1	4	3	4
Bank stability	10	6	3	5	6	6
Bank vegetative stability	10	9	7	9	7	8
Streamside vegetation cover	10	8	7	6	6	5
Total Habitat Bioassessment Score for the Site	135	35	27	36	38	47
Suitability for supporting diverse macroinvertebrate communities	excellent	poor	poor	poor	poor	moderate

5.5 Flow Regime

Flow patterns in the Isaac River (recorded at Deverill gauging station 130410A, 1968 – 2021) show that flows occur approximately 26% of the time (Figure 5.1), as discrete short-duration events (Figure 5.2). The most recent significant flow occurred in 2017, with a moderate flow in early 2021 (Figure 5.2). Waterways of the Broader Study Area have much smaller catchment areas than the Isaac River, and thus have flows more infrequently, with Hughes Creek recording flows about 5.7% of the time in the two and a half years from August 2017 to February 2020 (Figure 5.3).

Consequently, other waterways of the Project Area, which have even smaller catchment areas than Hughes Creek, are highly ephemeral, and aquatic habitat is dominated by dry stream bed for most of the time, with temporary hydrological habitats occurring in isolated pools within the channel for short periods after significant rain interspersed with large areas of dry stream bed.

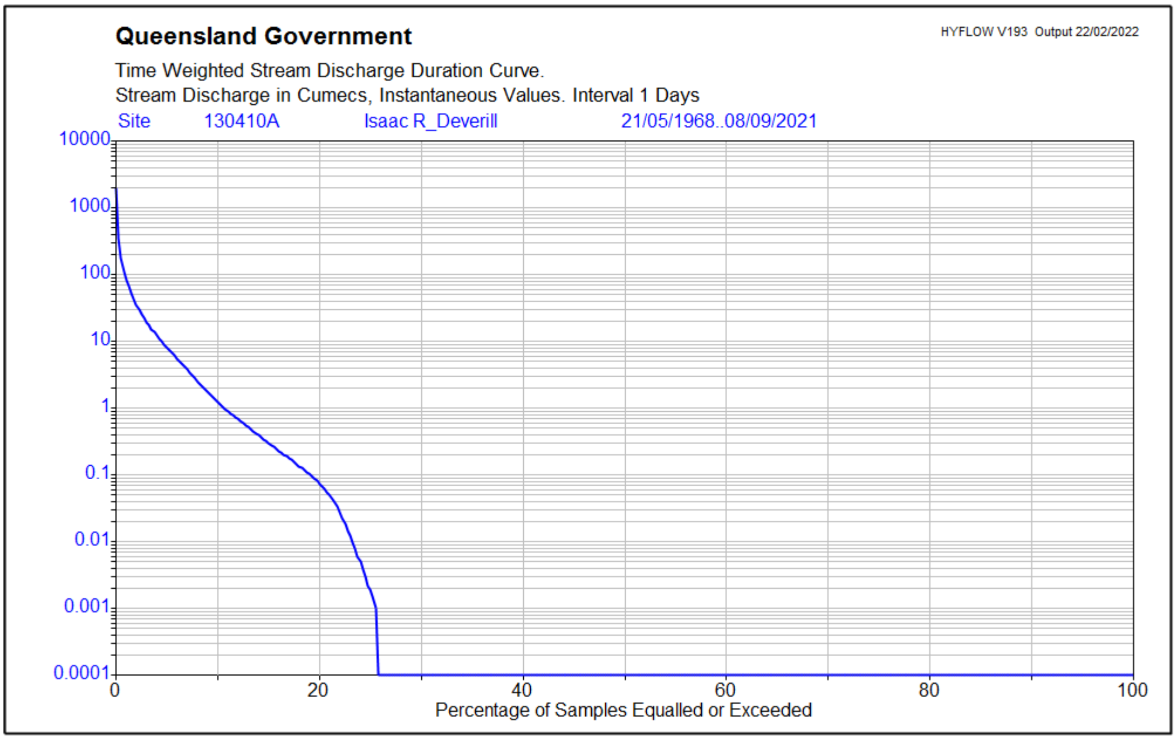


Figure 5.1 Flow duration curve for gauging station 130410A, based on flow records from 1968 to 2021.

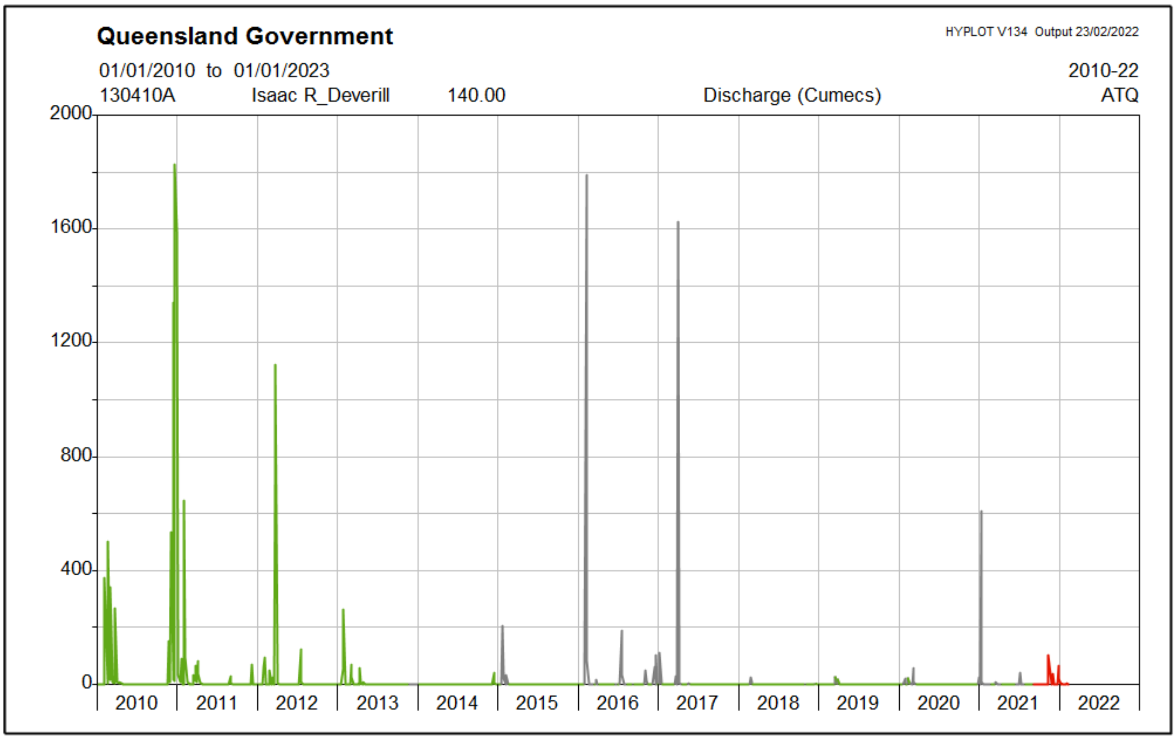
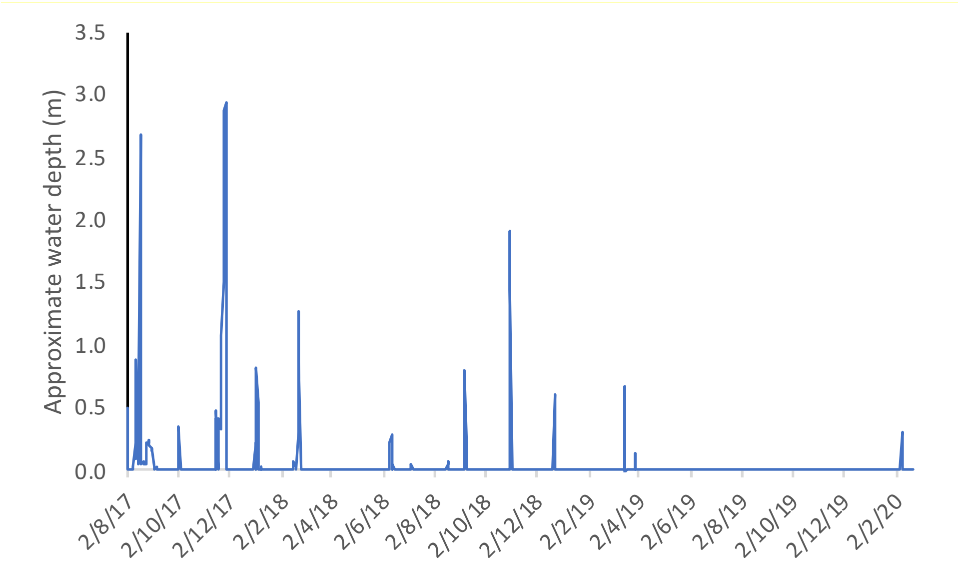


Figure 5.2 Stream flow at gauging station 130410A since January 2010.



Source of raw data: WRM (2020)

Figure 5.3 Approximate water depth measured at the Isaac Regional Council gauging station on Hughes Creek in the Broader Study Area from August 2017 to February 2020.

5.6 Aquatic (Surface Expression) Groundwater-Dependent Ecosystems

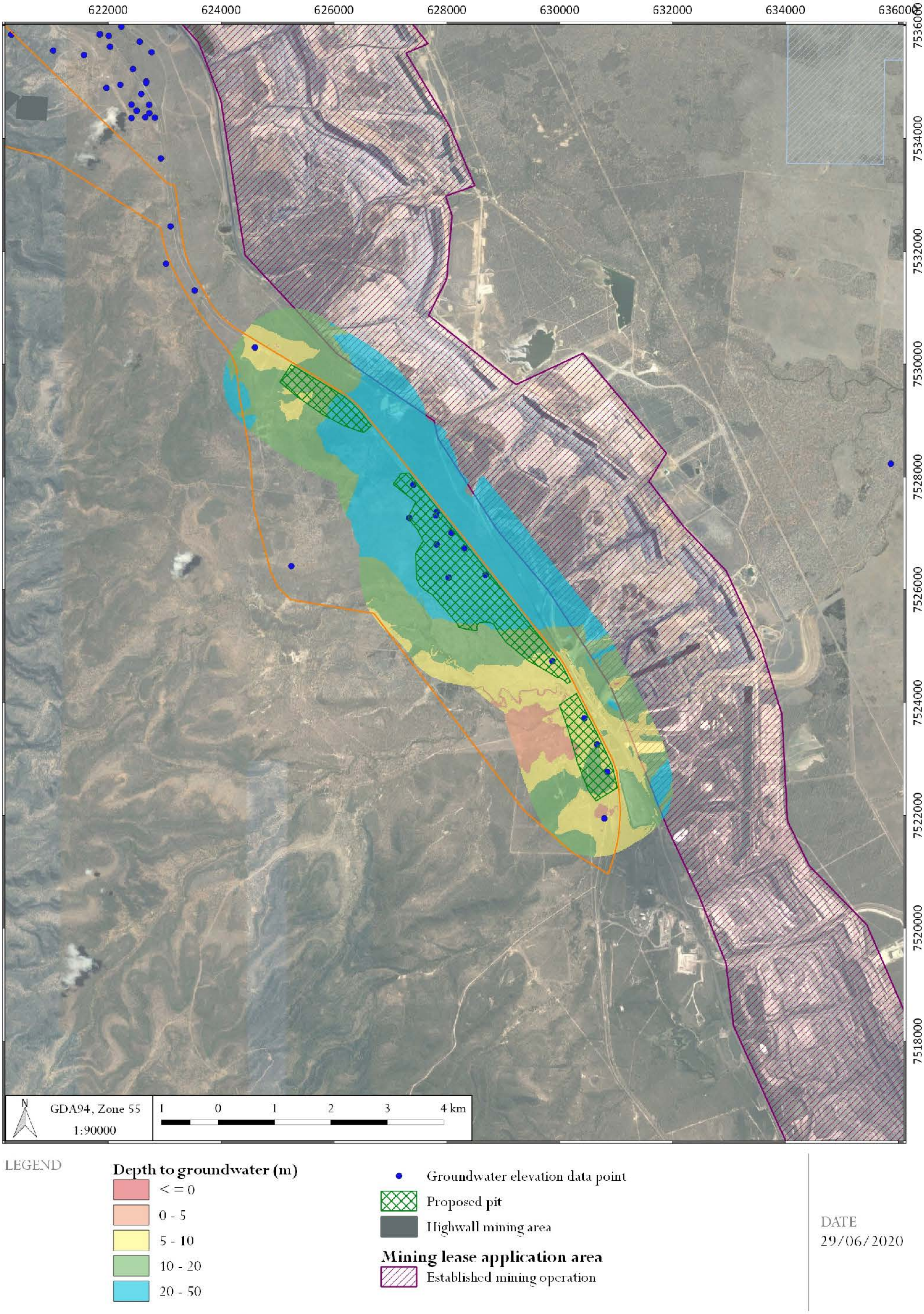
This section addresses the assessment of aquatic groundwater dependant ecosystems (GDEs) for the Project Area. Terrestrial GDEs are assessed separately in the Terrestrial Ecological Assessment for the Project (METServe 2022)

Aquatic GDEs are ecosystems that rely on the surface expression of groundwater, including surface water ecosystems which may have a groundwater component, such as perennial rivers, wetlands and springs. Terrestrial GDEs are ecosystems that rely on the subsurface presence of groundwater, including riparian vegetation that rely on groundwater to intersect root zones (BOM 2019).

The main stem of Hughes Creek within the specific Project Area is mapped as a potential aquatic GDE based on a national-scale desktop mapping, with small areas of potential aquatic GDE also mapped to the east of the specific Project Area (Map 5.6)

Hydrogeological studies completed for the Project indicate that depth to the groundwater table is <5 m along Hughes Creek, moderate in the southern and northern ends of the Project Area, and relatively deep (>10 to >20 m) for the central part of the Project Area (Map 5.5). However, satellite imagery (Figure 5.4), coupled with the aquatic habitat survey and flow data described above, confirms an absence of sustained surface water flows or other groundwater influences on surface water aquatic ecology in the Project Area. Figure 5.4 shows and absence of refugial pools along Hughes Creek, with a farm dam also dry. Thus, even the area of shallowest groundwater in the Project Area along Hughes Creek does not sustain surface expression aquatic GDEs. Indeed, key criteria presented in Doody et al. (2019), that indicate the potential for surface expression GDEs were not met in the Broader Study Area or specific Project Area, because:

- The Isaac River did not flow all year (i.e. flows occur about 26% of the time on the Isaac River, Figure 5.1, see also Figure 5.2), Hughes Creek about 6% of the time, and waterways of the specific Project study area would flow less than Hughes Creek
- The flow volume of specific waterways of the Project Area does not increase in the absence of rainfall or tributary inflows (see WRM 2022), and
- There were no springs or seeps at any survey site, and review of aerial imagery indicates an absence of springs from the Project Area.



hydrogeologist .com.au

Vulcan South Project - Groundwater Impact Assessment

Depth to groundwater

Map 5.5

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.

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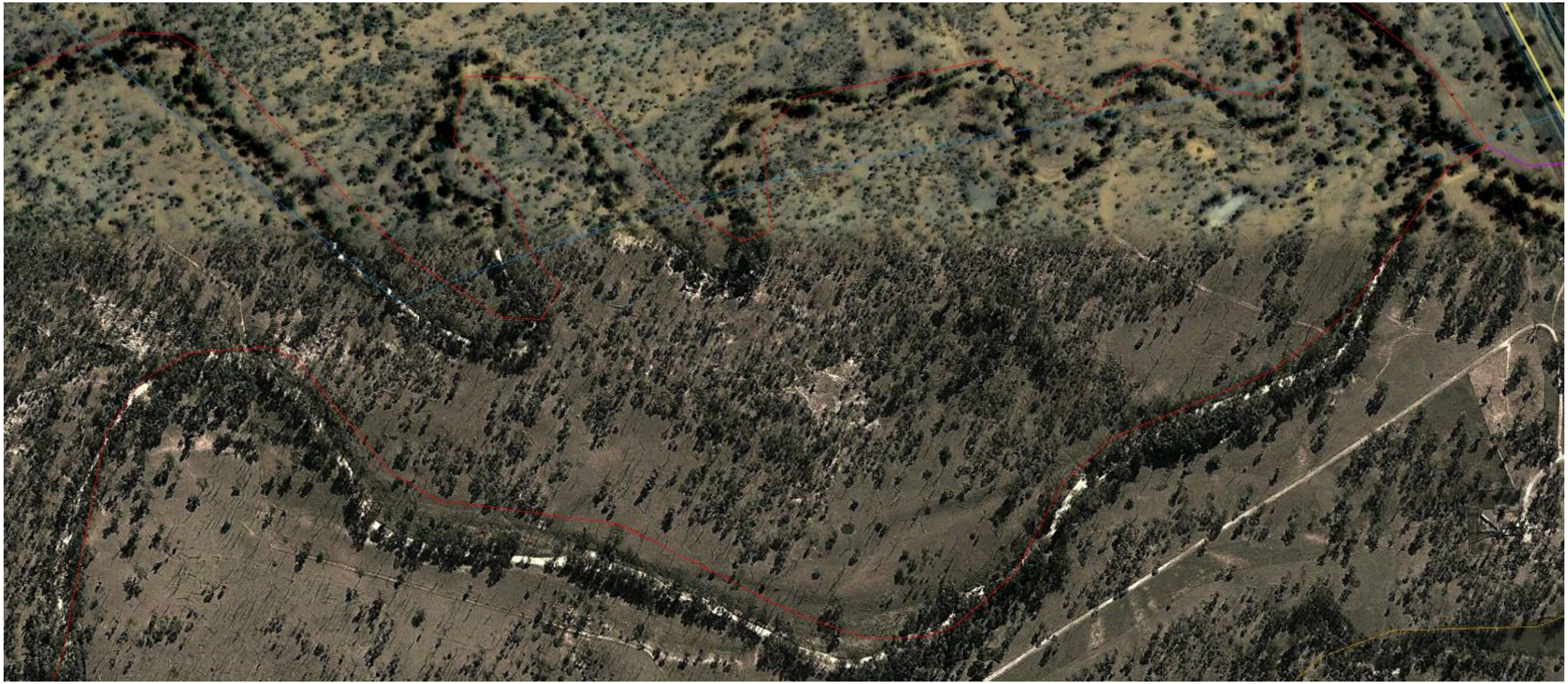
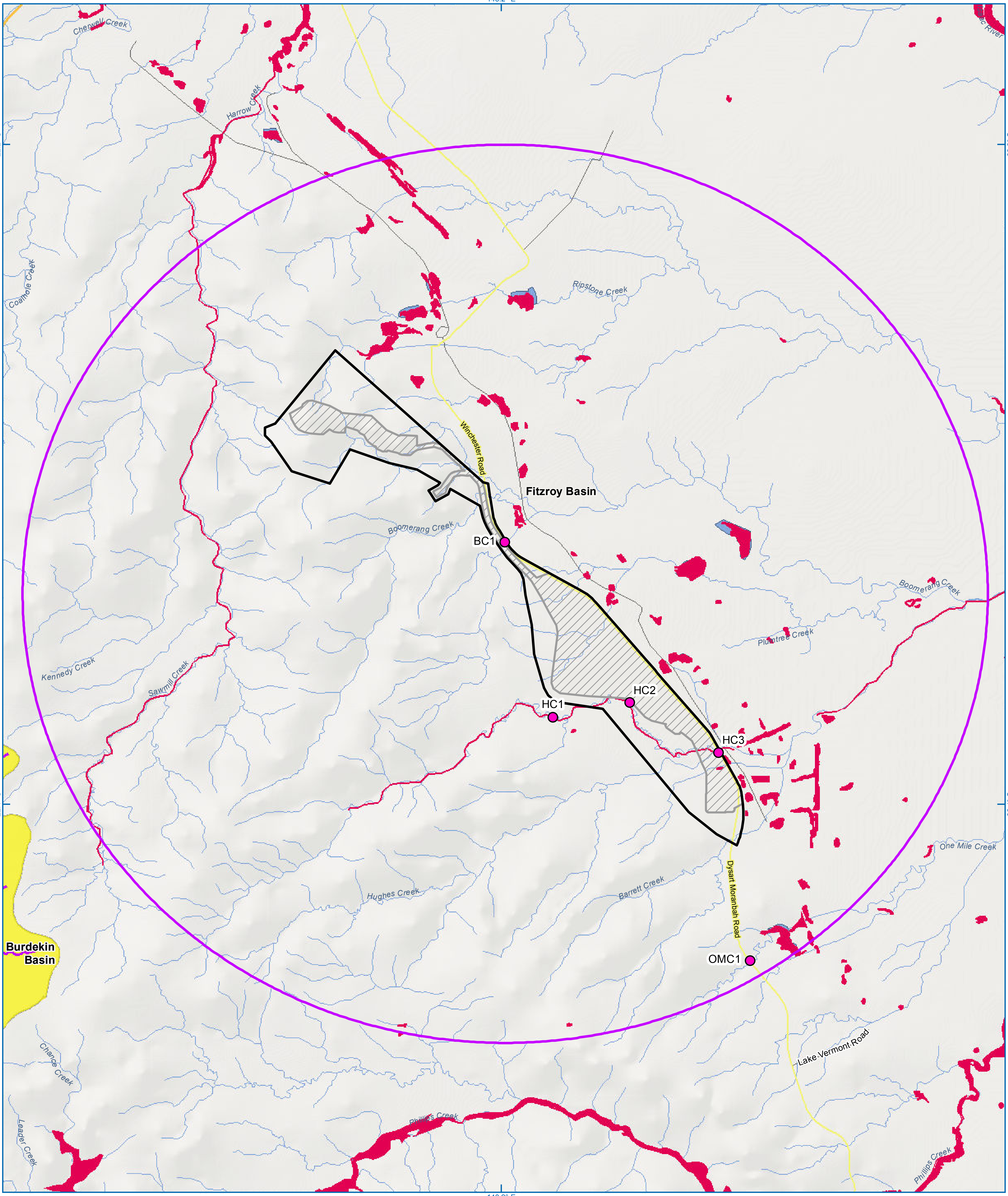


Figure 5.4 Satellite imagery of the reach of Hughes Creek within the specific Project Area mapped as a potential aquatic GDE, showing an absence of groundwater influences on surface water aquatic ecology.



Vulcan South Project: Aquatic Ecology Study

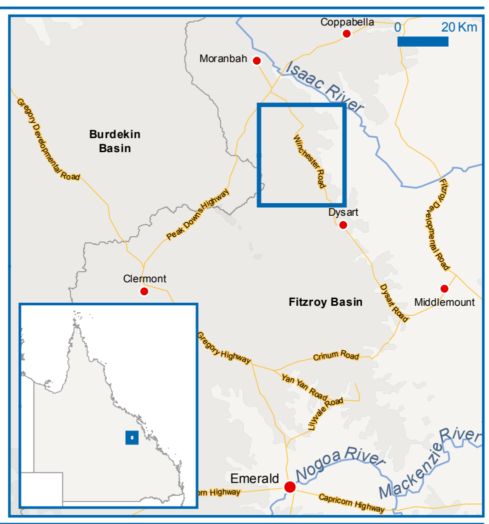
Map 5.6
Potential Aquatic Groundwater-dependent Ecosystems

LEGEND

- Broader Study Area
- Aquatic ecology survey sites
- Mining Lease Application Boundary
- Conservative Disturbance Footprint
- Potential Aquatic GDEs
- Surface Lines
- Potential Aquifer

Road Network

- Highway
- Main Road
- Local Road
- Watercourse



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SOURCES

DATE	DRAWN BY	VERSION	PROJECTION
2022-02-28	AB	02	Coordinate System: GCS GDA 1994 Datum: GDA 1994 Units: Degree

N

SCALE
0 3 6
Kilometres
Scale: 1:120,000 @ A3

5.7 Aquatic Biota of the Project Area

5.7.1 Aquatic Plants

Desktop Results

Aquatic plant communities of the region are typically species-poor and have low percent cover, which is likely due to the naturally harsh environmental conditions of ephemeral waterways (Van Manen 2005). Submerged aquatic plants were especially uncommon due to high turbidity (Van Manen 2005), with emergent taxa dominating aquatic plant communities, including smartweeds (*Persicaria* spp.), rushes (*Eleocharis* spp.) and sedges (*Cyperus* spp.). Swamp lily (*Ottelia ovalifolia*) is the most common aquatic plant not of an emergent growth form in the region, with *Nymphoides crenata* (a floating attached species) also known from the region (frc environmental unpublished data; DES 2020b).

None of the recorded aquatic plant species are listed as threatened species under the Commonwealth's EPBC Act or Queensland's NC Act. Water hyacinth (*Monochoria cyanea*), which is a restricted biosecurity matter under Queensland's *Biosecurity Act 2014*, is known from the region.

Field Survey Results

The aquatic plant survey at representative sites of the Broader Study Area found (Table 5.5):

- three common aquatic plant species, with *Cyperus* spp. and *Lomandra* sp. being relatively widespread, and *Juncus usitatus* found only at sites HC3 and BC1
- the percent cover of aquatic plants ranged from six at site HC3 to 30 at OMC1, and
- aquatic plants were found mostly on dry bed and banks, with *Cyperus* spp. found in water in low cover at sites BC1 and OMC1.

The aquatic plants of the specific Project Area would comprise only common, emergent species that would occur on dry bed or bank habitat most of the time. The aquatic plant community would be dominated by low diversity and percent cover of sedges (*Cyperus* spp.), common rush (*Juncus usitatus*) and matt rush (*Lomandra* sp.), with very low percent cover of taxa including smartweeds (*Persicaria* spp.) and spike rush (*Eleocharis* sp.) possibly occurring temporarily after wet periods.

Table 5.5 Results of aquatic plant survey.

Site	Percent Cover of Aquatic Plants		
	Juncus usitatus	*Cyperus* spp.	*Lomandra* sp.
HC1	–	21	5
HC2	–	15	3
HC3	2	3	1
BC1	1	12	15
OMC1	–	18	12

5.7.2 Macroinvertebrates

Desktop Results

The diversity of macroinvertebrates of ephemeral waterways of the region is typically lower than the default biological objective, with the diversity of sensitive taxa also low (i.e. low PET [Plecoptera, Ephemeroptera, Trichoptera] richness and low SIGNAL-2 scores) (frc environmental unpublished data):

- Taxonomic richness in edge habitat ranging 7 to 27
- PET richness in edge habitat ranging 1 to 3, and
- SIGNAL-2 scores in edge habitat ranging 2.1 to 4.2.

Aquatic macroinvertebrates of the region are dominated by insects (frc environmental, unpublished data):

- four families of beetles (Coleoptera)
- three families of flies and midges (Diptera)
- four families of bugs (Hemiptera)
- three families of dragonflies and damselflies (Odonata)
- two families (sensitive taxa) of mayflies (Ephemeroptera) and
- two families (sensitive taxa) of caddisflies (Trichoptera).

Other macroinvertebrate taxa recorded in the region include:

- two families of mussels and clams (Bivalvia)
- two families of snails (Gastropoda)
- one family of Hydrozoa
- mites (Acarina)
- three families of macrocrustacea (Decapoda):
  - glass shrimp (Atyidae)
  - crayfish (Parastacidae), and
  - freshwater crabs (Parathelphusidae).

Field Survey Results

The macroinvertebrate data at representative sites across the for the Broader Study Area show that (refer to Table 5.6):

- bed habitat was not present at site HC2, and edge habitat was not present at sites HC1 and HC3
- the abundance of macroinvertebrates was highly variable, and
- taxonomic richness, PET richness and SIGNAL-2 scores were typically lower than the default biological objective range.

There are several reasons why the default biological objectives were not commonly achieved at the representative sites of the Broader Study Area:

- Bed habitat does not have a specific default guideline, with the bed samples compared to the 'composite' guidelines, which were developed from macroinvertebrates samples from bed and riffle habitats. Thus, samples collected from only bed habitat, which typically has lower diversity and fewer sensitive taxa than those found in riffle habitat, would not be expected to commonly achieve the 'composite' guideline.
- Water levels of pools at some sites had increased in size and depth prior to the survey due to heavy rain; thus, edge habitats (and possibly some bed habitat) had not been inundated for more than a few days prior to sampling. However, as flows are short duration events (typically only days in duration), the macroinvertebrate

data provides a representative description of the typical macroinvertebrates of the Broader Project Area, including the specific Project Area.

- The percent saturation of dissolved oxygen was lower than water quality conditions that would support diverse macroinvertebrate communities (Table 5.3)
- The quality of habitat was not favourable for supporting diverse macroinvertebrate communities:
  - Riverine bioassessment scores were mostly 'poor', with one site having habitat complexity at the low end of moderate, indicating aquatic habitat at the sampled sites was generally not suitable for supporting diverse macroinvertebrate communities
  - Some sites did not have edge habitat present, and where edge habitat was present it was only recently inundated and of poor quality (i.e. trailing vegetation and organic matter was absent)
  - One site did not have adequate bed habitat present to sample macroinvertebrates, as it was a small, elongated pool adjacent to the bank composed almost exclusively of edge habitat
  - Bed substrate was dominated by sand, which has significantly fewer interstitial pores than coarse substrates (gravel, cobble) that provides suitable habitat for diverse macroinvertebrate communities.

The macroinvertebrate communities of the specific Project Area, even during above average wet seasons, would have typically low diversity, a low number of PET taxa and be dominated by tolerant taxa. Macroinvertebrates would be present only for brief periods during wet season flows, with the typically dry watercourses not having any aquatic macroinvertebrates for most of the time.

Table 5.6 Results of the macroinvertebrate survey – macroinvertebrate indices.

Site	Macroinvertebrate Indices			
	Abundance	Taxonomic richness	PET richness	SIGNAL-2 Score
Bed habitat				
Default biological objective composite habitat	**–**	**12 – 21**	**2 – 5**	**3.33 – 3.85**
HC1	636	18	1	3.06
HC2	–	–	–	–
HC3	101	9	1	3.04
BC1	98	13	1	3.14
OMC1	36	9	1	3.12
Edge Habitat				
Default biological objective edge habitat	**–**	**23 – 33**	**2 – 5**	**3.31 – 4.20**
HC1	–	–	–	–
HC2	186	13	1	3.37
HC3	–	–	–	–
BC1	336	20	2	2.90
OMC1	213	15	1	3.12

grey shading indicates a result lower than the guideline range

5.7.3 Fish

Desktop Results

Based on desktop assessment, twelve native species of fish are known from the region (frc environmental unpublished data; DES 2020b):

- common gudgeons (*Hypseleotris* spp.)
- spangled perch (*Leiopotherapon unicolor*)
- bony bream (*Nematolosa erebi*)
- Agassiz's glassfish (*Ambassis agassizii*)
- eastern River rainbowfish (*Melanotaenia splendida*)

- fly-specked hardyhead (*Craterocephalus stercusmuscarum*)
- Hyrtl’s tandan (*Neosilurus hyrtlii*)
- purple spotted gudgeon (*Mogurnda adspersa*)
- sleepy cod (*Oxyeleotris lineolata*)
- Rendahl’s catfish (*Porochilus rendahli*)
- Empire gudgeons (*Hypseleotris compressa*)
- blue catfish (*Neoarius graeffei*) and
- leathery grunter (*Scortum hillii*).

These are all common species that are tolerant of harsh environmental conditions (e.g. variable flow, fluctuating water quality) that are typical of ephemeral waterways of the region. All species are potadromous (i.e. they migrate to various extents within freshwaters), except Empire gudgeons which are diadromous (i.e. migrate between freshwater and saltwater). Leathery grunter is endemic to the Fitzroy River Basin. None of these species are listed as threatened species under the EPBC Act or NC Act.

Tilapia (*Oreochromis mossambicus*) has recently been caught from the Isaac River near the Project area (frc environmental unpublished data).

Field Survey Results

The fish survey result at representative sites across the Broader Study Area show (Table 5.7):

- only two sites had fish, and only three native species were recorded
- Agassiz’s glassfish was the only species found at more than one site, and
- the abundance of fish was relatively high at site OMC1 and very low at site HC1.

All native species are common and widespread in the region, and none are listed species. All are potadromous species (i.e. migrate only within freshwater sections of river and do not access estuaries or coastal waters).

Habitat and hydrological characteristics of waterways of the Broader Study Area (i.e. typically dry streams with very low cover of instream aquatic habitat features) mean that fish would not commonly be found in the Project Area. However, there may be brief occurrences of low abundance of some of the above listed species with good dispersal abilities during above average wet seasons, including species such as spangled perch, Hyrtl's tandan and common gudgeons. It is possible that pest fish including tilapia could occur in periodic wet conditions.

Table 5.7 Results of fish survey.

Species	Common names	Abundance	
		Site	
		HC1	OMC1
Native Fish			
Ambassis agassizii	Agassiz's glassfish	1	43
Melanotaenia splendida	eastern rainbowfish	1	
Mogurnda adspersa	purple spotted gudgeon	–	11

5.7.4 Turtles

Desktop Assessment

Three species of turtle are reported from the Broader Study Area: eastern long-necked turtle (*Chelodina longicolis*), Krefft's river turtle (*Emydura macquarii krefftii*) and broad-shelled river turtle (*Chelodina expansa*) (frc environmental unpublished data; DES 2020b). White-throated snapping turtle and Fitzroy River turtle are unlikely to occur in the Broader Study Area or specific Project Area (Section 5.1).

None of the known or possibly occurring species of turtle in the Broader Study Area are listed as threatened species under the Commonwealth's EPBC Act or Queensland's NC Act.

Field Survey Results

No turtles were caught during the field survey.

Habitat and hydrological characteristics of waterways of the Broader Study Area (i.e. typically dry streams with very low cover of instream aquatic habitat features) mean that turtles would not commonly be found in the Project Area. However, there may be brief occurrences of low numbers of eastern long-neck turtles, broad shelled river turtles or Krefft's river turtles on rare occasions, such as after extreme wet seasons.

5.8 Assessment of Environmental Value

5.8.1 AquaBAMM Criteria

The assessment of aquatic ecological value using the AquaBAMM criteria is presented in Table 5.8 and indicates overall low aquatic ecological value:

- low to moderate aquatic and catchment naturalness
- low diversity of common aquatic species (with no threatened or priority aquatic species)
- no threatened, priority or special habitat or geomorphic features present
- limited and temporary hydrological connectivity, and
- an absence of unique or representative aquatic ecosystems.

Table 5.8 Assessment of aquatic ecological value using the AquaBAMM criteria.

Criteria / Indicator	Measure	Assessment	Comments
1 Naturalness Aquatic			
1.1 Exotic flora / fauna	1.1.1 Presence of pest fish	possible	Tilapia known in Isaac River
	1.1.2 Presence of exotic aquatic plants	no	–
1.2 Aquatic communities	1.2.1 SOR vegetation condition	low	
	1.2.2 SIGNAL score	low	
	1.2.3 AUSRIVAS edge score	low	
	1.2.4 AUSRIVAS pool score	low	
	1.2.5 EPT score	low	
1.3 Channel features modification	1.3.1 SOR bank stability	moderate	
	1.3.2 SOR bed and bar stability	moderate	
	1.3.3 SOR aquatic habitat condition	low	
	1.3.4 Presence of dams / weirs	absent	Aerial imagery
	1.3.5 Inundation by dams / weirs	absent	Aerial imagery
	1.3.6 Snag removal	none	
1.4 Hydrological modification	1.4.1 Annual proportion of flow deviation	Low (unquantified)	
	1.4.2 % natural flows	<5%	
	1.4.3 % no flows	>95%	

Criteria / Indicator	Measure	Assessment	Comments
1.5 Water quality	1.5.1 Total phosphorous	–	Refer to surface water assessment[1]
	1.5.2 Total nitrogen	–	Refer to surface water assessment[1]
	1.5.3 Turbidity	generally achieved default WQO	
	1.5.4 Conductivity	generally achieved default WQO	
	1.5.5 pH	achieved default WQO	
2 Naturalness Catchment			
2.1 Exotic flora / fauna	2.1.1 Exotic plants in riparian zone	–	Refer to terrestrial ecology assessment[2]
2.2 Riparian disturbance	2.2.1 % remnant vegetation in riparian zone	–	Refer to terrestrial ecology assessment[2]
	2.2.2 % area of wetland RE relative to pre-clearing area	–	Refer to terrestrial ecology assessment[2]
	2.2.3 Total number of riverine REs relative to number of pre-clearing REs	–	Refer to terrestrial ecology assessment[2]
	2.2.4 SOR reach environs	low	
	2.2.5 SOR riparian vegetation condition	low	

Criteria / Indicator	Measure	Assessment	Comments
2.3 Catchment disturbance	2.3.1 % agriculture land use in catchment	–	Refer to terrestrial ecology assessment[2]
	2.3.2 % grazing land use in catchment	–	Refer to terrestrial ecology assessment[2]
	2.3.3 % vegetation in catchment	–	Refer to terrestrial ecology assessment[2]
	2.3.4 % settlement in catchment	–	Refer to terrestrial ecology assessment[2]
2.4 Flow modification	2.4.1 Farm dam storage (surface area)	low (unquantified)	Aerial imagery
3 Diversity and Richness			
3.1 Species diversity	3.1.1 Richness of amphibians	–	Refer to terrestrial ecology assessment[2]
	3.1.2 Richness of native fish	low	
	3.1.3 Richness of native reptiles	–	Refer to terrestrial ecology assessment[2]
	3.1.4 Richness of native water birds	–	Refer to terrestrial ecology assessment[2]
	3.1.5 Richness of aquatic plants	low	
3.2 Communities / assemblages	3.2.1 Number of macroinvertebrate families / taxa	low	
	3.2.2 Richness of riverine / wetland REs	–	Refer to terrestrial ecology assessment[2]

Criteria / Indicator	Measure	Assessment	Comments
3.3 Habitat	3.3.1 SOR channel diversity	low – only sinuous channel type	
3.4 Geomorphology	3.4.1 Richness of geomorphic features	low	
4. Threatened Species and Ecosystems			
4.1 Species	4.1.1 Presence of rare or threatened fauna species dependent on aquatic ecosystems	nil	
	4.1.2 Presence of rare or threatened flora species dependent on aquatic ecosystems	nil	
4.2 Communities assemblages	4.2.1 % of 'of concern' or 'endangered' wetland REs	–	Refer to terrestrial ecology assessment[2]
5 Priority Species and Ecosystems			
5.1 Species	5.1.1 Presence of aquatic ecosystem dependent 'priority' fauna	nil	
	5.1.2 Presence of aquatic ecosystem dependent 'priority' flora	nil	
	5.1.3 Presence of habitat for, or presence of, migratory waterbirds	–	Refer to terrestrial ecology assessment[2]
	5.1.4 Habitat for significant number of waterbirds	–	Refer to terrestrial ecology assessment[2]
5.2 Ecosystems	5.2.1 Presence of 'priority' ecosystems	nil	
6. Special Features			

Criteria / Indicator	Measure	Assessment	Comments
6.1 Geomorphic features	6.1.1 Presence of distinct, unique or special geomorphic features	nil	
6.2 Ecological processes	6.2.1 Presence of, or requirement for, distinct, unique or special ecological processes	nil	
6.3 Habitat	6.3.1 Presence of distinct, unique or special habitats, including refugia or critical habitats	nil	
6.4 hydrological	6.4.1 Presence of distinct, unique or special hydrological regimes (e.g. spring feed system)	nil	
7 Connectivity			
7.1 significant species or populations	7.1.1 The contribution (upstream or downstream) to maintenance of significant species or populations, including those features identified through Criterion 5 and/or 6	low	
	7.1.2 Possibility for migratory or routine 'passage' of fish and other fully aquatic species (upstream and/or downstream movement)	low	

Criteria / Indicator	Measure	Assessment	Comments
7.2 Aquatic groundwater dependent ecosystems (GDEs)	7.2.1 The contribution (upstream or downstream) to the maintenance of surface expression aquatic GDEs with significant biodiversity values, including those features identified through Criterion 5 and/or 6 (e.g. karsts, cave streams, artesian springs)	nil	
7.3 Floodplain and wetland ecosystems	7.3.1 The contribution (upstream or downstream) to the maintenance of floodplain and wetland ecosystems with significant biodiversity values, including those features identified through Criterion 5 and/or 6	nil	
7.4 Terrestrial ecosystems	7.4.1 The contribution (upstream or downstream) to the maintenance of terrestrial ecosystems with significant biodiversity values, including those features identified through Criterion 5 and/or 6	–	Refer to terrestrial ecology assessment[2]
7.5 Estuarine and marine ecosystems	7.5.1 The contribution (upstream or downstream) to the maintenance of estuarine and marine ecosystems with significant biodiversity values, including those features identified through Criterion 5 and/or 6	negligible	

Criteria / Indicator	Measure	Assessment	Comments
8. Representativeness			
8.1. Representativeness	Rarity of estuarine type in relation to geographic area	N/A	
	Uniqueness (river types) within a biogeographic area	low	

1 Surface water assessment (WRM 2022)

2 Terrestrial ecology assessment (METServe 2022)

5.8.2 Criteria Incorporating Legislative Matters

The assessment of aquatic ecological value of the waterways of the specific Project Area was assessed using the criteria presented in Table 4.5 (Table 5.9), with the:

- headwaters of Plumtree Creek assessed as having high aquatic ecological due to the presence of endangered wetland RE 11.4.9 in riparian areas
- mainstems of Hughes, Boomerang and Barrett Creeks assessed as having moderate aquatic ecological value because these waterways provide suitable habitat for common species of turtle, fish and macroinvertebrate in some wet seasons, are possibly important corridors for fish passage in some wet seasons, and have of-concern wetland RE 11.3.2 and RE 11.3.25 in their riparian zones
- other waterways of the specific Project area assessed as potentially having moderate aquatic ecological value because these waterways possibly provide suitable habitat for common species of turtle, fish and macroinvertebrate in some wet seasons, but are unlikely to provide important corridors for fish passage because hydrological connectivity is very limited (several days a year, with no hydrological connectivity on some years) and these systems do not contain or link key breeding, foraging or refugial habitat for fish.

Threatened aquatic fauna are highly unlikely to occur, there are no HEV waters, declared fish habitat areas, or category B or C regulated vegetation classes in the riparian zone.

No sensitive aquatic environmental receptors are likely to occur in waterways in the Project area.

Table 5.9 Assessment of Aquatic Ecological Value Incorporating Legislative Matters.

Aquatic Ecological Value	Aquatic Ecological Value Criteria	Headwaters of Plumtree Creek	Main stems of Hughes, Boomerang and Barrett Creeks	Other Waterways of specific Project Area
High	Aquatic MNES known or likely to occur	No	No	No
	Threatened aquatic species under the NC Act know or likely to occur	No	No	No
	Declared fish habitat area present	No	No	No
	High Ecological Value Wetlands present	No	No	No
	Endangered wetland Regional Ecosystems in riparian zone	Yes	No	No
Moderate	Suitable habitat for common species of turtle, fish and macroinvertebrate present	Possibly	Yes	Possibly
	Of-concern wetland Regional Ecosystems in Riparian zone	No	Yes	No
	Category B or C regulated vegetation in riparian zone	No	No	No
	Important corridor for fish passage	No	Yes	No
Low	No to all the above	–	–	–

6 Aquatic Ecological Impact Assessment and Mitigation

6.1 Sources of Potential Impact on Aquatic Ecological Values

The following potential sources of impact on aquatic ecological values associated with the Project were identified:

- discharge of mine-affected water to waterways
- localised sedimentation of waterways
- localised increases in turbidity and total suspended solids
- localised contamination of waterways
- waterway crossings
- cumulative impacts of the project interacting with nearby operational mines
- introduction of aquatic weeds to waterways
- disturbance to endangered riparian vegetation types.

Discharge of Mine-affected Water

Discharges of mine-affected water to waterways are either planned / controlled (i.e. in accordance with Environmental Authority (EA) release criteria for water quality and quantity, and receiving environment flow condition), or unplanned / uncontrolled (such as those that would occur from overspilling, seepage or failure of water management dams). Planned / controlled releases (i.e. those that comply with the applicable EA release criteria designed to protect environmental values) have low risk of adverse impact to the aquatic ecological values of receiving waters. However, unplanned discharges of water may not have the same water quality controls as planned discharges, and thus present some level of risk to the aquatic ecological values of receiving waters, although unplanned discharges are controlled by mine water infrastructure that is designed and constructed to industry standards.

Surface water management infrastructure for the Project will be established progressively to divert clean water catchments around operational areas and to manage runoff from disturbed areas. The proposed water management strategy and infrastructure is detailed in the Surface Water assessment for the Project (WRM 2022). The main components of water-related infrastructure include:

- diverted water drains, bunds and drainage diversions to divert runoff from undisturbed catchments around areas disturbed by mining
- flood protection levees along the southern side of the Vulcan North pit extent, along the western and south-eastern sides of the Vulcan Main pit, and around the Vulcan South pit
- sediment dams and drains to collect and treat runoff from waste rock emplacement areas; and
- mine-affected water drains and dams to store water pumped out of the open cut mining areas and to collect runoff from the infrastructure areas.

Mine affected water dams will be established as a water supply dams for dust suppression. These dams will also receive any accumulated pit water that requires dewatering. A series of drains and bunds will be established to direct runoff to sediment control structures. Discharge of mine-affected water to waterways is not planned.

Localised Sedimentation of Waterways

Sedimentation could result from vegetation clearing and earthworks during construction, operational and rehabilitation phases of the Project.

Sedimentation of waterways can impact aquatic ecology by smothering stream beds with fine material and decreasing bed roughness and reducing habitat diversity (e.g. smothering diverse substrate types such as sand, and gravels and cobbles, smothering woody debris, making pools shallower, and in-filling under-cut banks that provide important habitat for fish). Decreases in available habitat for aquatic fauna due to sedimentation could reduce breeding opportunities and increase predation (e.g. by birds); thus, may cause a localised decline in abundance and diversity of aquatic species.

Localised Increases in Turbidity and Suspended Solids in Surface Water

Increases in turbidity and suspended solids could result from vegetation clearing and earthworks during construction, operational and rehabilitation phases of the Project.

Increased turbidity and suspended solids may negatively impact fish and macroinvertebrates, because highly turbid water reduces respiratory and feeding efficiency (ANZG 2018). Increased turbidity may also adversely affect submerged aquatic plants as light penetration (required for photosynthesis) is reduced. Reduced light penetration can also lead to a reduction in temperature throughout the water column (DNR 1998).

Small increases in turbidity would be unlikely to have a significant impact on aquatic ecology, as aquatic species of the region are tolerant of moderate turbidity. However, significant increases in turbidity could adversely impact the health, feeding and breeding ecology of some species of macroinvertebrates and fishes, and aquatic plant growth.

Localised Contamination of Waterways

Fuels, oils and other chemicals (e.g. lubricants and solvents) required for the operation of vehicles and machinery are toxic to aquatic flora and fauna at relatively low concentrations. Spilt fuel is most likely to enter waterways via an accidental spill on the roads near waterway crossings; or when there are construction activities adjacent to waterways. A significant fuel spill to waterways (in the order of tens or hundreds of litres) is likely to have a considerable local impact on both flora and fauna, with the size of spill and the volume of water in the creeks being the most significant factors influencing the length of stream impacted. Other wastes associated with vehicle and machine maintenance also have the potential to contribute to the degradation of aquatic ecosystems.

Waterway Crossings

Waterway crossings are planned for the Saraji Road realignment, highwall mining haul road and construction of other tracks and linear infrastructure.

Poorly designed and constructed crossings may create waterway barriers that prevent or impede movements of aquatic fauna such as fishes and turtles during flow events, especially low flow events. Many of the fish native to ephemeral systems in central Queensland migrate up and downstream and between different habitats at particular stages of their lifecycle, especially at the start of the wet season. Blockages to fish passage and stream flows may prevent ephemeral wet season aquatic habitat being available to fish and turtles or mean that fish and turtles cannot move to dry season refugial habitat at the end of the wet season, and thus perish.

Crossings of waterways may cause bank instability if remediation works are not adequately designed and implemented. Bank erosion causes localised sedimentation of waterways and can cause localised increases in turbidity.

Cumulative Impacts

Cumulative impacts of the Project with nearby operational and proposed mining projects on water quality and altered flows in the Isaac River (due to loss of catchment area) were assessed in the Surface Water Assessment (WRM 2022):

- water will be managed in accordance with a water management system that is designed to operate in accordance with proposed EA conditions, within an existing and overarching strategic framework for management of cumulative impacts of mining activities (i.e. Model Water Conditions for Mines in the Fitzroy Basin and the EPP(Water) for the Fitzroy Basin); and
- changes in flows in the Isaac River due to loss of catchment area from the multiple mining operations would be undetectable.

Introduction of Aquatic Weeds to Waterways

Vehicles and machinery can be vectors of dispersal for aquatic biosecurity matters such as listed aquatic weeds. Aquatic weeds can reduce the habitat quality of waterways for native fish, and dense growth of aquatic weeds can cause a barrier to fish passage. The spread of aquatic weeds (e.g. through vehicle movements) listed under the Queensland *Biosecurity Act 2014*, is a contravention of this legislation.

Disturbance to Endangered Riparian Vegetation Types

RE 11.4.9 is an endangered wetland vegetation type, with a small patch of this vegetation type in riparian zones of the headwaters of Plumtree Creek, noting non-riparian areas of this vegetation type are assessed in the Terrestrial Ecology Assessment (METServe 2022). The patch of RE 11.4.9 in riparian zones of the headwaters of Plumtree Creek is outside the proposed disturbance footprint and the Project MLA; thus, is highly unlikely to be adversely impacted by the Project.

6.2 Risk-based Impact Assessment

The risk assessment determined the level of risk as an outcome of the consequence and likelihood of the potential impact (Table 6.1 to Table 6.3). The 5 x 3 risk matrix (Table 6.3) gives risk scores ranging between one and 15, with risk being:

- low, when the score is <5
- medium, when the score is >5 but <10, and
- high, when the score is >10.

Table 6.1 Ratings used to assess the likelihood of potential impacts.

Rating	Likelihood of occurrence
Very high (5)	Almost certain to occur frequently
High (4)	Probably would happen sometimes to frequently
Moderate (3)	Could happen sometimes
Low (2)	Remote possibility of occurring or not expected to occur
Very low (1)	Would not happen at all

Table 6.2 Ratings used to assess the consequence of potential impacts.

Rating	Consequence of potential impacts
High	Catastrophic, irreversible, or critical long-term environmental harm or loss; significant harm or loss of sensitive components of the environment; significant harm or loss of protected components of the environment, such as protected wetlands or MNES.
Moderate	Significant short-term but reversible harm of the environment; minor environmental harm to sensitive or protected components of the environment, such as protected wetlands or MNES.
Low	Unfavourable impact with no material harm to the environment and no impact on sensitive or protected components of the environment.

Table 6.3 Environmental risk matrix.

		Likelihood				
		Very Low (1)	**Low (2)**	**Moderate (3)**	**High (4)**	**Very High (5)**
Consequence	**Low (1)**	1	2	3	4	5
	Moderate (2)	2	4	6	8	10
	High (3)	3	6	9	12	15

Table 6.4 Risk-based Impact Assessment.

Source of Potential Impact	Mitigations	Consequence of Impact	Likelihood of Impact	Mitigated Risk to Aquatic Ecosystem EV
Release of mine-affected water	The mine water dams will be designed to manage the risk of failure The mine water dams, and other water management systems will be built above the Q1000 flood level The Project is outside the probable maximum flood level A Receiving Environment Monitoring Program will be implemented for the operational stage of the Project	Moderate (2) Waterways of the Project Area do not have sensitive in-stream environmental receptors The small area of RE 11.4.9 in the riparian zones of headwaters of Plumtree Creek is not a sensitive environmental receptor to in-stream disturbances Non-permanent, reversible harm	Low (2) Not expected to occur given the mitigations	Low (2 x 2 = 4)
Localised sedimentation of waterways associated with runoff from mining areas during and after mining	An Erosion and Sediment Control Plan (ESCP) will be prepared and implemented Runoff from unrehabilitated overburden dumps will be directed to sediment control dams, in accordance with the ESCP. Progressive rehabilitation of mined areas	Low (1) Waterways of the Project Area do not have sensitive in-stream environmental receptors The small area of RE 11.4.9 in the riparian zones of headwaters of Plumtree Creek is not a sensitive environmental receptor to in-stream disturbances Unfavourable impact with no material harm to the environment	Low (2) Not expected to occur given mitigations	Low (1 x 2 = 2)

Source of Potential Impact	Mitigations	Consequence of Impact	Likelihood of Impact	Mitigated Risk to Aquatic Ecosystem EV
Localised increases in turbidity and suspended solids in surface water associated with runoff from mine areas during and after mining	An Erosion and Sediment Control Plan (ESCP) will be prepared and implemented Runoff from unrehabilitated overburden dumps will be directed to sediment control dams, in accordance with the ESCP. Progressive rehabilitation of mined areas	Low (1) Waterways of the Project Area do not have sensitive in-stream environmental receptors The small area of RE 11.4.9 in the riparian zones of headwaters of Plumtree Creek is not a sensitive environmental receptor to in-stream disturbances Unfavourable impact with no material harm to the environment	Low (2) Not expected to occur given mitigations	Low (1 x 2 = 2)
Localised contamination of waterways from spills of hydrocarbons and chemicals from vehicles and machinery	All applicable materials will be stored and handled in accordance with the relevant legislative requirements and Australian Standards, including but not limited to the provisions of: AS 3780:2008 – The storage and handling of corrosive substances AS 1940:2004 – The storage and handling of flammable and combustible liquids AS 3833:2007 – Storage and handling of mixed classes of dangerous goods in packaged and intermediate bulk containers AS 2187.1:1998 – The storage, transport, and use of explosives Refuelling will be in designated bunded areas away from waterways Spill response procedure will be developed	Moderate (2) Waterways of the Project Area do not have sensitive in-stream environmental receptors The small area of RE 11.4.9 in the riparian zones of headwaters of Plumtree Creek is not a sensitive environmental receptor to in-stream disturbances disturbance Non-permanent, reversible harm	Low (2) Not expected to occur given mitigations	Low (2 x 2 = 4)
Waterway crossings	Road crossings of waterways, especially Hughes Creek and Boomerang Creek, will be in accordance with the accepted development requirements for waterway barrier works (DAF 2018) to minimise impacts to fish passage. Other road crossings and pipeline crossings will consider the accepted development requirements for waterway barrier works (DAF 2018) to minimise impacts to fish passage Works within a waterway will be conducted in the following order of preference: 1. conducting works when no water is present 2. conducting works in times of no flow 3. conducting works in times of flow but in a way that does not negatively impact the flow of water within the waterway	Moderate (2) Several of the waterways that will be directly crossed have moderate ecological values are likely important corridors for fish passage in some wet seasons Unfavourable impact with no material harm to the environment	Low (2) Not expected to occur given mitigations	Low (2 x 2 = 4)

Source of Potential Impact	Mitigations	Consequence of Impact	Likelihood of Impact	Mitigated Risk to Aquatic Ecosystem EV
Cumulative impacts	Water will be managed in accordance with a water management system that is designed to operate in accordance with proposed EA conditions, within an existing and overarching strategic framework for management of cumulative impacts of mining activities (i.e. Model Water Conditions for Mines in the Fitzroy Basin and the EPP(Water) for the Fitzroy Basin). Changes in flows in the Isaac River due to loss of catchment area from the multiple mining operations would be undetectable.	Moderate (2) Waterways of the Project Area have low to moderate ecological values Non-permanent, reversible harm	Low (2) Not expected to occur given mitigations	Low (2 x 2 = 4)
Introduction of aquatic weeds to waterways via contaminated machinery and vehicles	All vehicles requiring access to private land adjacent to Vulcan South Project operational areas must have a valid biosecurity hygiene declaration Weed monitoring and response protocols will be developed	Moderate (2) Waterways of the Project Area have low to moderate ecological values Non-permanent, reversible harm	Low (2) Not expected to occur given mitigations	Low (2 x 2 = 4)
Disturbance to endangered riparian vegetation types	The patch of RE 11.4.9 in riparian zones of the headwaters of Plumtree Creek is outside the proposed disturbance footprint; thus, is highly unlikely to be adversely impacted by the Project. Disturbance exclusion zones will be established around this patch of vegetation	Low (1) The patch of RE 11.4.9 in riparian zones of the headwaters of Plumtree Creek is outside the proposed disturbance footprint	Low (2) Not expected to occur given mitigations	Low (1 x 2 = 2)

6.3 Assessment of Potential Impacts to aquatic MNES species

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

- lead to a long-term decrease in the size of a population (important population for vulnerable species)
- reduce the area of occupancy of the species (important population of a vulnerable species)
- fragment an existing population (important population of a vulnerable species) into two or more populations
- adversely affect habitat critical to the survival of a species
- disrupt the breeding cycle of a population (important population of a vulnerable species)
- modify, destroy, remove, isolate, or decrease the availability or quality of habitat to the extent that the species is likely to decline
- result in invasive species that are harmful to a critically endangered, endangered, or vulnerable species becoming established in the endangered, critically endangered or vulnerable species' habitat
- introduce disease that may cause the species to decline, and / or
- interfere with the recovery of the species.

The two aquatic MNES species known from the broader Fitzroy River Basin are highly unlikely to occur in waterways of the Broader Study Area or the Project Area, with the nearest suitable habitat for both species (i.e. white throated snapping turtle and Fitzroy River turtle) some 115 km downstream from the Project Area.

Thus, populations of these MNES species are sufficiently displaced from the Project area to have no risk of direct or indirect impact from the Project. The mitigations described above further reduce any risk of indirect impacts.

7 Conclusions

The assessment of aquatic ecological value using the AquaBAMM criteria showed:

- low to moderate aquatic and catchment naturalness
- low diversity of common aquatic species (with no threatened or priority aquatic species)
- no threatened, priority or special habitat or geomorphic features present
- limited and temporary hydrological connectivity, and
- an absence of unique or representative aquatic ecosystems.

The assessment of aquatic ecological value based on regulatory instruments indicated that the:

- headwaters of Plumtree Creek have high aquatic ecological due to the presence of endangered wetland RE 11.4.9 in riparian areas
- mainstems of Hughes, Boomerang and Barrett Creeks have moderate aquatic ecological value because these waterways provide suitable habitat for common species of turtle, fish, and macroinvertebrate in some wet seasons, are possibly important corridors for fish passage in some wet seasons, and have of-concern wetland RE 11.3.2 and RE 11.3.25 in their riparian zones
- other waterways of the specific Project area have potentially moderate aquatic ecological value because these waterways possibly provide suitable habitat for common species of turtle, fish and macroinvertebrate in some wet seasons, but are unlikely to provide important corridors for fish passage because hydrological connectivity is very limited (several days a year, with no hydrological connectivity on some years) and these systems do not contain or link key breeding, foraging or refugial habitat for fish.

Threatened aquatic fauna are highly unlikely to occur, there are no HEV waters, declared fish habitat areas, or category B or C regulated vegetation classes in the riparian zone.

No sensitive aquatic environmental receptors are likely to occur in waterways in the Project area.

The following potential sources of impact on aquatic ecological values associated with the Project were identified:

- discharge of mine-affected water to waterways
- localised sedimentation of waterways
- localised increases in turbidity and total suspended solids
- localised contamination of waterways
- waterway crossings
- cumulative impacts with other nearby mining projects
- introduction of aquatic weeds to waterways, and
- disturbance of endangered riparian vegetation types.

All sources of impact were assessed as having a low risk of adverse impact to aquatic ecological values.

The two aquatic MNES species known from the broader Fitzroy River Basin are highly unlikely to occur in waterways of the Broader Study Area or the Project Area, with the nearest suitable habitat for both species (i.e. white throated snapping turtle and Fitzroy River turtle) some 115 km downstream from the Project Area. Thus, populations of these MNES species are sufficiently displaced from the Project Area to have no risk of direct or indirect impact from the Project.

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Appendix A MNES Search Results

Appendix B White-throated snapping turtle (*Elseya albagula*)

Description

The white-throated snapping turtle (*Elseya albagula*) is one of the largest short-necked freshwater turtles in Australia. Adults of this species are large and heavily built. Females are larger than males, but males have a longer tail length than females (Hamann et al. 2007; Limpus et al. 2007). Straight carapace length for adult males ranges from 15.6 – 29.2 cm, while the average carapace length for adult females ranges from 26.1 – 40.1 cm (Limpus et al. 2007). The size of white-throated snapping turtles also varies between geographic locations; however, the cause of this variation is unknown (Hamann et al. 2007; Limpus et al. 2007). Female white-throated snapping turtles are distinguished from similar species by irregular white or cream markings on the face, and the shell margin is strongly serrated on juveniles (Threatened Species Scientific Committee 2014).

Status Under Commonwealth and State Legislation

The white-throated snapping turtle is listed as critically endangered under the EPBC Act and endangered under the NC Act.

Distribution

The white-throated snapping turtle is restricted to the Fitzroy, Mary and Burnett river catchments in Queensland (Threatened Species Scientific Committee 2014). The species has also been recorded in:

- small coastal river adjacent basins, including the Kolan and Gregory-Burrum systems (Hamann et al. 2007)
- impoundments upstream of weirs such as Eden Bann Weir and Glebe Weir (Limpus et al. 2007), and
- the spring-fed pools of the Dawson River (frc environmental 2008; Hamann et al. 2007).

There has been a severe decrease in the abundance of immature white-throated snapping turtles in wild populations throughout the Fitzroy, Mary, and Burnett River catchments (Hamann et al. 2007; Limpus 2008; Limpus et al. 2011). The wild population is composed primarily of aging adults in each catchment, and there has been a substantial failure to recruit new adults into the breeding populations due to nest predation by a range of exotic and native predators, with only:

- 0.5% of adults being new recruits to the breeding population in the Fitzroy River catchment (211 adult females examined)
- 0.9% of adults being new recruits to the breeding population in the Burnett River catchment (an additional 0.9% of the adults were identified to their 2nd breeding season; 331 adult females examined), and
- 1.1% of adults being new recruits to the breeding population in the Mary River catchment (175 adult females examined) (Threatened Species Scientific Committee 2014).

Genetic studies indicate some distinction between the population of white-throated snapping turtles in the Fitzroy River catchment and populations in the Mary and Burnett River catchments. This indicates these populations have been separated for a long time and could be considered Evolutionary Significant Units (Threatened Species Scientific Committee 2014; Todd et al. 2013).

Habitat

White-throated snapping turtles are habitat specialists that prefer permanent, clear, well oxygenated water that is flowing and contains shelter (e.g. large woody debris and undercut banks) (EHP 2011; Todd et al. 2013). The species has also been recorded in non-flowing waters, such as impoundments, but only in low numbers (Threatened Species Scientific Committee 2014). Within the greater Fitzroy, Burnett and Mary river catchments, this species has been recorded almost exclusively in close association with permanent flowing stream reaches that are typically characterised by a sand-gravel substrate with submerged rock crevices, undercut banks and / or submerged logs and fallen trees (Hamann et al. 2007). Capture records suggest that white-throated snapping turtles are rarely found in reaches without such refuge (Hamann et al. 2007; Limpus et al. 2007). Across its distribution, individuals have been recorded from both shallow flowing pools and deeper slow flowing pools (Hamann et al. 2007).

White-throated snapping turtles are rarely present in water bodies that are isolated from flowing streams, such as farm dams or sewage treatment plants, suggesting that the species does not move extended distances over dry land (Hamann et al. 2007). However, white-throated snapping turtles have been observed walking short distances from drying waterholes to nearby water bodies (Limpus et al. 2007).

Ecology

The life history of white-throated snapping turtles is characterised by a long life span and slow growth to maturity (Threatened Species Scientific Committee 2014). The age at first breeding is approximately 15 to 20 years (Limpus et al. 2011). Breeding occurs once per year, mostly during autumn and winter, with adult females breeding in each successive year unless the turtle has been injured or debilitated, or riverine habitat has been altered (e.g. water extraction, drought or weeds) (EHP 2011; Threatened Species Scientific Committee 2014). Females generally nest on sandy banks, although nests have been observed on loose gravels and soils. Females lay a single clutch of eggs during the breeding season, with an average of 14 eggs per clutch (Hamann et al. 2007; Limpus et al. 2011). Nests are generally laid in areas of low canopy cover and in areas of dense grass cover; however, dense weeds at the water's edge may limit suitability of potential nesting banks (Hamann et al. 2007; Limpus et al. 2011). Nests are an average of 16.6 m from the water's edge, with eggs laid in deep chambers (greater than 20 cm in depth) and on banks with a slope of up to 26.5º (Hamann et al. 2007; Limpus et al. 2011). However, nests have been recorded up to 60 m from the water (Hamann et al. 2007). White-throated snapping turtles will repeatedly use specific areas of banks over multiple years (Limpus et al. 2007).

There is no parental care, and egg and small juvenile survival is typically low (Hamann et al. 2007; Heppell et al. 1996). There is abundant evidence of nesting in all three river basins (i.e. Fitzroy, Burnett and Mary River Basins), but most eggs are lost to predation or trampling by stock (Hamann et al. 2007; Limpus et al. 2011). The population growth or decline rate is highly responsive to changes in adult survivorship, rather than changes in egg or juvenile survivorship (Heppell et al. 1996). Nonetheless, where egg predation rates are high, population growth rate will be constrained.

White-throated snapping turtles feed primarily on aquatic plants along with fruits and leaves from overhanging riparian vegetation (Limpus et al. 2007). They may also eat periphyton, freshwater bivalves and insects, particularly when plant food resources are limited (Limpus et al. 2007).

Little is known of the movement patterns of these turtles in the greater Fitzroy River catchment. However, in the Burnett River they generally have small home ranges of less than 500 m and have limited spatial and temporal movements (Hamann et al. 2007).

Threats

The principal threat to white-throated snapping turtles in all three catchments is the excessive loss of eggs and hatchlings due to predation (Threatened Species Scientific Committee 2014). Primary predators include feral (e.g. foxes, dogs, pigs, and cats) and native (e.g. water rats and lizards) animals. Trampling of nests by cattle is also a major threat.

An additional threat to this species includes limited suitable habitat, which is highly fragmented across its distribution range due to dams and weirs. Waterway impoundments, such as dams, barrages, and weirs, also form significant barriers to the passage of freshwater turtles. The number of dead and injured turtles can be much greater in pools immediately downstream of weirs than in pools distant from weirs, presumably a result of turtles being swept downstream and over impoundments during major and sudden water releases (Hamann et al. 2007).

Other threats to this species are:

- stocking of fish into dam impoundments for recreational fishing
- recreational fishing resulting in hook injuries
- boat strike
- loss of nesting habitat to weed infestation in the riparian zone
- dense aquatic weeds in the waterways, and
- water extraction for agriculture and irrigation (Limpus et al. 2011).

Recovery Actions

Protection of nests and hatchlings is the key recovery action needed for this species, with water supply infrastructure operations needed to protect some specific nesting locations (DotEE 2017). Other generic recovery actions are presented in the Recovery Plan (DotEE 2017).

Occurrence In and Surrounding the Project area

See Section 5.1 of report.

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Appendix C Fitzroy River turtle (*Rheodytes leukops*)

Description

Fitzroy River turtles (*Rheodytes leukops*) are distinguished by a white inner ring around the eye, a pale yellow or cream belly, and large, pointed conical tubercles on their shell and neck (Threatened Species Scientific Committee 2008). While few studies have specifically examined the size distribution of this turtle across its range, there are significant differences in the size of adults from populations at different locations (Limpus et al. 2007). These differences were attributed to independent factors (for example, environmental differences between locations) and indicate that Fitzroy River turtle populations are not uniform across the greater Fitzroy River Basin (Limpus et al. 2007).

Adult male Fitzroy River turtles have slightly longer tail length than adult females (Limpus et al. 2007). Carapace length alone is not a reliable indication of sex, as there is considerable overlap in the size ranges of adult males and females; however, when used in conjunction with tail length (beyond the carapace), adults can be assigned to a sex with relative certainty (Limpus et al. 2007). In general, adult males have an approximate straight carapace length range of 20–26 cm, while adult females have an approximate range of 20–28 cm (Limpus et al. 2007).

Status Under Commonwealth and State Legislation

The Fitzroy River turtle is listed as vulnerable under the EPBC Act and vulnerable under the NC Act.

Distribution

The Fitzroy River turtle is restricted to the Fitzroy River Basin (Threatened Species Scientific Committee 2008). The species occurs in permanent freshwater rivers from the Fitzroy Barrage to Theodore Weir and Duck Ponds, upstream of the Comet-Mackenzie River confluence, as well as through Marlborough Creek (Limpus et al. 2007). It has also been found in isolated permanent waterholes on the Connors River (frc environmental 2010; Limpus et al. 2007). The species is not known to inhabit small farm dams or ephemeral waterways (Limpus et al. 2007).

Habitat

Fitzroy River turtles occur in flowing rivers with large deep pools with rocky, gravelly, or sandy substrates connected by shallow riffle areas (Cogger et al. 1993; Threatened Species Scientific Committee 2008; Tucker et al. 2001). Riffle zones are an important habitat for the Fitzroy River turtle, with the home ranges of individuals typically overlapping these habitats (Tucker et al. 2001), possibly due to increased foraging success in these habitats (Legler & Cann 1980) or a greater efficiency of respiration in highly oxygenated waters (Franklin 2000; Gordos et al. 2004; Priest 1997). However, under low-flow conditions, or as riffle zones become seasonally ephemeral, the Fitzroy River turtle retreats to deeper pool habitat, or even isolated waterholes, next to riffle zones (Limpus et al. 2007; Tucker et al. 2001).

Riffle zones are likely to be ephemeral throughout most of the range of the Fitzroy River turtle, therefore this species should not be considered a riffle zone specialist (Limpus et al. 2007). Using riffle habitat to forage for abundant food sources such as benthic invertebrates and algae during the wet season and early dry season allows the turtles to take up nutrients and build fat reserves for the dry season, which is essential when preparing to breed (Limpus et al. 2007). Fitzroy River turtles captured from riffle zones tend to be larger than those found in pools and this may be an indicator of better health or condition of turtles in riffle zones, potentially reflecting greater feeding opportunities in riffles (M. Gordos, Conservation Manager, NSW DPI pers. com. July 2007). Therefore, while large, slow-flowing pools can support populations of Fitzroy River turtles these pools are likely to have a lower carrying capacity than reaches containing riffle habitat (Limpus et al. 2007).

Ecology

The age at first breeding for Fitzroy River turtles is approximately 15 to 20 years (Limpus et al. 2011). Females can lay multiple clutches of eggs each year between September and November, averaging 60 to 70 eggs per clutch (EHP 2011; GHD 2015). Female Fitzroy River turtles nest on sandy or loam banks that are free from extensive weeds, and which form during floods (Limpus et al. 2007). Nests are an average of 5.6 m back from the water's edge, with some observed up to 15 m away (Cann 1998; Cogger et al. 1993; Limpus et al. 2007). Eggs are typically laid in deep chambers, with an average depth of 14.7 cm to the top egg and 20.7 cm to the bottom of the nest (Limpus et al. 2007). Nesting success is negatively influenced by habitat degradation and poor health of individuals (Limpus et al. 2007).

Home ranges vary widely among individuals, however, on average, Fitzroy River turtles appear to have a local mean range of 562 m (Tucker et al. 2001). Individual turtles can have long sedentary periods, ranging from 3 to 24 hours. When active, movement is up to 20 m per day on average, with a range of 0 to 350 m per day (Tucker et al. 2001).

Under low flow events, or as riffle zones became seasonally ephemeral, or dry completely, female Fitzroy River turtles retreat to deeper sections of pool habitats adjacent to riffle zones (Tucker et al. 2001). No seasonal movement patterns have been observed for this species. It has been reported that the current population of Fitzroy River turtles is likely to consist entirely of adults, with no recruitment of juveniles (Norris & Low 2005; Threatened Species Scientific Committee 2008)

Threats

The main threat to Fitzroy River turtle populations is the loss and disturbance of habitat from agriculture, mining, damming of rivers and pollution of habitats (Cogger et al. 1993). Dams and weirs within the Fitzroy River catchment also pose a threat to the preferred habitat of this species as they form large impoundments and reduce the natural condition of riffles throughout the year (Tucker et al. 2001).

Waterway impoundments, such as dams, barrages, and weirs, also form significant barriers to the passage of freshwater turtles. The number of dead and injured turtles can be much greater in pools immediately downstream of weirs than in pools distant from weirs, presumably a result of turtles being swept downstream and over impoundments during major and sudden water releases (Hamann et al. 2007).

Predation of eggs by feral (e.g. foxes, dogs, pigs and cats) and native (e.g. water rats and lizards) animals (Threatened Species Scientific Committee 2008) is also a significant threat.

Recovery Actions

There is currently no recovery plan for the Fitzroy River turtle; however, recovery actions identified by the Commonwealth and State agencies include:

- feral animal and weed control through eradication or control plans
- habitat improvement by managing grazing and by managing waterways
- habitat protection through:
  - stock management in riparian areas
  - riparian rehabilitation projects

  - maintenance and protection of nesting banks
  - maintenance of stream flow and connectivity between impoundments, and
  - improving water quality in the lower Fitzroy River catchment
- improving recruitment of hatchlings, and
- encouraging boat owners to look out for and avoid turtles.

Occurrence In and Surrounding the Project area

See Section 5.1 of report.

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Appendix D Site Habitat Sheets

Site HC1

Surveyed 11/04/2019

Habitat Score [a] P

Downstream in 2019

Upstream in 2019

Left bank in 2019

Right bank in 2019

Channel Morphology

Stream order	3
Pattern	mildly sinuous
Flow Regime	ephemeral
Channel Width	15 m
Water Level	no flow – isolated pool
Wetted Width	1.2 m
Water Depth	0.3 m
Flow	no flow
Bank Stability	moderate
Bank Shape	steep-moderate convex, undercut in one area

Substrate

Composition	bedrock	0%
	boulder	0%
	cobble	0%
	pebble	0%
	gravel	5%
	sand	80%
	silt / clay	15%
Deposits	sand	silt
Bed Stability	moderate aggradation	

Aquatic Habitat

Aquatic Plants	present
Dominant Species	Cyperus sp.
Habitat Diversity	poor
Habitat Present	shallow pool
	leaves

Riparian Zone

Riparian Width	10-15 m
Land Use	grazing
Disturbance	high
Dominant Species	native
Species Present	grasses, *Eucalypt*
Weed Species	*grasses, Ageratum houstonianum, Bidens pilosa, Xanthium occidentale, Parthenium hysterophorus*

Comments: One isolated pool in a deep corner of the channel. Blanketing silt present in this area and for 10m downstream, the bed is otherwise sandy. Small and large woody debris built up around tree trunks from high flows. The banks are around 5m high, moderately steep and covered with grasses, shrubs and trees. Water mildly turbid.

Site	HC2		
Surveyed	10/04/2019	**Habitat Score** [a]	P

Downstream in 2019

Upstream in 2019

Left bank in 2019

Right bank in 2019

Channel Morphology		**Substrate**			**Aquatic Habitat**		**Riparian Zone**	
Stream order	3	**Composition**	bedrock	0%	**Aquatic Plants**	present	**Riparian Width**	10-15 m
Pattern	regular meanders		boulder	0%	**Dominant Species**	Cyperus sp.	**Land Use**	grazing
Flow Regime	ephemeral		cobble	0%	**Habitat Diversity**	poor	**Disturbance**	high
Channel Width	10 m		pebble	0%	**Habitat Present**	shallow pool	**Dominant Species**	native
Water Level	no flow – isolated pool		gravel	5%		tree roots	**Species Present**	grasses, *Eucalypt, Parthenium hysterophorus*
Wetted Width	0.5 m		sand	80%		leaves and twigs	**Weed Species**	grasses
Water Depth	0.2 m		silt / clay	15%				
Flow	no flow	**Deposits**	sand	silt				
Bank Stability	low	**Bed Stability**	moderate aggradation					
Bank Shape	Vertical - steep convex, concave and undercut							

Comments: One very small, isolated pool at site. Blanketing silt, large and small woody debris present in vicinity of pool. The rest of the site has a flat sandy bed. 75% of the bank is eroded and vertical, with roots hanging through. Above these areas banks are covered in grasses and trees. Creek is in a valley with steep banks.

Site	HC3		
Surveyed	12/04/2019	**Habitat Score** [a]	P

Downstream in 2019

Upstream in 2019

Left bank in 2019

Right bank in 2019

Channel Morphology

Stream order	4
Pattern	irregular meanders
Flow Regime	ephemeral
Channel Width	9 m
Water Level	no-flow isolated pool
Wetted Width	1.5 m
Water Depth	0.4 m
Flow	no-flow
Bank Stability	moderate
Bank Shape	Vertical to moderate - concave, convex and stepped

Substrate

Composition	bedrock	0%
	boulder	3%
	cobble	0%
	pebble	0%
	gravel	0%
	sand	90%
	silt / clay	7%
Deposits	sand	silt
Bed Stability	moderate aggradation	

Aquatic Habitat

Aquatic Plants	present
Dominant Species	Juncus sp. and Cyperus sp.
Habitat Diversity	poor
Habitat Present	shallow pool
	woody debris
	leaves and twigs

Riparian Zone

Riparian Width	10-15 m
Land Use	road/rail/grazing
Disturbance	very high
Dominant Species	exotic
Species Present	grasses, Eucalypt, Melaleuca
Weed Species	grasses, *Parthenium hysterophorus* *Ageratum houstonianum*, *Bidens pilosa*

Comments: Small, isolated pool under highway. The water was stagnant with a film on the surface and a strong odour. Most of the bed was sandy, and still wet. There was a red and black film on the sand in areas. The banks were moderately steep and densely vegetated. There was a build-up of large and small woody debris on the upstream side of the bridge. The banks were eroded under the highway.

Site BC1

Surveyed 10/04/2019

Habitat Score [a] **P**

Downstream in 2019

Upstream in 2019

Left bank in 2019

Right bank in 2019

Channel Morphology

Stream order	3
Pattern	mildly sinuous
Flow Regime	ephemeral
Channel Width	15 m
Water Level	no flow – isolated pool
Wetted Width	2 m
Water Depth	0.4 m
Flow	no flow
Bank Stability	high
Bank Shape	moderate convex

Substrate

Composition	bedrock	0%
	boulder	0%
	cobble	0%
	pebble	2%
	gravel	5%
	sand	88%
	silt / clay	5%
Deposits	sand	
Bed Stability	moderate aggradation	

Aquatic Habitat

Aquatic Plants	present
Dominant Species	Cyperus polystachyos
Habitat Diversity	moderate
Habitat Present	shallow pool
	macrophytes
	man-made structures
	small woody debris

Riparian Zone

Riparian Width	5 m
Land Use	road/rail/grazing
Disturbance	very high
Dominant Species	exotic
Species Present	Grasses, Melaleuca
Weed Species	grasses, *Ageratum houstonianum*

Comments: Small, isolated pools under rail bridge and highway. Some instream aquatic plants. Extensive grasses and some aquatic plants on banks. Substrate mostly sand with some gravel, blanketing silt in places. Iron staining and black deposits throughout creek. Bed still very damp. Large woody debris caught on bridges from high flow.

Site	OMC1		
Surveyed	10/04/2019	**Habitat Score [a]**	M

Downstream in 2019

Upstream in 2019

Left bank in 2019

Right bank in 2019

Channel Morphology		Substrate			Aquatic Habitat		Riparian Zone	
Stream Order	2	**Composition**	bedrock	0%	**Aquatic Plants**	present	**Riparian Width**	15 m
Pattern	straight		boulder	0%	**Dominant Species**	Cyperus polystachyos	**Land Use**	road/rail/native forest
Flow Regime	ephemeral		cobble	0%	**Habitat Diversity**	moderate	**Disturbance**	very high
Channel Width	6 m		pebble	0%	**Habitat Present**	shallow pool	**Dominant Species**	exotic
Water Level	no flow – isolated pool		gravel	0%		woody debris	**Species Present**	grasses
Wetted Width	4 m		sand	70%		man-made structures	**Weed Species**	grasses, *Ageratum houstonianum*
Water Depth	1 m		silt / clay	30%				
Flow	no flow	**Deposits**	silt					
Bank Stability	moderate	**Bed Stability**	moderate aggradation					
Bank Shape	low to steep, concave and convex							

Comments: Two isolated pools at site, a shallow pool under the rail and a deeper pool under the road bridge. Water turbid. Creek is noticeably narrower either side of the road and rail bridges. Banks dense with weeds and scattered trees. Native aquatic plants present.

a habitat score is based on the habitat bioassessment score for each site (P – poor, M – moderate, G – good, E – excellent)