FINAL REPORT

Worsley Alumina Refinery

Carter's Freshwater Mussel Annual Monitoring Program, 2024

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Revision Schedule

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Executive Summary

South32 Worsley Alumina Pty Ltd (Worsley Alumina) currently operates the Boddington Bauxite Mine (BBM), Worsley Refinery (the Refinery), and port operations at the Bunbury Port. Worsley Alumina is expanding their existing operations at the BBM and the Refinery, collectively referred to as the Worsley Mine Expansion (WME). The WME comprises three development envelopes: the Worsley Mine Development Envelope (WMDE), the Bauxite Transport Corridor (BTC), and the Contingency Bauxite Mining Envelope (CBME), with the latter located at the Refinery, approximately 15 km northwest of the town of Collie. An artificial freshwater lake (referred to as Freshwater Lake) is situated at the Refinery and supplies raw water for operations. The Refinery and Freshwater Lake are located at the headwater of the Augustus River.

Carter's Freshwater Mussel, *Westralunio carteri* Iredale, 1934, is one of three freshwater mussel taxa endemic to the southwest of Western Australia and is listed under the Western Australian *Biodiversity Conservation Act 2016* (BC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as Vulnerable. The species has declined by more than 40% in extent of occurrence (EOO) within the last 50 years. Relevant to Worsley Alumina operations, Freshwater Lake, the Augustus River and other perennial freshwater rivers and lakes within the region are known to support populations of Carter's Freshwater Mussel. In 2021, Worsley Alumina funded a baseline survey within Freshwater Lake and the Augustus River to document the extent of Carter's Freshwater Mussel relative to Refinery operations, as well as a regional survey of the Hotham River, Williams River and Murray River. In addition, Worsley Alumina funded the preparation of the Carter's Freshwater Mussel Management Plan and Monitoring Program (CFMMPMP) to provide guidance on managing potential impacts to Carter's Freshwater Mussel populations within Freshwater Lake and the Augustus River, associated with the proposed WME. This report provides the results of the 2024 Carter's Freshwater Mussel annual monitoring program (2024 monitoring program) which aims to monitor Carter's Freshwater Mussel in Freshwater Lake and the Augustus River with regional context inferred from the Brunswick River, Ernest River and Lunenburgh River Dam.

The objective of the 2024 monitoring program (hereafter, "2024 survey") was to monitor Carter's Freshwater Mussel populations and their habitat conditions at Freshwater Lake and along the Augustus River, within and immediately adjacent to the CBME, to detect potential adverse impacts from the South32 WME, in comparison to historical data and regional reference sites. The following tasks were undertaken to meet the objective:

- Collection of water and sediment samples from Freshwater Lake, the Augustus River and regional reference sites for:
  - chemical analysis, comparing results to baseline data and available guidance; and
  - for future development of site-specific guideline values (SSGVs) to complement the Carter's Freshwater Mussel annual monitoring program.
- Verification of the population size of Carter's Freshwater Mussel in Freshwater Lake, including shallow and deep-water habitats.
- Assessment of the population density of Carter's Freshwater Mussel in Freshwater Lake and the Augustus River, targeting shallow and deep-water habitats.
- Reporting of the key findings in relation to the management objectives and environmental criteria defined in the CFMMPMP.

Water quality at Freshwater Lake, the Augustus River, and the regional reference sites during the 2024 Carter's Freshwater Mussel annual monitoring program was characterised by near neutral to slightly alkaline pH and low salinity and was well-oxygenated. The ANZECC & ARMCANZ (2000a) upper trigger value for electrical conductivity (120 µS/cm) in upland rivers was exceeded in the Augustus River sites during both November 2024 and February 2025. The ANZECC & ARMCANZ (2000a) lower trigger value for dissolved oxygen in upland rivers (<90%) was exceeded only in the Augustus River at Site AR2_21 in February 2025 with a dissolved oxygen measurement of 67.9%, but no other exceedances were observed across any other river or lake/dam sites. The ANZECC & ARMCANZ (2000a) upper trigger value for total phosphorus (0.02 mg/L) in upland rivers was marginally exceeded in November 2024 at the two Augustus River sites sampled (AR1_21 and AR2_21) with total phosphorus concentrations of 0.03 mg/L at both sites. No exceedances for Water Quality Australia (2021) DGVs were observed for ammonia or metals and metalloids in any of the sites sampled during the 2024 survey.

Despite the observed exceedances of ANZECC & ARMCANZ (2000a) for electrical conductivity, dissolved oxygen and total phosphorus, this does not appear to be limiting to Carter's Freshwater Mussel.

Sediment quality at Freshwater Lake, the Augustus River, and the regional reference sites during the 2024 Carter's Freshwater Mussel annual monitoring program was characterised as slightly acidic in the Augustus River and regional reference sites with pH ranging from 5.6 to 6.6 and near neutral, ranging from 6.4 to 7.0 at Freshwater Lake sites. Sediment salinity was low, ranging from 77 to 293 mg/kg across all sites sampled. The lack of surface water at sites within the Augustus River downstream from the v-notch weir at sites AR1_21 and AR3_21, sampled during February 2025, was also reflected in sediment moisture content, with moisture contents of 40.3% at AR1_21 and 5.6% at AR3_21. Similarly, sediment moisture content at Site AR1_21 (downstream from the v-notch weir) was drier at 26.6% than above the v-notch weir at site AR2_21 (above the v-notch weir) where sediment moisture content measured 73.8% in November 2024. The dryness and lack of surface water at the Brunswick River (RR10_99) and the Ernest River (RR02_99) was also reflected in sediment moisture content, which measured 5.5% and <1.0% in the Brunswick River (RR10_99) and the Ernest River (RR02_99) during February 2025. There were no exceedances in available Water Quality Australia (2021) DGVs for any of the other sediment quality parameters tested for at any of the 2024 survey sites.

Live and dead Carter's Freshwater Mussel individuals were observed in Freshwater Lake and the Augustus River, but unlike the 2023 monitoring program, none were found at Brunswick River (RR10_99), where they had been observed previously. The survey conditions in February 2025 were considerably drier than they had been during the 2023 monitoring program and in November 2023 and November 2024. The patterns emerging from the 2024 survey suggest that water and sediment quality is less of an issue to freshwater mussels in the monitoring areas than drying. Mortalities of freshwater mussels observed during the 2024 survey are most likely a result of drying, particularly given Site AR2_21 with water pooled upstream from the v-notch weir in Augustus River had a substantially lower freshwater mussel mortality rate than sites that had ceased to flow downstream from the weir. Freshwater mussel abundance and density also had a decreasing gradient with the distance from the v-notch weir in the Augustus River, with abundance and density being greater at AR1_21 than AR3_21, with the latter site being further downstream from the v-notch weir and much drier. Similarly, no freshwater mussels were found in the two regional reference sites at Brunswick River (RR10_99) and Ernest River (RR02_99) that were substantially drier than any of the other sites in February 2025.

In Freshwater Lake, Carter's Freshwater Mussel occupies a band of soft clayey sediment, which occurred at depths of between 1 and about 4 m during the 2024 survey. Drying events and lake level drawdown within Freshwater Lake have clearly resulted in the stranding of Carter's Freshwater Mussels, which has led to mortalities of the species, as evidenced from empty and bleached shells that have baked dry in the summer sun and heat. Nevertheless, Freshwater Lake continues to support the species. Evidence of recruitment was apparent from the recording of small Carter's Freshwater Mussels <30 mm in length (possibly as young as 2-6 years old) in both Freshwater Lake and the Augustus River. Although age-at-length estimates of Carter's Freshwater Mussel individuals across the survey sites are not known, maximum shell lengths could represent individuals >20 years old. Additionally, the smaller sized freshwater mussels downstream from the v-notch weir suggests either that successive drying events have stunted growth, although age-at-length estimates for Carter's Freshwater Mussel individuals across survey sites could affirm that this is the case.

Following completion of the 2024 monitoring program, the following recommendations are provided for consideration by South32:

- Review the adequacy of current environmental flow regimes for maintaining Carter's Freshwater Mussel within Freshwater Lake and the Augustus River.
- Establish new regional reference sites in suitable waterways, preferably containing permanent surface water and a population of freshwater mussels confirmed to be actively recruiting.
- Estimate age-at-length on shells collected during the 2024 monitoring program to inform whether smaller sizes at dry sites represent stunting or actual age in comparison with sites upstream from the v-notch weir.
- Develop a mitigation strategy to reduce mortality in Freshwater Lake (e.g., mussel relocation as water recedes).
- Implement a tracking program to monitor survival more closely between years and ensure mortality is from the previous season and not earlier. This will better inform management and monitoring programs.

Table ES-1: Address of CFMMPMP outcome-based management provisions.

Outcome-based Management Objectives		Trigger Criteria	Trigger Criteria Exceeded?	Threshold Criteria	Threshold Criteria Exceeded?
IW1	**Minimise adverse impacts to CFM due to project-related land clearing surrounding Freshwater Lake or Augustus River.**	• Clearing occurs without an authorised internal permit within the CBME, but outside the 50 m buffer zone of Freshwater Lake.	• Not applicable to this scope of work	• Unauthorised clearing or disturbance within the 50 m buffer zone of Freshwater Lake.	• Not applicable to this scope of work
		• Clearing occurs without an authorised internal permit within the CBME, but outside the 200m buffer zone of Augustus River.	• Not applicable to this scope of work	• Unauthorised clearing or disturbance within the 200m buffer zone of Augustus River.	• Not applicable to this scope of work
IW2	**Avoid adverse impacts to Carter's Freshwater Mussel from decreased water levels below minimum caused by excessive water abstraction within Freshwater Lake.**	• Water levels recorded below 231 m AHD in Freshwater Lake.	• ✗ Trigger criteria exceeded within Freshwater Lake (<231 m AHD from 10 April 2024 to 29 May 2025)	• Water levels recorded below 225 m AHD for a period of three months in Freshwater Lake.	• Threshold criteria not exceeded within Freshwater Lake
IW3	**Avoid adverse impacts to Carter's Freshwater Mussel from changes in suspended solids due to Project-related sedimentation.**	• Isolated occurrence of overtopping of sediment trap(s) into Freshwater Lake.	• Not applicable to this scope of work	• Continued occurrence / or overtopping of multiple sediment trap(s) into Freshwater Lake.	• Not applicable to this scope of work
IW3	**Avoid adverse impacts to Carter's Freshwater Mussel from changes in suspended solids due to Project-related sedimentation.**	• Total Suspended Soilds: >8 mg/L in the surface water of Freshwater Lake and Augustus River in a single monitoring event.	• Not monitored during 2024	• Total Suspended Soilds: >15 mg/L in the surface water of Freshwater Lake and Augustus River in a single monitoring event.	• Not monitored during 2024
IW4	**Avoid adverse impacts to Carter's Freshwater Mussel from elevated mercury (Hg) levels in the surface water of Freshwater Lake or Augustus River and in the sediment of Freshwater Lake.**	• Dissolved Mercury: >0.00006 mg/L in the surface water of Freshwater Lake and Augustus River, in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or Augustus River	• Dissolved mercury: >0.0006 mg/L in the surface water of Freshwater Lake and Augustus River, in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or Augustus River
		• Total Mercury: 0.15 mg/kg in the sediment of Freshwater Lake and Augustus River, in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or Augustus River	• Total Mercury: 1.0 mg/kg in the sediment of Freshwater Lake and Augustus River, in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or Augustus River
IW5	**Avoid adverse impacts to Carter's Freshwater Mussel from elevated aluminium, cadmium, copper, lead, and zinc concentrations in the surface water of Freshwater Lake or Augustus River.**	• Dissolved Aluminium: >0.027 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or Augustus River	• Dissolved Aluminium: >0.055 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or Augustus River
		• Dissolved Cadmium: >0.00006 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or Augustus River	• Dissolved Cadmium: >0.0002 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or Augustus River
		• Dissolved Copper: >0.001 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or Augustus River	• Dissolved Copper: >0.0014 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or Augustus River
		• Dissolved Lead: >0.001 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or Augustus River	• Dissolved Lead: >0.034 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or Augustus River
		• Dissolved Zinc: >0.0024 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or Augustus River	• Dissolved Zinc: >0.008 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or Augustus River
IW6	**Minimise adverse impacts to Carter's Freshwater Mussel from salinisation of the surface water of Freshwater Lake and Augustus River.**	• Salinity >1.6 g/L in the surface water of Freshwater Lake and/or Augustus River in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or the Augustus River	• Salinity >3 g/L in the surface water of Freshwater Lake and/or Augustus River in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or the Augustus River
		• Individual mortality recorded of Carter's Freshwater Mussel at Freshwater Lake.	• ✗ Trigger criteria exceeded within Freshwater Lake with 37 dead Carter's Freshwater Mussel individuals recorded from deep-water sites	• 50% reduction in Carter's Freshwater Mussel known population size (individuals) in Freshwater Lake.	• ✗ Threshold criteria exceeded with mortality at 56.25%
		• Reduction in density (per square metre) of Carter's Freshwater Mussel by >20% recorded at Augustus River.	• Trigger criteria not exceeded within Augustus River	• 50% reduction in Carter's Freshwater Mussel known density (per square metre) in Augustus River.	• Trigger criteria not exceeded within Augustus River

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Abbreviations

Abbreviations	Full Name
AHD	Australian Height Datum
AR	Prefix for site codes referring to ‘Augustus River’
BBM	Boddington Bauxite Mine
BC Act	Western Australian *Biodiversity Conservation Act 2016*
BTC	Bauxite Transport Corridor
CBME	Contingency Bauxite Mining Envelope
DBCA	Department of Biodiversity, Conservation and Attractions (Government of Western Australia)
DPIRD	Department of Primary Industries and Regional Development (Government of Western Australia)
DWER	Department of Water and Environmental Regulation
EP Act	Western Australian *Environmental Protection Act 1986*
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
FWL	Prefix for site codes referring to Worsley ‘Freshwater Lake’
GL	gigalitre
H	Refers to shell height of individual mussels, measured from about the mid-point between the beak and the posterior end of a valve to the ventral edge
IBRA	Interim Biogeographic Regionalisation for Australia
L	Refers to shell length of individual mussels, measured from the anterior to posterior ends of a shell valve
LR	Prefix for site code referring to ‘Lunenburgh River’
RLA	Refinery Lease Area
RR	Prefix for site codes referring to ‘Regional River’
SSGV	Site-specific guideline value
SWL	Surface Water License
WMDE	Worsley Mining Development Envelope
WME	Worsley Mine Expansion

Glossary

Term	Definition
glochidia	The larval stage of freshwater mussels in the families Unionidae, Margaritiferidae and Hyriidae, that is usually parasitic on fish
taxa	Plural of taxon – a scientifically named rank of living organism such as species or subspecies
endemic	Native and restricted to a certain place
nacreous layer	In reference to Carter's Freshwater Mussel, the inner layer of the shell composed of nacre also known as mother-of-pearl; it is an organic–inorganic composite substance that is usually irredescent and smooth and is the same substance pearls are made of
periostracum	In reference to Carter's Freshwater Mussel, the brown proteinaceous horn-like layer covering the outside of the shell

1. Introduction

1.1 Background

South32 Worsley Alumina Pty Ltd (Worsley Alumina) currently operates the Boddington Bauxite Mine (BBM), Worsley Refinery (the Refinery), and port operations at the Bunbury Port. Worsley Alumina is expanding their existing operations at the BBM and the Refinery, collectively referred to as the Worsley Mine Expansion (WME). The WME comprises three development envelopes: the Worsley Mine Development Envelope (WMDE), the Bauxite Transport Corridor (BTC), and the Contingency Bauxite Mining Envelope (CBME), with the latter located at the Refinery, approximately 15 km northwest of the town of Collie and approximately 143 km south of Perth (**Figure 1-1**). The CBME is a key component of the WME, is approximately 747 hectares (ha) in size, and is located within the boundary of the Refinery Lease Area (RLA), situated approximately 65 km southwest of Boddington (**Figure 1-1**). An artificial freshwater lake (referred to as Freshwater Lake) is situated at the Refinery and supplies raw water for operations. The Refinery and Freshwater Lake are located at the headwater of the Augustus River, which continues downstream of Freshwater Lake.

Carter's Freshwater Mussel, *Westralunio carteri* Iredale, 1934, is one of three freshwater mussel taxa endemic to the southwest of Western Australia (Klunzinger *et al.* 2022). Like other freshwater mussel species, its larvae (glochidia) attach to fish for three to four weeks while undergoing a stage of metamorphosis (Klunzinger *et al.* 2012b). This phase of its life cycle is a dispersal mechanism. Carter's Freshwater Mussel is listed under the Western Australian *Biodiversity Conservation Act 2016* (BC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as Vulnerable. Carter's Freshwater Mussel occurs in westerly-flowing freshwater streams, rivers, lakes and some wetlands within permanent water from Gingin Brook in the Moore-Hill Rivers Basin, north of Perth, southward to the Blackwood River Basin to within 5 km to 150 km of the west coast of south-western Australia (Klunzinger *et al.* 2022). The species has declined by more than 40% in extent of occurrence (EOO) within the last 50 years (Klunzinger *et al.* 2015; Walker *et al.* 2014), which led to its listing as Vulnerable. Freshwater Lake, the Augustus River and other perennial freshwater rivers and lakes within the region are known to support populations of Carter's Freshwater Mussel (Hale *et al.* 2000; Stantec 2021; 2024; WRM 2005).

In 2021, Worsley Alumina funded a baseline survey within Freshwater Lake and the Augustus River to document the extent of Carter's Freshwater Mussel relative to Refinery operations (Stantec 2021), as well as a regional survey of the Hotham River, Williams River and Murray River (Stantec 2022) as part of the environmental approval assessment process for the proposed WME. In addition, Worsley Alumina funded the preparation of the Carter's Freshwater Mussel Management Plan and Monitoring Program (CFMMPMP) (Stantec 2023), to provide guidance on managing potential impacts to Carter's Freshwater Mussel populations within Freshwater Lake and the Augustus River, associated with the proposed WME. The first annual monitoring program was undertaken in 2023 to monitor Carter's Freshwater Mussel in Freshwater Lake and the Augustus River with regional context inferred from sites selected in the Brunswick River, Ernest River and Lunenburgh River Dam (Stantec 2024).

1.2 Legislative Context

Current Worsley Alumina operations are regulated by the Department of Water and Environmental Regulation (DWER) under Part V of the Western Australian *Environmental Protection Act 1986* (EP Act). The BBM EP Act licence was approved in 1983 and last amended in 2022 (L5960/1983/11) and the Refinery's EP Act licence was approved in 1981 and last amended in 2022 (L4504/1981/17). Worsley Alumina also holds a DWER Surface Water Licence (SWL6804(4)). Carter's Freshwater Mussel baseline surveys, the annual monitoring program, and the CFMMPMP were developed and implemented in alignment with the following legislation and guidance, as far as practicable:

- Western Australian *Biodiversity Conservation Act 2016*;
- Western Australian *Environmental Protection Act 1986*;
- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*;
- Environmental Factor Guideline – Inland Waters (EPA 2018);
- Environmental Factor Guideline – Terrestrial Fauna (EPA 2016);
- Environmental Management Plan Guidelines (DCCEEW 2024);

- Conservation Advice – *Westralunio carteri* Carter's freshwater mussel (TSSC 2018); and
- Field sampling guidelines: A guideline for field sampling for surface water quality monitoring programs (DoW 2009).

1.3 Objective and Scope

The objective of the 2024 Carter’s Freshwater Mussel annual monitoring program (2024 monitoring program) was to monitor Carter’s Freshwater Mussel populations and their habitat conditions at Freshwater Lake and along the Augustus River, within and immediately adjacent to the CBME, to detect potential adverse impacts from the South32 WME, in comparison to historical data and regional reference sites. The following tasks were undertaken to meet the objective:

- Collection of water and sediment samples from Freshwater Lake, the Augustus River and regional reference sites for:
  - chemical analysis, comparing results to baseline data and available guidance; and
  - for future development of site-specific guideline values (SSGVs) to complement the Carter’s Freshwater Mussel annual monitoring program.
- Verification of the population size of Carter’s Freshwater Mussel in Freshwater Lake, including shallow and deep-water habitats.
- Assessment of the population density of Carter’s Freshwater Mussel in Freshwater Lake and the Augustus River, targeting shallow and deep-water habitats.
- Reporting of the key findings in relation to the management objectives and environmental criteria defined in the CFMMPMP.

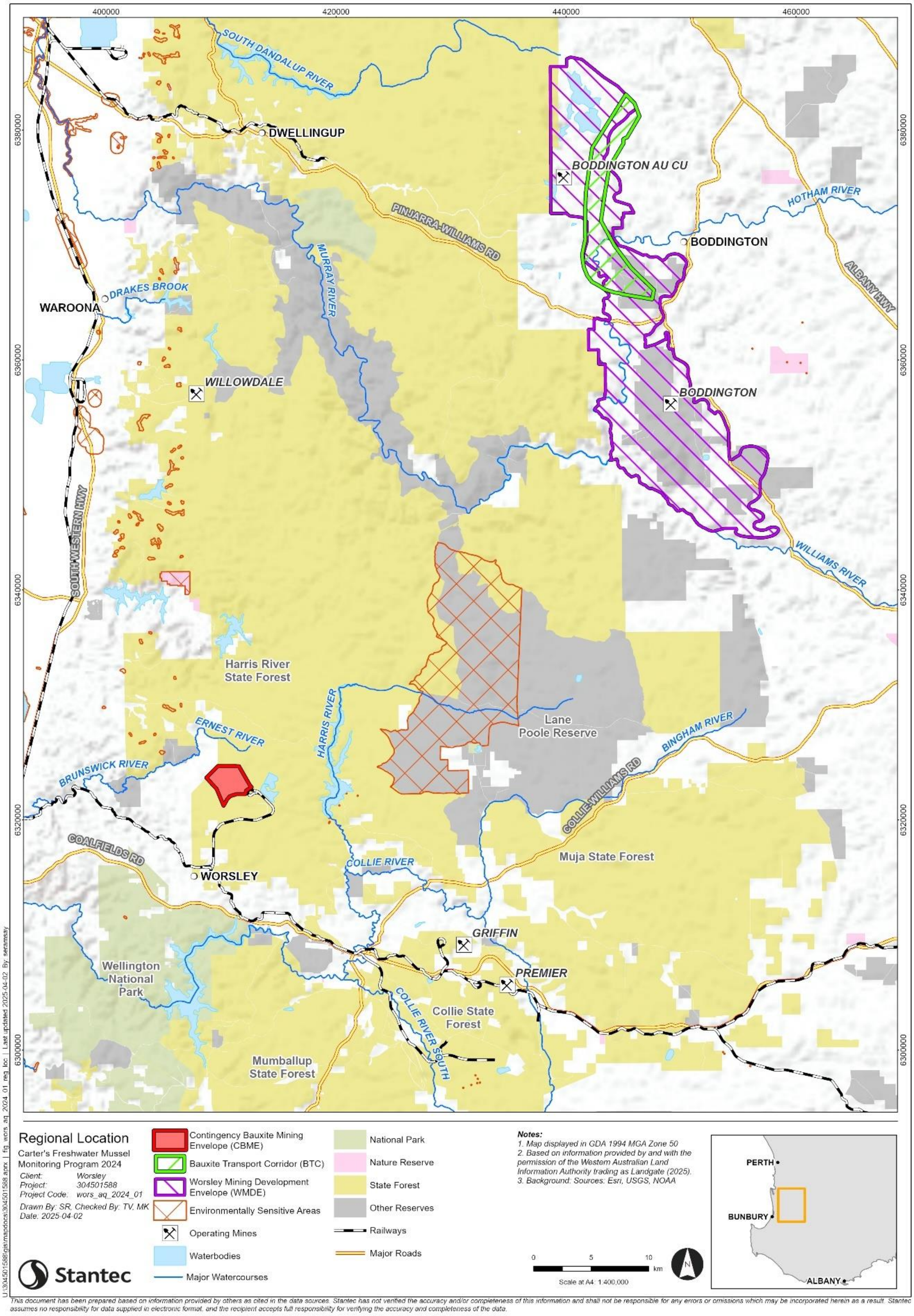

Figure 1-1: Regional location of the Worsley Mine Expansion development envelopes, including the Contingency Bauxite Mining Envelope.

2. Existing Environment

2.1 Biogeographic Location

The Refinery, its associated water supply reservoir (Freshwater Lake), the Augustus River, and the regional reference waterways are situated within the Northern Jarrah Forest subregion (JAF01), as defined by the Interim Biogeographic Regionalisation for Australia (IBRA) classification system (Thackway and Cresswall 1995) (**Figure 2-1**). The Northern Jarrah Forest subregion is situated east of the Darling Scarp, with an average elevation of 300 m above sea level, covering a land area of 22,559.04 km^2. Geology comprises Archaean granite and metamorphic rocks capped by an extensive lateritic duricrust that has been dissected by later drainage and interrupted by occasional granite hills. The vegetation is dominated by overstoreys of Jarrah (*Eucalyptus marginata*) – Marri (*Corymbia calophylla*) forest in the west, with Bullich (*Eucalyptus megacarpa*) and Swan River Blackbutt (*Eucalyptus patens*) in the valleys, giving way to Wandoo (*Eucalyptus wandoo*) woodlands in the east, with Powder-bark Wandoo (*Eucalyptus accedens*) on breakaways (Williams and Mitchell 2001). Soils in the bioregion are characterised as infertile, phosphorus deprived and often salt-laden.

2.2 Hydrology and Drainage

The Refinery, CMBE and associated Freshwater Lake are surrounded by the Harris River State Forest, with the Harris River Dam located approximately 10 km to the east of the Refinery (**Figure 1-1)**. The Augustus River is a tributary of the Brunswick River, one of the major river systems within the Collie River Basin (AWRC 1976), with the confluence of the two rivers located approximately 5 km downstream of the CBME (South32 2019). The Augustus River was dammed in 1980 to create the approximately 62 ha reservoir, Freshwater Lake (**Figure 1-1**), with water abstracted from Freshwater Lake to supply Refinery operations.

Freshwater Lake has a maximum capacity of 6 gigalitres (GL) and dead storage of 1 GL, resulting in an available storage capacity of 5 GL (GRM 2020). In accordance with SWL6804(4), the maximum annual abstraction limit from Freshwater Lake is 5.4 GL (GRM 2020). The lake is recharged directly and indirectly by rainfall, with drainage from the Augustus River headwater diverted around the Refinery entering the lake via a series of sediment traps. In addition, Freshwater Lake is supplemented with water imported from the Harris River, as required, to meet the minimum water level requirements. Therefore, water level within Freshwater Lake fluctuates markedly with changes in annual rainfall and abstraction rates for Refinery operations. As with the majority of rivers and creeks of southwestern Australia, the Augustus River downstream of Freshwater Lake flows seasonally, with peak flow during winter and spring coinciding with peak rainfall during June and July (South32 2019). Over summer (December-February), the Augustus River recedes to a series of pools.

Figure 2-1: Location of the Contingency Bauxite Mining Envelope within the Northern Jarrah Forrest subregion.

2.3 Climate

The climate of the Collie area is typical of Mediterranean climatic regions, with cool wet winters and hot dry summers (GRM 2020). Rainfall occurs primarily between May and September, coinciding with the lowest average minimum temperatures (3.2°C to 8.1°C) (**Figure 2-2**) recorded from the weather station nearest to the CBME and the Refinery (Collie East 009994), located approximately 3.8 km to the southeast (BoM 2023). The highest maximum temperatures are typically recorded between December and February, ranging from 29°C to 31°C (BoM 2023), with the highest maximum temperature recorded in January 2023 (31.8°C), similar to maximum temperatures recorded in 2021 and 2022 (**Figure 2-2**) (BoM 2025).

In the 12 months prior to the 2024 survey, monthly rainfall ranged from no rainfall in February 2024 to 184.8 mm of rainfall in August 2024. In relation to the long-term average monthly rainfall available for the weather station (dating back to 2002), monthly rainfall was below average except for in July, August and October 2024 when monthly rainfall was 17 mm, 68.8 mm and 15.5 mm above-average, respectively (**Figure 2-2**). Total annual rainfall recorded in 2024 was 548.4 mm, an increase from 2023 when 462.2 mm of rain fell at Collie East Weather Station (BoM 2025), which is lower than the long-term annual average of 683.0 mm, as well as total rainfall recorded in 2021 (930 mm) and 2022 (581.8 mm). Annual rainfall in 2019 was the lowest on record at 311.2 mm, 45.5% of the average; this was followed by two above-average rainfall years in 2020 and 2021 with the last three years having been below average in the region (**Figure 2-3**).

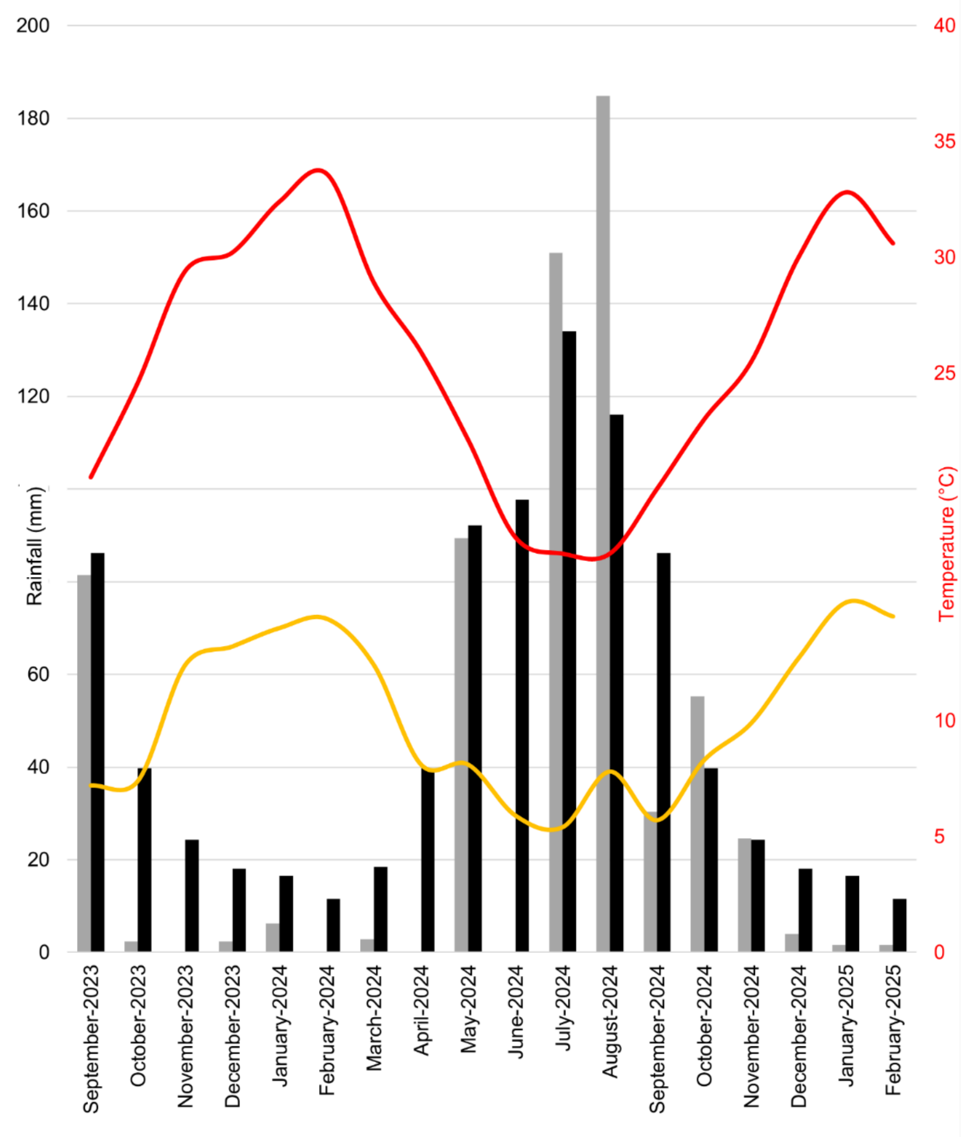

Figure 2-2: Total monthly rainfall (■), long-term average monthly rainfall (■), long-term average monthly maximum temperature (—) and long-term average monthly minimum temperature (—) recorded at Collie East Weather Station (BoM Site No. 009994) between September 2023 and February 2025.

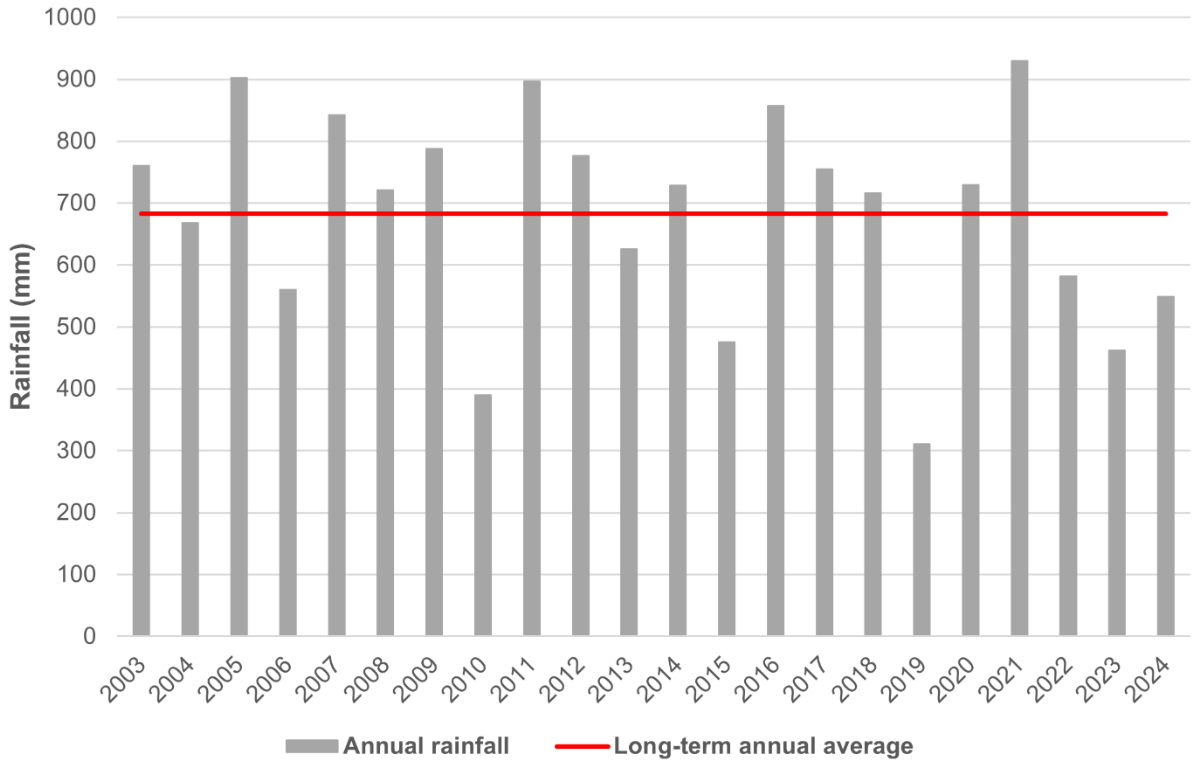

Figure 2-3: Annual rainfall ( ) and long-term average annual rainfall (—) recorded at Collie East Weather Station (BoM Site No. 009994) between 2003 and 2024.

3. Methods

3.1 Monitoring Program

The 2024 survey was undertaken on the 12th of November 2024 and the 9th, 10th, 11th and 17th of February 2025, and was aligned with the CFMMPMP (Stantec 2023). Shallow-water habitat monitoring was undertaken by Principal Aquatic Ecologist Michael Klunzinger (15 years' experience) and Graduate Aquatic Ecologist Kate Walker (2 years' experience). A deep-water SCUBA dive survey was undertaken by Stantec's Scientific Diving Team on the 17th of February 2025 by Principal Environmental Scientist Ruchira Somaweera (17 years' experience), Graduate Environmental Scientist Kai Krueger (2 years' experience), and Graduate Environmental Scientist Madeline George (2 years' experience), with the third member of the Scientific Diving Team staying on shore as a spotter to be available in the case of emergency. Sampling was conducted under the following licenses (**Appendix A**):

- Fauna Taking (Biological Assessment) Licence No. BA27000963-c, pursuant to Regulation 27 of the Biodiversity Conservation Regulations 2018, issued by the Western Australian Department of Biodiversity, Conservation and Attractions (DBCA);
- Lawful Authority to undertake "Authorised Activities" on specified CALM Land, pursuant to Regulation 4(1) of the Conservation and Land Management Regulations 2002 issued by the DBCA; and
- Instrument of Exemption No. 251309825, pursuant to Section 7(1) of the *Fish Resources Management Act 1994*, issued by the Western Australian Department of Primary Industries and Regional Development (DPIRD).

During the 2024 survey, a total of 13 sites were assessed, consisting of seven sites in Freshwater Lake, three sites in the Augustus River, and three regional reference sites in the Lunenburgh River Dam, Brunswick River and Ernest River (**Figure 3-1**). Water quality, sediment quality and quantitative Carter's Freshwater Mussel sampling was conducted at the shallow-water sites and targeted Carter's Freshwater Mussel sampling was conducted at the deep-water sites in Freshwater Lake (**Figure 3-1**). At the request of the client, FWL5_99 (Stantec 2024) was not sampled in 2025. Additionally, FWL07_23, FWL08_23 and FWL09_23 were not surveyed due to time constraints.

To maintain consistency among sites established by Stantec between 2021 and 2024, the naming convention of sites are prefixed with the same site code. The suffix code refers to the last two digits of the sampling year in which a site was established. If a site does not change from its precise locality, the year in which it was originally established remains the same. A complete list of historical sites and sampling components are provided in **Appendix B**. In addition to the sampling components outlined below, habitat characterisation (**Appendix C),** photographic monitoring (**Appendix D**), and spatial referencing was also undertaken at all sites. Raw Carter's Freshwater Mussel shell measurement data is provided in **Appendix E**. Detailed methods associated with each of the sampling components is presented in subsequent sections.

Table 3-1: Sites and sampling components assessed during the 2024 survey.

Classification	Waterbody	Site ID	Location (UTM)	Date	Water Quality	Sediment Quality	Habitat Characteristics	Quantitative Mussel Sampling	Targeted Mussel Sampling
Impact	Freshwater Lake	FWL1_24	50 H 410040, 6322977	10/02/2025	✓	✓	✓	✓	
		FWL2_24	50 H 410399, 6322159	10/02/2025	✓	✓	✓	✓	
		FWL3_23	50 H 410392, 6323135	10/02/2025	✓	✓	✓	✓	
		FWL4_24	50 H 410838, 6323502	10/02/2025	✓	✓	✓	✓	
		FWL_Dive1_21	50 H 410039, 6322977	17/02/2025			✓		✓
		FWL_Dive2_24	50 H 410216, 6322781	17/02/2025			✓		✓
		FWL_Dive3_24	50 H 410362, 6323083	17/02/2025			✓		✓
	Augustus River	AR1_21	50 H 409047, 6323850	11/02/2025	✓	✓	✓	✓	
		AR2_21	50 H 409233, 6323778	11/02/2025	✓	✓	✓	✓	
		AR3_21	50 H 408538, 6324014	11/02/2025	✓	✓	✓	✓	
Regional Reference	Lunenburgh River	LR_Dam_21	50 H 405512, 6319488	09/02/2025	✓	✓	✓	✓	
	Ernest River	RR02_99	50 H 406017, 6324679	09/02/2025	✓	✓	✓	✓	
	Brunswick River	RR10_99	50 H 408648, 6328622	09/02/2025	✓	✓	✓	✓	

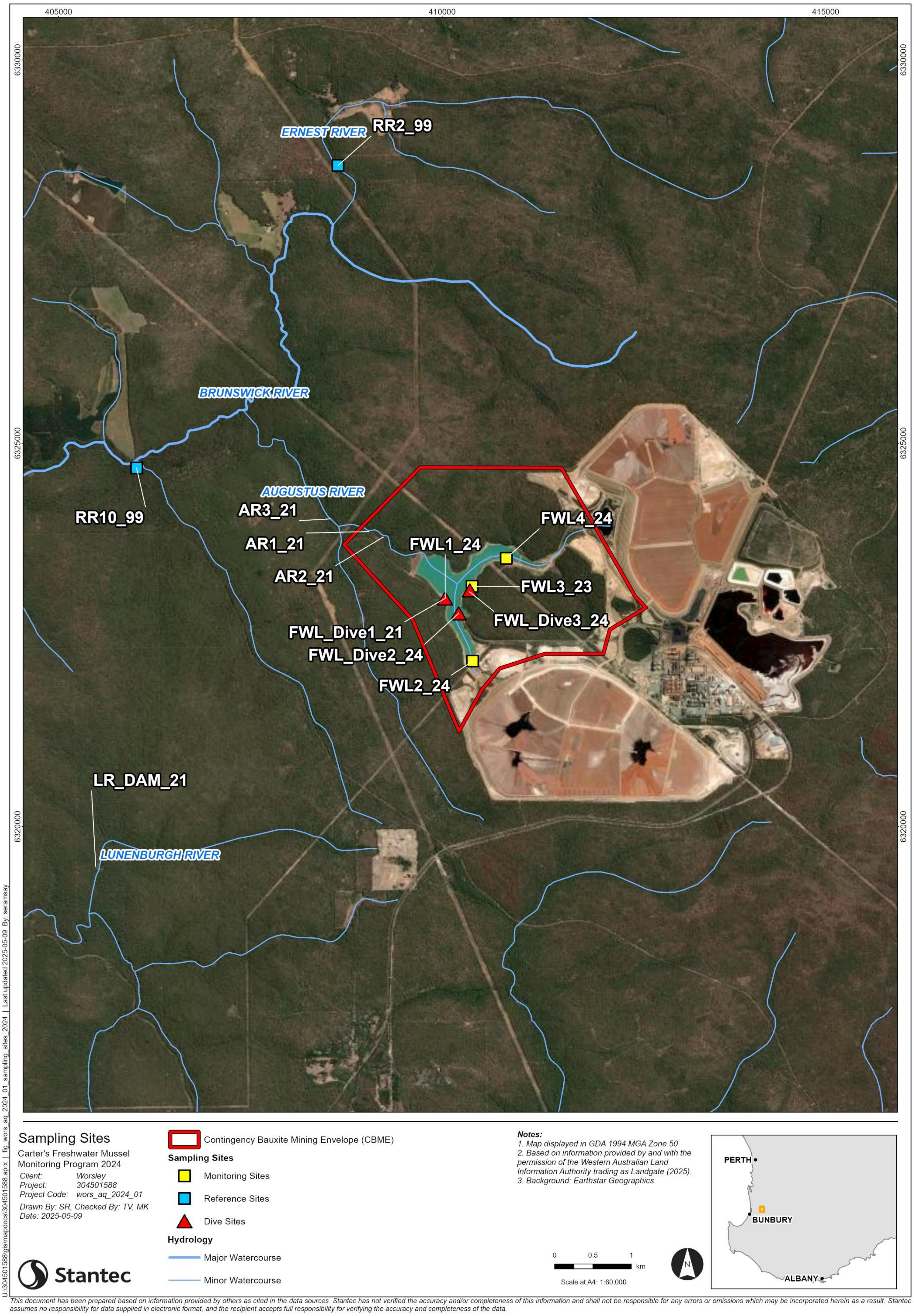

Figure 3-1: Sites sampled within Freshwater Lake and the Augustus River, Lunenburgh River Dam, Brunswick River and Ernest River as part of the 2024 survey.

3.2 Water Quality

Basic water quality parameters were measured *in situ* using a portable, hand-held water quality field meter (Professional Plus Handheld Multiparameter Model PSE1 – 1m, YSI Inc., 1725 Brannum Lane, Yellow Springs, OH 45387, USA), including salinity (mg/L), electrical conductivity (as specific conductivity (SPC) µs/cm), dissolved oxygen (% and mg/L), temperature (°C) and pH (pH units). The water quality field meter was calibrated according to manufacturer's standards prior to the field survey. A summary of *in situ* water quality measurments are provided in **Appendix C**.

Water samples were collected from eight sites for laboratory analysis, using protocols commensurate with NATA-accredited testing during the field survey, with parameters analysed listed in **Table 3-2**. Water samples were not collected from sites where surface water was absent. For each site, bottles were labelled with the date and time of sampling, site identification code, project identification code, and the names of the samplers. A water sample was collected from 10 cm below the water's surface using a plastic bucket, taking care to avoid filling with any floating debris. Each sterilised analytical sample bottle (containing preservative where required) was filled with water using a sterile syringe and sealed, excluding air from the samples. Samples taken for the analysis of a suite of nutrients were filtered through a 45 µm filter cartridge attached to the syringe. Following collection, the samples were stored in an esky with ice and moved into a refrigerator (a freezer for nutrient suite samples) at a temperature setting of 4°C, as instructed by Australian Laboratory Services[1] (ALS). After all samples had been collected, they were transported in an esky with ice back to Stantec, Perth, stored in a refrigerator (a freezer for nutrient suite samples) overnight and shipped to ALS via courier the next morning for analysis. Holding times were met for all parameters except for pH at all sites; these results are to be considered indicative only.

Surface water pH was compared to the classification system outlined by Finlay and Bogard (2022), comprising neutral 7.0, acidic <7.0 and alkaline >7.0 categories. In the context of Carter's Freshwater Mussel salinity tolerance (Klunzinger *et al.* 2015), the following classification system (*sensu* Williams (1987)) was used for comparison of water quality:

- fresh (<3,000 mg/L or <5,558 µS/cm);
- slightly saline (3,000 mg/L - 10 mg/L or 5,558 µS/cm - 17,022 µS/cm);
- saline (10,000 mg/L – 100,000 mg/L or 17,022 µS/cm - 130,084 µS/cm); and
- highly saline (>100,000 mg/L or >130,084 µS/cm.

Basic water quality parameters and nutrient concentrations were compared to the following ANZECC & ARMCANZ (2000a) lower and upper trigger values for the southwest of Western Australia:

- wetlands for Freshwater Lake sites; and
- upland rivers for the Augustus River sites, as well as the regional reference sites.

Concentrations of metals and metalloids ("metals") were compared to the Water Quality Australia (2021) Australian & New Zealand Guidelines for Fresh & Marine Water Quality default guideline values (DGVs), for the protection of:

- 80% of species in freshwater, representative of highly disturbed ecosystems; and
- 95% of species in freshwater, representative of slightly to moderately disturbed ecosystems.

These values were used in the absence of SSGVs for comparison and are considered default values only. Where an 80% or 95% trigger value was not available, a Water Quality Australia (2021) DVG with an unknown species protection percentage was used instead and comparison should be considered indicative only.

[1] *NATA-accredited service provider Accreditation No. 2562.*

Table 3-2: Parameters analysed from water quality samples during the 2024 survey.

Basic Parameters	Major Ions	Nutrients	Dissolved Metals	
pH	Bicarbonate	Ammonia	Aluminium	Manganese
Total Dissolved Solids	Calcium	Ammonium	Arsenic	Mercury
Electrical Conductivity	Carbonate	Nitrite + Nitrate	Barium	Molybdenum
	Chloride	Total Nitrogen	Boron	Nickel
	Magnesium	Total Kjeldahl Nitrogen	Cadmium	Selenium
	Potassium	Total Phosphorus	Chromium	Uranium
	Sodium		Cobalt	Vanadium
	Sulphate		Copper	Zinc
			Iron	
			Lead	

3.3 Sediment Quality

Sediment samples were collected from 10 sites for laboratory analysis, using protocols commensurate with NATA-accredited testing during the field survey, with parameters analysed listed in **Table 3-3**. For each site, collection jars were labelled with the date and time of sampling, site identification code, project identification code, and the names of the samplers. The top 2 cm of sediment was scraped into a sterilised glass jar (excluding voids), provided by ALS. Following collection, the samples were stored in an esky with ice and moved into a freezer to extend the holding time for nitrate, as instructed by ALS. After all samples had been collected, they were transported in an esky with ice back to Stantec, Perth, stored in a freezer overnight and shipped to ALS via courier the next morning for analysis. Holding times were met for all parameters.

Sediment pH was compared to the classification system developed by Hazelton and Murphy (2007) comprising slightly acidic (6.1-6.5), neutral (6.6-7.4), mildly alkaline (7.4-7.8), and moderately alkaline (7.9-8.4) categories, noting that this classification system was developed for application to soil in agricultural environments. Concentrations of metals were compared to the Water Quality Australia (2021) DGVs and upper guideline values (GV-High) for sediment, with toxicity-related effects to species potentially observed at concentrations above the GV-High value.

Table 3-3: Parameters analysed from sediment samples during the 2024 survey.

Basic Parameters	Major Ions	Nutrients	Total Metals	
pH	Bicarbonate	Nitrite + Nitrate	Aluminium	Manganese
Total Soluble Salts	Calcium	Total Nitrogen	Arsenic	Mercury
Moisture Content	Carbonate	Total Kjeldahl Nitrogen	Boron	Molybdenum
	Chloride	Total Phosphorus	Cadmium	Nickel
	Magnesium	Total Organic Carbon	Chromium	Selenium
	Potassium		Cobalt	Uranium
	Sodium		Copper	Vanadium
	Sulphate		Lead	Zinc

3.4 Freshwater Mussel Ecological Survey

3.4.1 Quantitative Sampling – Shallow-water Sites

The 2024 survey aligned with the CFMMPMP (Stantec 2023), which followed established methods (Klunzinger 2012; Klunzinger *et al.* 2012a; Klunzinger *et al.* 2011a; Klunzinger *et al.* 2011b; Lymbery *et al.* 2008; Sheldon *et al.* 2020). At each site, a 50 m to 100 m reach of waterway was visually inspected for the presence of Carter's Freshwater Mussel shells or live individuals. At each site, other than at Freshwater Lake, wearing waders, one person entered the water to a maximum depth of waist-deep and conducted tactile searches (bending over standing up) of the waterway substrate by using a sieve (to reduce the chance of overlooking smaller individuals) or fine-toothed rake. Where individuals were found, a 50 m long transect was established, perpendicular to the water's edge, to a maximum water depth of 1 m using a graduated field measuring tape between temporary star pickets hammered into the ground. Employment of a sieve was useful to reduce the chance of overlooking smaller individuals.

At each site, quantitative sampling comprised:

- deployment of 10 x 1 m^2 PVC quadrats placed randomly along the 50 m transect on substrate considered suitable for Carter's Freshwater Mussel with the start and end point of each transect, as well as each individual quadrats, marked using a handheld GPS unit with coordinates recorded; and
- collection of individuals within each quadrat which were counted and measured for height, length and width (**Figure 3-2**).

Quadrat sampling was undertaken to reduce sampling bias and to estimate Carter's Freshwater Mussel patch density. When Carter's Freshwater Mussel individuals were located within the sediment, they were inspected to determine if they were alive or dead. If shells were fully intact without holes in them and could not be pried apart, they were determined to be alive. Each live individual was measured to the nearest 0.1 mm using handheld vernier callipers and released back to their approximate point of collection. The presence of dead individuals or shell fragments were also recorded, and shells were retained in plastic Ziplock bags labelled with survey date and site for later measurement. Empty (dead) shells were subsequently measured using the same methodology. This was a time savings measure to maximise efficiency in the field. Statistical analyses were undertaken using online software (Statistics_Kingdom 2017).

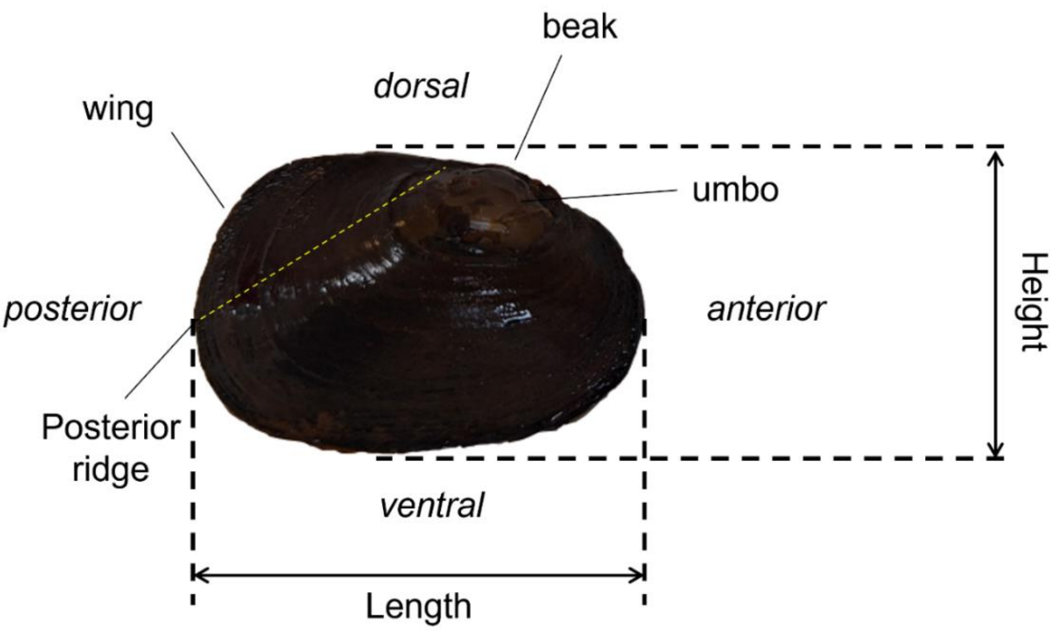

Figure 3-2: Carter's Freshwater Mussel shell anatomy, shell measurements (Height and Length) and orientation descriptors (provided in italics). The image shown is the right valve of an individual collected during the field survey.

3.4.2 Targeted Searches – Deep-water Sites

Targeted freshwater mussel searches were undertaken via SCUBA diving at three sites within Freshwater Lake, each within 50 m from the shoreline. Within each site, a transect was established by rolling out a weighted measuring tape perpendicular to the shore. One diver on each side of the transect conducted visual and tactile searches of the lake substate, and depth and temperature were recorded at regular intervals until the end of the transect was reached. Carter's Freshwater Mussel individuals were collected in mesh dive bags and taken to shore to be measured as described above. At each sampling transect, Carter's Freshwater Mussel individuals were determined to be alive or dead, and dead shells were retained while live individuals were released by the divers to their approximate place of collection. Quadrat sampling was not conducted at Freshwater Lake deep-water sites due to visibility and sediment stability limitations associated with SCUBA diving.

4. Results and Discussion

4.1 Habitat Conditions

Habitat conditions across impact and regional reference sites varied in substrate, sediment composition, waterway morphology, and riparian vegetation condition. Downstream from the dam wall, Freshwater Lake is devoid of riparian vegetation and, thus, devoid of complex submerged habitats such as large woody debris or leaf litter. The fluctuations in water level are accompanied by a large distance from the shoreline to the riparian vegetation zone, with vegetation often greater than 15 m from the water's edge. Submerged macrophytes are also rare in the lake, likely attributed to characteristically high turbidity and low light penetration (Stantec 2024). Within the Freshwater Lake sites, shorelines were composed of dry, cracked clay with sand and cobbles. Within wadable areas to depths of approximately 1 m, substrates were primarily compacted clay with rock and cobble. There was a gradient of sediment softening with depth within Freshwater Lake sites.

The Augustus River sites comprised a narrow riverine stream. Water was pooled upstream from the v-notch weir within site AR2, but the riverbed downstream from the weir was dry in February 2025. This contrasts with the conditions observed during the 2023 monitoring program (Stantec 2024) and in November 2024, where the field survey was undertaken in November 2023, when water was still flowing downstream from the v-notch weir. Sampling during the 2024 survey was undertaken during February 2025 with the dry conditions attributed, in part, to reduced base flow experienced by the southwest of Western Australia between February and March (Andrys *et al.* 2017; Silberstein *et al.* 2012), but also from the lack of environmental flow releases.

The regional reference sites, RR02_99 (Ernest River) and RR10_99 (Brunswick River), while intended to be riverine reference sites comparable to the Augustus River sites (AR1-AR3), were drier with no surface water present and no Carter's Freshwater Mussel individuals observed during the 2024 survey. This contrasts with the 2023 monitoring program (Stantec 2024) where both waterways were flowing. These sites comprise a combination of narrow sections of river fringed by dense riparian vegetation. The Lunenburgh River Dam (LRDam_21), which contained permanent water, shared similar habitat and substrate characteristics with Freshwater Lake, with substrates comprising sand and clay and limited in-stream habitat. However, some submerged macrophytes, leaf litter and detritus were present at Lunenburgh River Dam, providing more complexity than Freshwater Lake.

4.2 Water Level & Flow

Between May 2021 and January 2025, the water level at Freshwater Lake has fluctuated between a minimum of 230 m AHD and a maximum of 238 m AHD (**Figure 4-1**). During the 2024 survey, the water level fell below the trigger criteria of 231 m AHD, specified in the CFMMPMP (Stantec 2023), between April and May 2024. This minimum water level was lower than it had been in previous years (2021-2023) and coincided with peak abstraction rates. The maximum water level recorded during the 2024 survey between September and October 2024 was marginally higher than during the 2023 monitoring program (Stantec 2024). The pattern of maximum and minimum water levels remains consistent between years, with maximum water levels occurring between August and September, following winter rains, and minimum water levels occurring through the dry, hot summer months between October and April.

Worsley Alumina's Surface Water License (SWL6804(4)) stipulates that water must be released from Freshwater Lake at a rate of 35 L/hr (equating to 2.9 L/5 mins), into the Augustus River between September and December each year, with the aim of maintaining environmental flows in the downstream receiving environment (GRM 2020). During the 2024 survey, peak flow rates of between 25 L/5 mins and 55 L/5 mins within the Augustus River were recorded in July, August and September 2024 (**Figure 4-3**). Low and cease to flow periods were recorded between January and May 2024 and January and February 2025. Similar low flow trends were observed in previous years, although cease to flow periods were not recorded in 2021, 2022 or 2023 (**Figure 4-3**).

Peak flow rates of between 23 L/5 mins and 53 L/5 mins were observed between July and September 2024 with a decrease in flow rate below 2.9 L/5 mins occurring between mid-September and mid-October 2024. Flow rate was maintained near the required 2.9 L/5 mins stipulated in SWL6804(4) between mid-September and November 2024 with a decrease below 2.9 L/5 mins after the 26th November 2024, potentially breaching the minimum requirement for maintaining environmental flow in December 2024.

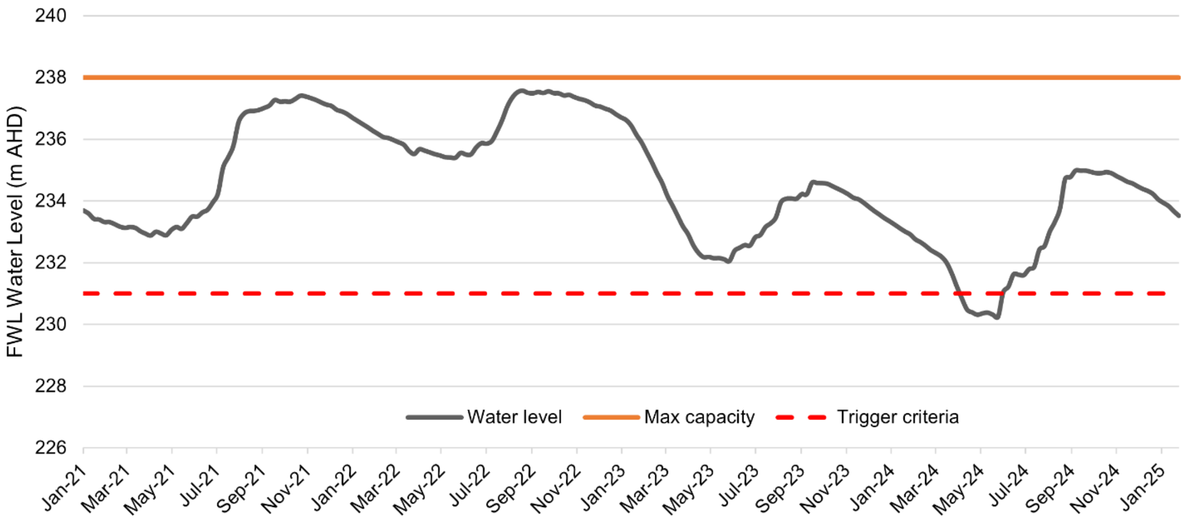

Figure 4-1: Water level, maximum storage capacity and trigger criteria at Freshwater Lake between January 2021 and January 2025.

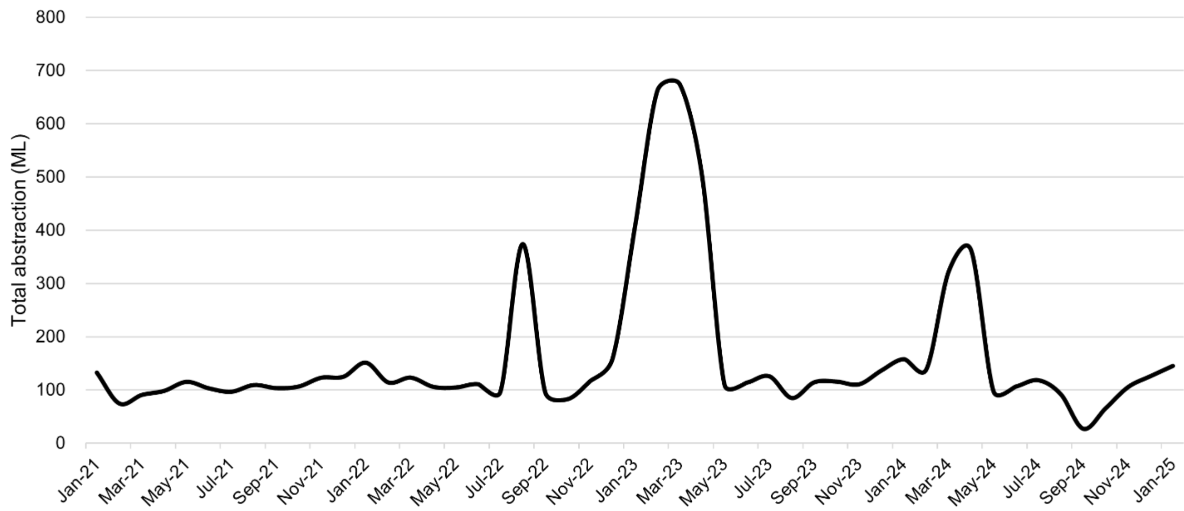

Figure 4-2: Total water abstraction at Freshwater Lake between January 2021 and January 2025.

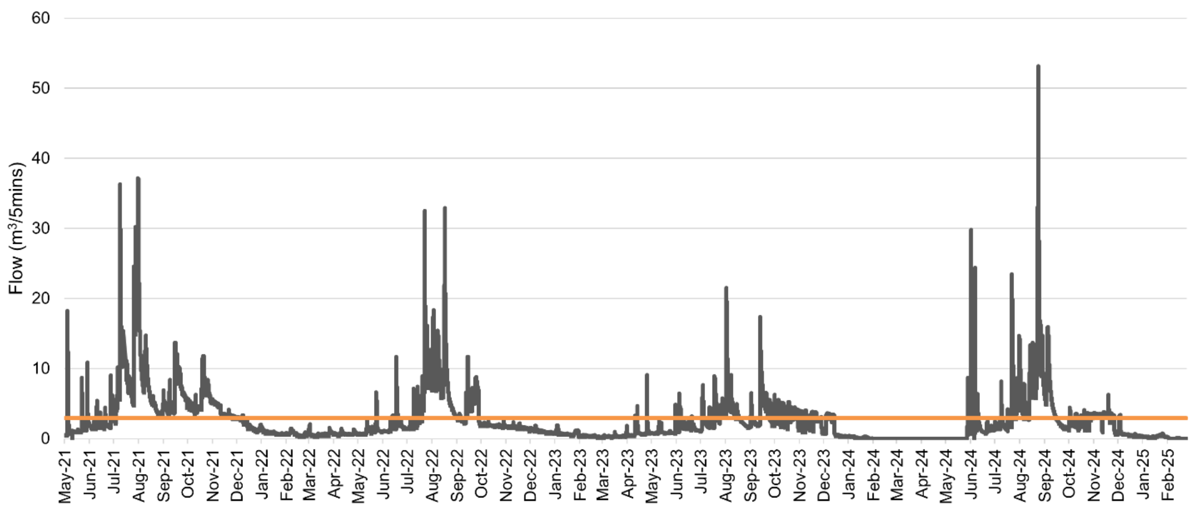

Figure 4-3: Discharge rate (—) measured at Augustus River v-notch weir (data supplied by Worsley South 32) and average required release rate (—) between 2021 and 2025.

4.3 Water Quality

The pH of surface water assessed at the Freshwater Lake sites during the 2024 survey was classified as slightly alkaline (Finlay and Bogard 2022), ranging from 7.3 to 8.1, and the Augustus River was classified as neutral (Finlay and Bogard 2022) with a pH of 6.9 to 7.4 (**Table 4-1** and **Appendix C)**. The pH of surface water at the only regional reference site, the Lunenburgh River Dam, was 7.3 and was classified as alkaline (Finlay and Bogard 2022). These values are similar to those recorded during the 2023 monitoring program (Stantec 2024). While the upper and lower pH limits for Carter's Freshwater Mussel are unknown, the species is known to occur in water where pH ranges from 4.5 to 10.0 (Klunzinger *et al.* 2022). During the 2024 survey, pH did not exceed the ANZECC & ARMCANZ (2000a) upland river or wetland trigger values.

Salinity, measured as total dissolved solids (TDS), ranged from 132 mg/L to 137 mg/L within Freshwater Lake, and from 114 mg/L to 165 mg/L at the Augustus River, classified as freshwater *sensu* Williams (1987). Salinity at the Lunenburgh River Dam was comparable (158 mg/L), although slightly elevated compared to Freshwater Lake (**Table 4-1, Figure 4-4**). As there is no ANZECC & ARMCANZ (2000a) trigger value available for salinity in mg/L, electrical conductivity data was also collected, with all impact and regional reference sites (247 µS/cm – 281 µS/cm) exceeding the ANZECC & ARMCANZ (2000a) upland river trigger value for river sites (120 µS/cm), but not the upland wetland trigger value (1,500 µS/cm) for Freshwater Lake or Lunenburgh River Dam sites (**Figure 4-5**, **Appendix C**). Overall, the salinity recorded across all sites during the 2024 survey was below the tolerance range for Carter's Freshwater Mussel (Klunzinger et al. 2015).

Dissolved oxygen, measured as % saturation *in situ*, ranged from 105.46% to 113.74% in Freshwater Lake, with values recorded from the Augustus River (67.91%) and the Lunenburgh River Dam (92.67%) lower in comparison during the 2024 survey (**Table 4-1**). The Augustus River site was also lower than the lower ANZECC & ARMCANZ (2000a) upland river trigger value (90%) for February 2025 but not November 2024; however, this is not uncommon for well-vegetated rivers of the region where Carter's Freshwater Mussel is present (Klunzinger *et al.* 2015). All results were comparable to the 2023 monitoring program (Stantec 2024). It is noted that *in situ* measurements of dissolved oxygen were taken during the day when considerable increases in dissolved oxygen concentrations from photosynthetic organisms can occur (Humphrey and Simpson 1985), so results should be considered indicative only. While the dissolved oxygen tolerance limits for Carter's Freshwater Mussel are unknown, other species of freshwater mussel are susceptible to low dissolved oxygen, including *Alathyria jacksoni* and, although to a lesser extent, *Velesunio ambiguus* from the Murray-Darling Basin (Sheldon and Walker 1989) and *Velesunio angasi* from the Northern Territory (Humphrey and Simpson 1985).

Water temperature, recorded *in situ*, during February 2025 ranged from 24.4°C to 26.0°C at the Freshwater Lake shallow-water sites, and was 22.6°C at the Augustus River site AR2, and 26.9°C at the Lunenburgh River Dam site LR_Dam_21 (**Table 4-1**). At deep-water Freshwater Lake sites, surface water temperature was approximately 23°C to a depth of approximately 5 m, where a thermocline was encountered, below which, the temperature was approximately 17°C (**Table 4-1** and **Appendix C**). The upper water temperature tolerance of Carter's Freshwater Mussel has been documented at 32.8°C for 50% mortality (LT50) of individuals, with 95% mortality (LT95) of individuals occurring at 33.4°C (Perera 2023). Field observations by Klunzinger et al. (2015) indicate that water temperatures above 30°C are limiting to the species, consistent with recent findings (Perera 2023); therefore, temperature was not considered to be a limiting factor during the 2024 survey.

Total nitrogen concentrations were below their respective ANZECC & ARMCANZ (2000a) trigger values for upland wetlands and rivers at all for the 2024 survey (**Table 4-1**). Total phosphorus concentrations were slightly above their respective ANZECC & ARMCANZ (2000a) trigger value (0.02 mg/L) for upland rivers in Augustus River during November 2024 but not in February 2025. all sites in Freshwater Lake and Lunenburgh River Dam for the 2024 survey. Total phosphorus concentrations were below their respective ANZECC & ARMCANZ (2000a) trigger value (0.06 mg/L) for upland wetlands in Freshwater Lake and Lunenburgh River Dam. Nutrient concentrations have generally decreased since 2021 within Freshwater Lake, the Augustus River, and the Lunenburgh River Dam (**Appendix F**). Concentrations of total nitrogen were below the estimated upper limit of 0.69 mg/L for Carter's Freshwater Mussel across all sites (**Table 4-1**), noting that precise tolerance limits of this variable have not been determined for the species (Klunzinger *et al.* 2015). At a finer scale, localised nutrient concentrations, particularly interstitial ammonia can be limiting to freshwater mussels, especially glochidia and juveniles (Kleinhenz *et al.* 2019; Walker *et al.* 2014), but these effects are unlikely to be detected through the sampling design of the Carter's Freshwater Mussel annual monitoring program. Total phosphorus has not been shown to have negative effects on Carter's Freshwater Mussel distribution, with studies showing salinity, hydrology and total nitrogen to be far more influential environmental variables (Klunzinger *et al.* 2015).

Concentrations of dissolved metals across sampling sites were generally below the limit of analytical detection except for aluminum, barium, copper, iron, manganese and molybdenum (**Table 4-1**). Of these metals, Water Quality Australia (2021)

DGVs are only available for aluminum, copper and manganese, with concentrations of aluminium (<0.005 mg/L to 0.05 mg/L), not exceeding the DVG for the protection of 95% of species (0.06 mg/L) across all sites (**Table 4-1**, **Figure 4-6**). Manganese concentrations were well below the DGV for the protection of 95% of species (1.9 mg/L) across all sites. Copper was largely undetectable across sampling sites, except in Freshwater Lake, where two of the sites had copper concentrations that were only just detectable at 0.001mg/L, and all sites were thus, well below the DGV for the protection of 95% of species (0.0014 mg/L) (**Table 4-1**, **Figure 4-7**). Average concentrations have decreased since 2021 across Freshwater Lake, the Augustus River, and the Lunenburgh River Dam (**Appendix F**). Although elevated aluminium concentrations were observed in several of the survey sites, it is likely that this could be attributed to naturally-occurring aluminium within the surrounding catchments, as evidenced by the exceedance within the Brunswick River during the 2023 monitoring program (Stantec 2024). Although elevated concentrations of metals have the potential to be toxic to freshwater mussels (Jorge *et al.* 2013; Naimo 1995; Walker *et al.* 2014), metal toxicity studies have not been undertaken on Carter's Freshwater Mussel and toxicity tolerance limits are currently unknown. Concentrations of mercury, required to be assessed in accordance with the CFMMPMP (Stantec 2023), were below detection at all sites across Freshwater Lake, the Augustus River, and the regional reference sites (**Table 4-1**) during the 2024 monitoring program.

Table 4-1: Surface water quality data recorded from Freshwater Lake, the Augustus River, Lunenburgh River Dam, Ernest River and Brunswick River, November 2024 and February 2025.

Water Quality Parameters		LoR	Impact									Regional Reference			ANZECC & ARMCANZ (2000a)				Water Quality Australia (2021) DGVs	
			Freshwater Lake				Augustus River					Lunenburgh River Dam	Ernest River	Brunswick River	Upland River Trigger		Wetlands Trigger			
			February 2025				November 2024		February 2025			February 2025								
			FWL1_24	FWL2_24	FWL3_23	FWL4_24	AR1_21	AR1_21	AR1_21	AR2_21	AR3_21	LR_DAM_21	RR02_99	RR10_99	Lower	Upper	Lower	Upper	80%	95%
Basic	pH (unit)	0.01	7.8	7.8	7.8	7.7	7.35	7.31	7.3	7.4	dry	7.3	dry	dry	6.8	8.0	7.0	8.5	-	-
	Total Dissolved Solids	10	134	137	132	135	114	114	165	151	dry	158	dry	dry	-	-	-	-	-	-
	Electrical Conductivity (µS/cm)	1	250	248	247	262	247	240	272	270	dry	281	dry	dry	-	120	-	1,500	-	-
	Dissolved Oxygen (%) (*in situ*)	-	113.7	112.3	105.5	109.0	99.9	100.6	dry	67.9	dry	92.7	dry	dry	90	-	90	120	-	-
	Temperature ºC (*in situ*)	-	24.43	26.00	25.10	24.77	1.9	1.6	dry	22.63	dry	26.93	dry	dry	-	-	-	-	-	-
Major Ions	Sodium	1	40	42	41	46	38	38	40	42	dry	43	dry	dry	-	-	-	-	-	-
	Magnesium	1	4	4	4	4	5	4	6	6	dry	6	dry	dry	-	-	-	-	-	-
	Calcium	1	4	5	5	5	4	4	5	4	dry	4	dry	dry	-	-	-	-	-	-
	Potassium	1	1	2	2	2	1	1	2	2	dry	2	dry	dry	-	-	-	-	-	-
	Chloride	1	65	66	65	69	48	47	84	82	dry	92	dry	dry	-	-	-	-	-	-
	Bicarbonate	1	33	32	33	32	28	25	32	26	dry	12	dry	dry	-	-	-	-	-	-
	Sulphate	1	14	15	15	15	13	13	5	10	dry	8	dry	dry	-	-	-	-	-	-
	Carbonate	1	<1	<1	<1	<1	<1	<1	<1	<1	dry	<1	dry	dry	-	-	-	-	-	-
Nutrients	Total Nitrogen	0.1	0.4	0.4	0.6	0.3	0.2	<0.1	0.1	0.3	dry	0.3	dry	dry	-	0.45	-	1.5	-	-
	Total Kjeldahl Nitrogen	0.1	0.2	0.2	0.4	0.1	0.2	<0.1	0.1	0.3	dry	0.3	dry	dry	-	-	-	-	-	-
	Nitrite + Nitrate	0.01	0.18	0.15	0.18	0.17	0.04	0.03	<0.01	<0.01	dry	<0.01	dry	dry	-	-	-	-	-	-
	Total Phosphorus	0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.03	<0.01	<0.01	dry	<0.01	dry	dry	-	0.02	-	0.06	-	-
	Ammonia	0.01	<0.01	0.04	0.02	<0.01	0.02	0.01	<0.01	0.03	dry	<0.01	dry	dry	-	-	-	-	2,300	1,430
	Ammonium	0.01	<0.01	0.04	0.02	<0.01	0.02	<0.01	<0.01	0.03	dry	<0.01	dry	dry	-	-	-	-	-	-
Metals & Metalloids	Aluminum	0.01	0.03	0.03	0.03	0.05	<0.005	<0.005	<0.01	<0.01	dry	0.02	dry	dry	-	-	-	-	0.15	0.055
	Arsenic	0.001	<0.001	<0.001	<0.001	<0.001	<0.0002	<0.0002	<0.001	<0.001	dry	<0.001	dry	dry	-	-	-	-	0.14	0.013
	Barium	0.001	0.006	0.006	0.006	0.006	0.0125	0.0118	0.02	0.014	dry	0.012	dry	dry	-	-	-	-	-	-
	Boron	0.05	<0.05	<0.05	<0.05	<0.05	0.007	0.007	<0.05	<0.05	dry	<0.05	dry	dry	-	-	-	-	2.5	0.94
	Cadmium	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00005	<0.00005	<0.0001	<0.0001	dry	<0.0001	dry	dry	-	-	-	-	0.0008	0.0002
	Chromium	0.001	<0.001	<0.001	<0.001	<0.001	<0.0002	<0.0002	<0.001	<0.001	dry	<0.001	dry	dry	-	-	-	-	0.04	0.001
	Cobalt	0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	dry	<0.001	dry	dry	-	-	-	-	0.0014	-
	Copper	0.001	<0.001	<0.001	0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	dry	0.001	dry	dry	-	-	-	-	0.0025	0.0014
	Iron	0.05	<0.05	<0.05	<0.05	<0.05	0.111	0.107	0.28	0.15	dry	0.06	dry	dry	-	-	-	-	-	-
	Lead	0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	dry	<0.001	dry	dry	-	-	-	-	0.0094	0.0034
	Manganese	0.001	<0.001	0.002	<0.001	<0.001	0.0152	0.0138	0.049	0.019	dry	<0.001	dry	dry	-	-	-	-	3.6	1.9
	Mercury	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00004	<0.00004	<0.0001	<0.0001	dry	<0.0001	dry	dry	-	-	-	-	0.0054	0.0006
	Molybdenum	0.001	0.001	0.002	0.002	0.001	0.0004	0.0005	<0.001	<0.001	dry	<0.001	dry	dry	-	-	-	-	0.034	-
	Nickel	0.001	<0.001	<0.001	<0.001	<0.001	<0.0005	0.0006	<0.001	<0.001	dry	<0.001	dry	dry	-	-	-	-	0.017	0.011
	Selenium	0.01	<0.01	<0.01	<0.01	<0.01	0.0008	0.0008	<0.01	<0.01	dry	<0.01	dry	dry	-	-	-	-	0.034	0.011
	Uranium	0.001	<0.001	<0.001	<0.001	<0.001	<0.00005	<0.00005	<0.001	<0.001	dry	<0.001	dry	dry	-	-	-	-	0.0005	-
	Vanadium	0.01	<0.01	<0.01	<0.01	<0.01	<0.0002	<0.0002	<0.01	<0.01	dry	<0.01	dry	dry	-	-	-	-	0.006	-
	Zinc	0.005	<0.005	<0.005	<0.005	<0.005	<0.001	<0.001	<0.005	<0.005	dry	<0.005	dry	dry	-	-	-	-	0.031	0.008

Note: all units are mg/L unless otherwise specified; red shading indicates exceedance of the ANZECC & ARMCANZ (2000a; 2000b) trigger values for southwest Western Australia or the Water Quality Australia (2021) DVGs for the protection of 99% of species in pristine freshwater systems; purple shading indicates the use of a Water Quality Australia (2021) DVG with an unknown species protection percentage.

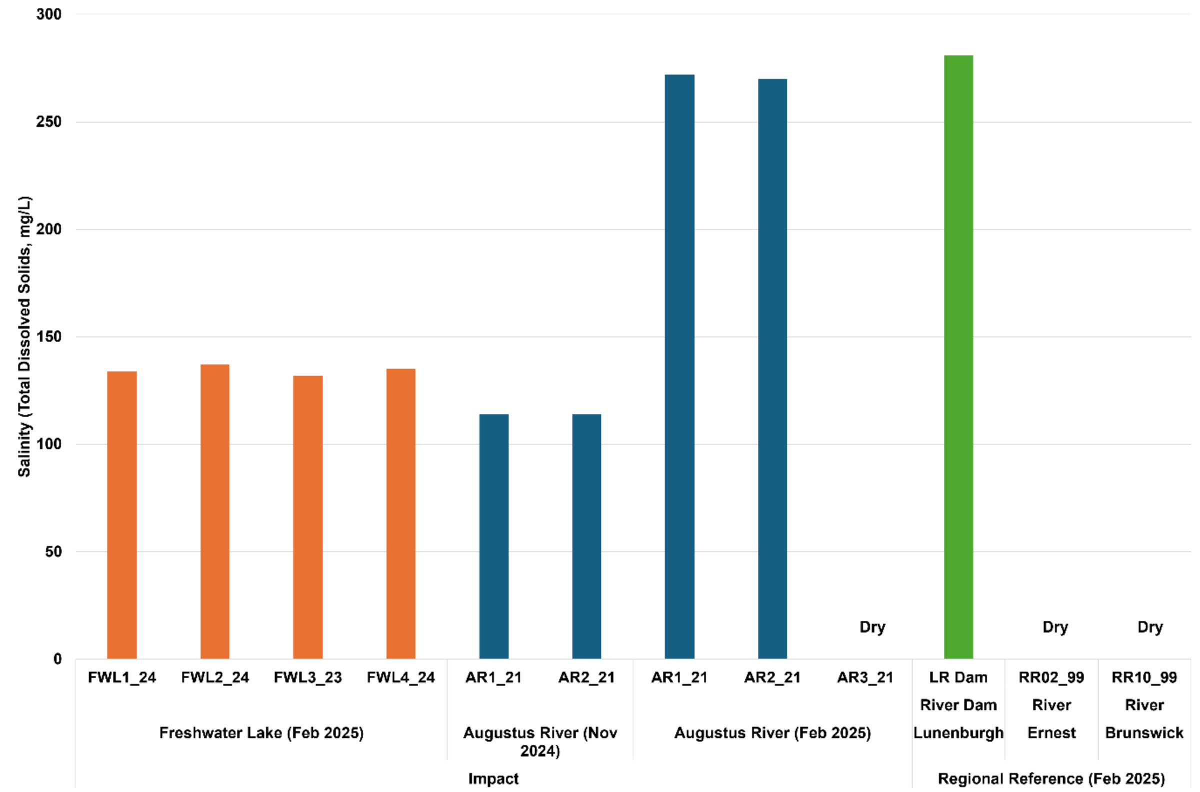

Figure 4-4: Salinity (as Total Dissolved Solids) of surface water from Freshwater Lake, the Augustus River, Lunenburgh River Dam, Ernest River and Brunswick River, November 2024 and February 2025.

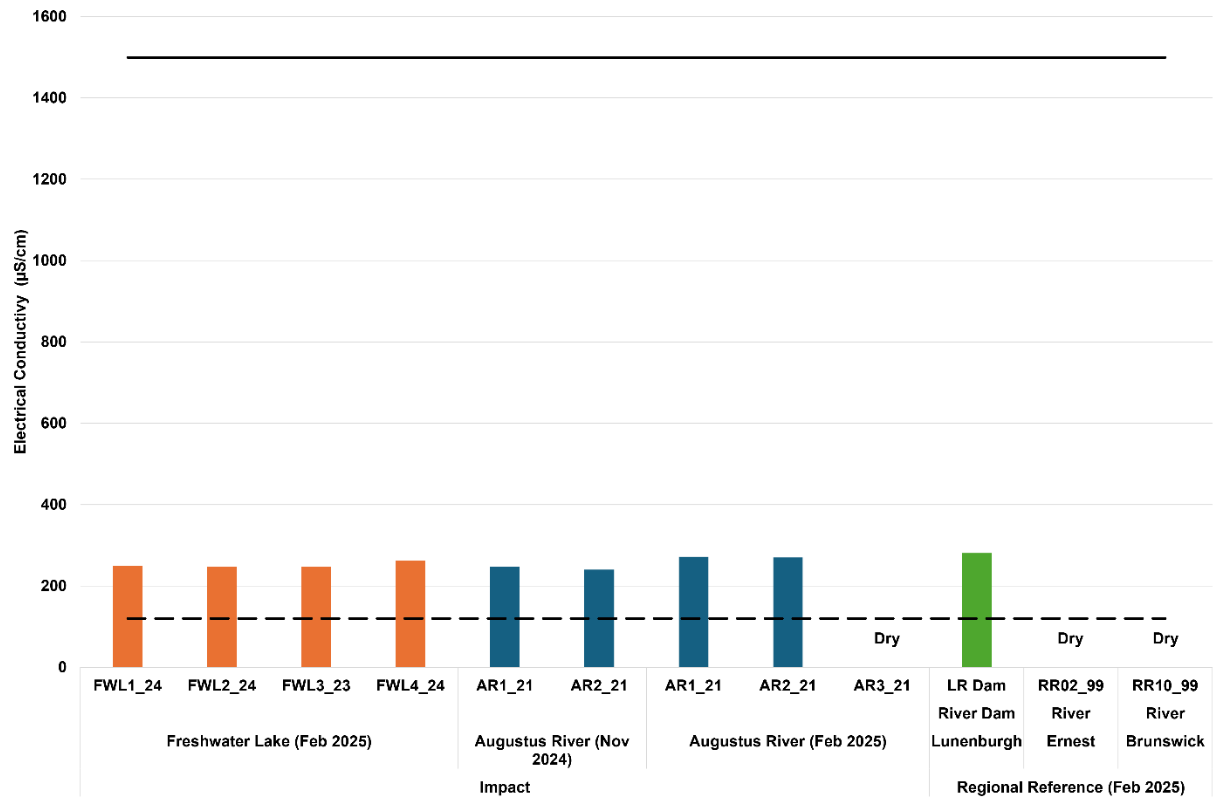

Figure 4-5: Electrical conductivity of surface water from Freshwater Lake, the Augustus River, Lunenburgh River Dam, Ernest River and Brunswick River, compared to ANZECC & ARMCANZ (2000a) upland river trigger value (dashed line) and upland wetland value (solid line), November 2024 and February 2025.

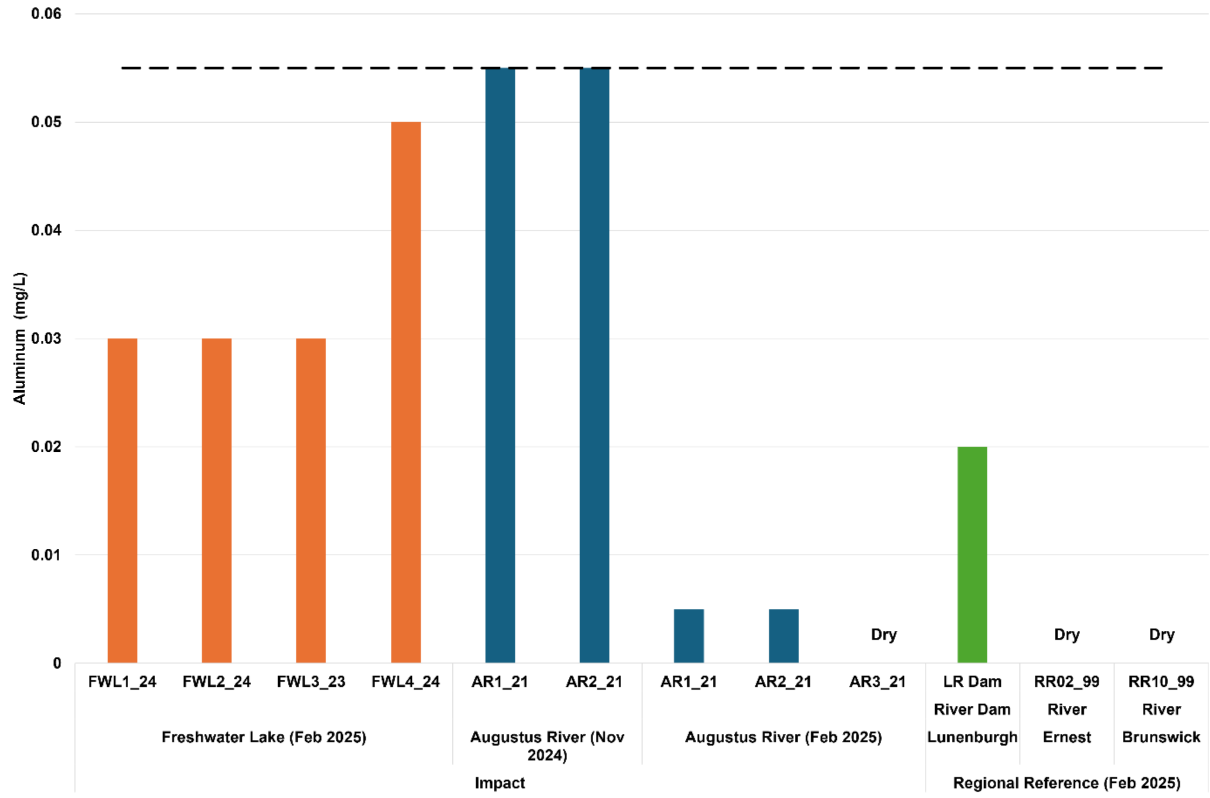

Figure 4-6: Aluminium concentrations recorded from surface water from Freshwater Lake, the Augustus River, Lunenburgh River Dam, Ernest River and Brunswick River, compared to Water Quality Australia (2021) 95% (dashed line) DGV, November 2024 and February 2025.

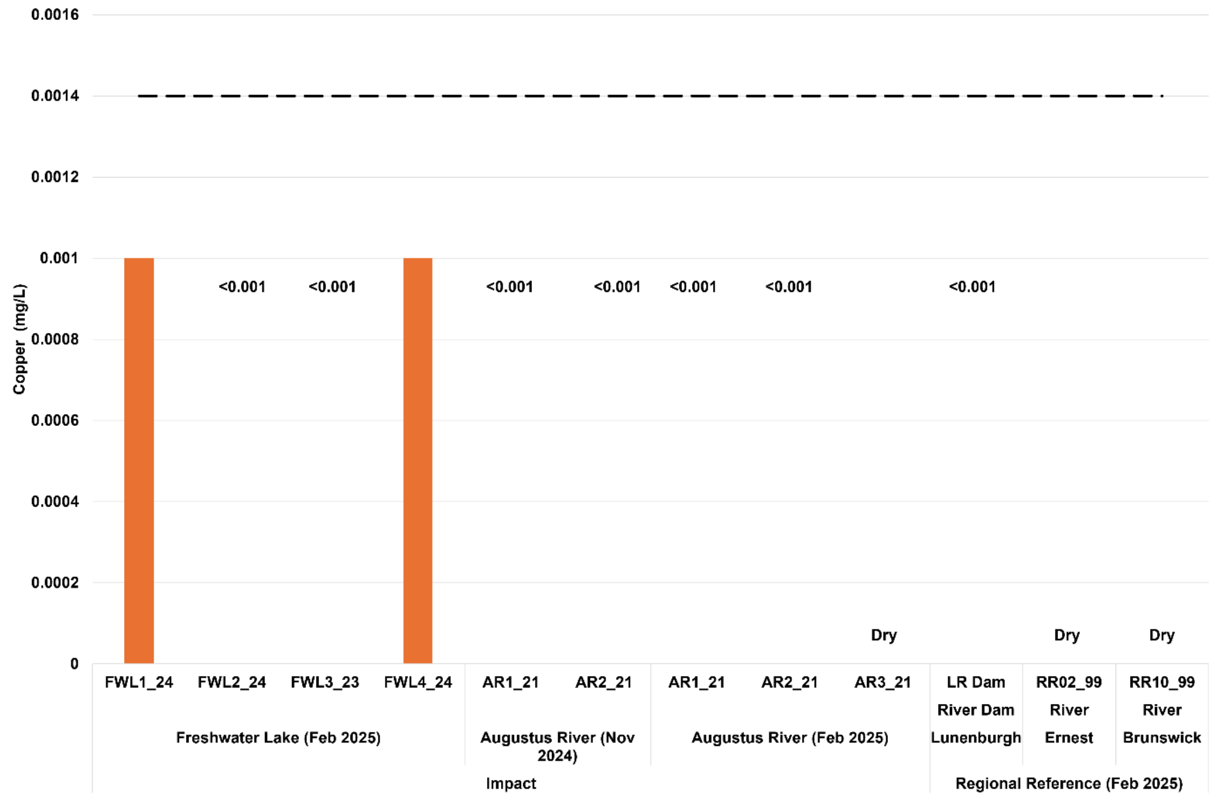

Figure 4-7: Copper concentrations recorded from surface water from Freshwater Lake, the Augustus River, Lunenburgh River Dam, Ernest River and Brunswick River, compared to Water Quality Australia (2021) 95% (dashed line) and 99% (solid line) DGV, November 2024 and February 2025.

4.4 Sediment Quality

The pH of sediment assessed at Freshwater Lake sites during the 2024 survey ranged from 6.4 to 7.0, from 5.6 to 6.6 at the Augustus River sites, and measured 6.6, 6.2 and 6.6 for the Lunenburgh River Dam, Brunswick River (RR10_99) and Ernest River (RR02_99), respectively (**Table 4-2**), classified as neutral to slightly acidic (Hazelton and Murphy 2007). These results were comparable to those recorded during the 2023 monitoring program (Stantec 2024) and are considered typical of the region (van Gool *et al.* 2018).

Sediment salinity, measured as total soluble salts (TSS), at Freshwater Lake sites ranged from 82 mg/kg to 293 mg/kg (**Table 4-2**). Similarly, salinity within the Augustus River ranged from 77 mg/kg to 244 mg/kg, and the regional reference sites were also comparable, ranging from 94 mg/kg to 143 mg/kg (**Table 4-2**, **Figure 4-8**). Given the presence of live Carter's Freshwater Mussel individuals at the Augustus River sampling sites, where sediment salinity varied by more than 100 mg/kg, sediment salinity was not considered to be a limiting variable during the 2024 survey.

Sediment moisture ranged from 19.6% to 40.1% at the shallow-water sites in Freshwater Lake, and from 5.6 % to 73.8% along the Augustus River, with the highest sediment moisture content value of all of the sites (73.8 %) recorded at site AR2_21, located upstream of the v-notch weir (**Table 4-2**, **Figure 4-8**). Sediment moisture was lowest at sites lacking surface water in February 2025 (**Table 4-2**, **Figure 4-8**).

The dominant cation in the sediment across all sampling sites for the 2024 survey was sodium, with other major cations (potassium, magnesium and calcium) all below the limit of reporting (**Table 4-2**), as was the case for the 2023 monitoring program (Stantec 2024). Unlike the 2023 monitoring program (Stantec 2024), sulphate was typically the less dominant anion across the Freshwater Lake and regional reference sites, generally lower in concentration than chloride, with carbonate being below limit of reporting across all sites (**Table 4-2**). In Augustus River sites, sulphate was the dominant anion except at site AR3 where chloride was higher than sulphate. Similar to the 2023 monitoring program (Stantec 2024), the concentration of sulphate was higher at site AR1 than any other site (**Table 4-2**), likely due to large deposits of decaying detritus settling at the v-notch weir wall (Stantec 2024). Acid sulphate soils are a major issue for freshwater fauna and can cause acidic water conditions that have been known to kill Carter's Freshwater Mussel, such as in Mussel Pool, within Whiteman Park, where the species no longer survives as a result (Department of Water and Environmental Regulation 2021)

Concentrations of nutrients within the sediment were variable across Freshwater Lake sites, with total nitrogen ranging from 560 mg/kg to 1,360 mg/kg, total phosphorus ranging from 86 mg/kg to 128 mg/kg, and total organic carbon ranging from 1.67 mg/kg to 1.79 mg/kg (**Table 4-2**). Nutrient concentrations in the Augustus River were also variable across sites, with total nitrogen ranging from 500 mg/kg to 2,810 mg/kg and total phosphorus ranging from 60 mg/kg to 243 mg/kg (**Table 4-2**). Total organic carbon ranged from 1.19 to 4.86 mg/kg across the Augustus River sites. At regional reference sites, total nitrogen ranged from 160 mg/kg to 1,290 mg/kg, total phosphorus ranged between 85 mg/kg and 116 mg/kg, and total organic carbon ranged from 0.68 mg/kg to 1.89 mg/kg. Similarly to nutrient concentrations recorded during the 2023 monitoring program (Stantec 2024), higher concentrations of nutrients in the Augustus River and at the regional reference sites may be attributed to increased organic material entering the system from riparian vegetation, due to the rivers location within a heavily forested catchment, unlike Freshwater Lake sites (**Appendix D**).

Concentrations of metals were generally above the limit of reporting excluding boron and cadmium and, similar to the 2023 monitoring program (Stantec 2024), all metals were below the Water Quality Australia (2021) DGVs and GV-High values where available. Aluminium concentrations in Freshwater Lake ranged between 18,600 mg/kg and 37,900 mg/kg, and were comparable to concentration recorded from the Augustus River (12,600 mg/kg to 26,600 mg/kg) (**Table 4-2**). Sediment aluminium concentrations in the Lunenburgh River Dam (LR_Dam_21; 18,900 mg/kg) and the Brunswick River (RR10_99; 17,900 mg/kg) were comparable to some Augustus River and Freshwater Lake sites, while in the Ernest River (RR02_99), the concentration was considerably lower at 5,950 mg/kg (**Table 4-2**). None of the sediment metal concentrations exceeded the Water Quality Australia (2021) DGV or GV-High values for any of the sites in the 2024 survey (**Table 4-2**), as was the case during the 2023 survey (Stantec 2024).

Table 4-2: Sediment quality data recorded from Freshwater Lake, the Augustus River, Lunenburgh River Dam, Ernest River and Brunswick River, February 2025.

Sediment Quality Parameters		LOR	Impact									Regional Reference			Water Quality Australia (2021)	
			Freshwater Lake				Augustus River					February 2025				
			February 2025				November 2024		February 2025			Lunenburgh River Dam	Brunswick River	Ernest River		
			FWL1_24	FWL2_24	FWL3_23	FWL4_24	AR 1_21	AR 2_21	AR 1_21	AR 2_21	AR 3_21	LR_Dam_21	RR10_99	RR02_99	DGV	GV-High
Basic	pH (Unit)	0.1	6.4	6.5	7.0	6.9	5.6	5.6	5.7	5.9	6.2	6.6	6.2	6.6	-	-
Basic	Total Soluble Salts (TSS)	5	82	293	125	239	77	167	173	98	244	103	143	94	-	-
Basic	Moisture Content (%)	1	27.0	40.1	19.6	39.2	26.6	73.8	40.3	21.7	5.6	35.6	5.5	<1.0	-	-
Cations and Anions	Sodium	10	40	80	40	110	30	170	70	20	60	50	40	20	-	-
Cations and Anions	Calcium	10	<10	<10	<10	<10	<10	30	<10	<10	<10	<10	<10	<10	-	-
Cations and Anions	Magnesium	10	<10	<10	<10	<10	<10	20	<10	<10	<10	<10	<10	<10	-	-
Cations and Anions	Potassium	10	<10	<10	<10	<10	<10	20	<10	<10	<10	<10	<10	<10	-	-
Cations and Anions	Chloride	10	30	110	30	110	20	120	40	20	60	50	30	20	-	-
Cations and Anions	Sulphate	10	30	10	20	70	30	390	100	50	40	20	20	10	-	-
Cations and Anions	Bicarbonate	5	8	8	82	47	<5	<5	<5	6	468	20	296	143	-	-
Cations and Anions	Carbonate	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	-	-
Nutrients	Total Nitrogen	20	860	950	560	1,360	510	2,810	1,540	500	1,010	1,290	1,140	160	-	-
Nutrients	Total Phosphorus	2	123	127	86	128	60	243	124	86	177	115	116	85	-	-
Nutrients	Total Organic Carbon (%)	0.02	1.68	-	1.79	-	1.19	4.86	-	-	2.60	0.68	1.89	0.97	-	-
Nutrients	Total Kjeldahl Nitrogen	20	860	950	560	1,360	510	2810	1,540	500	1,010	1,290	1,130	160	-	-
Nutrients	Nitrite + Nitrate	0.1	0.2	0.2	0.2	0.4	<0.1	0.1	0.1	0.1	3.5	0.2	5.9	0.3	-	-
Metals and Trace Elements	Aluminium	50	32,900	20,100	18,600	37,900	10,000	41,300	19,800	26,600	12,600	18,900	17,900	5,950	-	-
Metals and Trace Elements	Arsenic	1	<1.00	<1.00	<1.00	1	<1.00	2.40	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	20	70
Metals and Trace Elements	Boron	50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	-	-
Metals and Trace Elements	Cadmium	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.5	10
Metals and Trace Elements	Chromium	1	29	20	14	34	8.4	28.8	15	36	8	18	8	8	80	370
Metals and Trace Elements	Cobalt	0.5	4.0	2.0	0.6	7.2	2.6	38.2	8.5	2.1	20.9	14.3	6.6	2.6	-	-
Metals and Trace Elements	Copper	1	20	2	1	14	3.6	24.1	15	3	6	13	6	2	65	270
Metals and Trace Elements	Lead	1	12	7	13	13	5.0	15.5	11	7	8	14	8	4	50	220
Metals and Trace Elements	Manganese	10	45	157	48	134	15	128	52	52	660	102	60	34	-	-
Metals and Trace Elements	Mercury	0.01	0.03	0.04	0.01	0.02	<0.01	0.09	0.03	<0.01	0.02	0.02	0.02	<0.01	0.15	1
Metals and Trace Elements	Molybdenum	0.1	0.7	0.4	0.4	1.3	<2.0	<2.0	0.4	0.7	0.4	0.3	0.2	0.1		
Metals and Trace Elements	Nickel	1	7	2	2	7	4.8	36.8	8	6	7	7	5	3	21	52
Metals and Trace Elements	Selenium	0.1	0.2	0.3	<0.1	0.2	0.3	1.4	0.3	<0.1	0.4	0.3	0.2	<0.1	-	-
Metals and Trace Elements	Uranium	0.1	1.7	1.3	1.5	2.1	-	-	1.3	0.8	1.0	0.9	0.7	0.3		
Metals and Trace Elements	Vanadium	2	81	45	35	110	-	-	51	105	34	52	31	24	-	-
Metals and Trace Elements	Zinc	1	12	7	2	25	6.9	45.2	22	7	16	8	7	6	200	410

Note: all units are mg/kg unless otherwise specified.

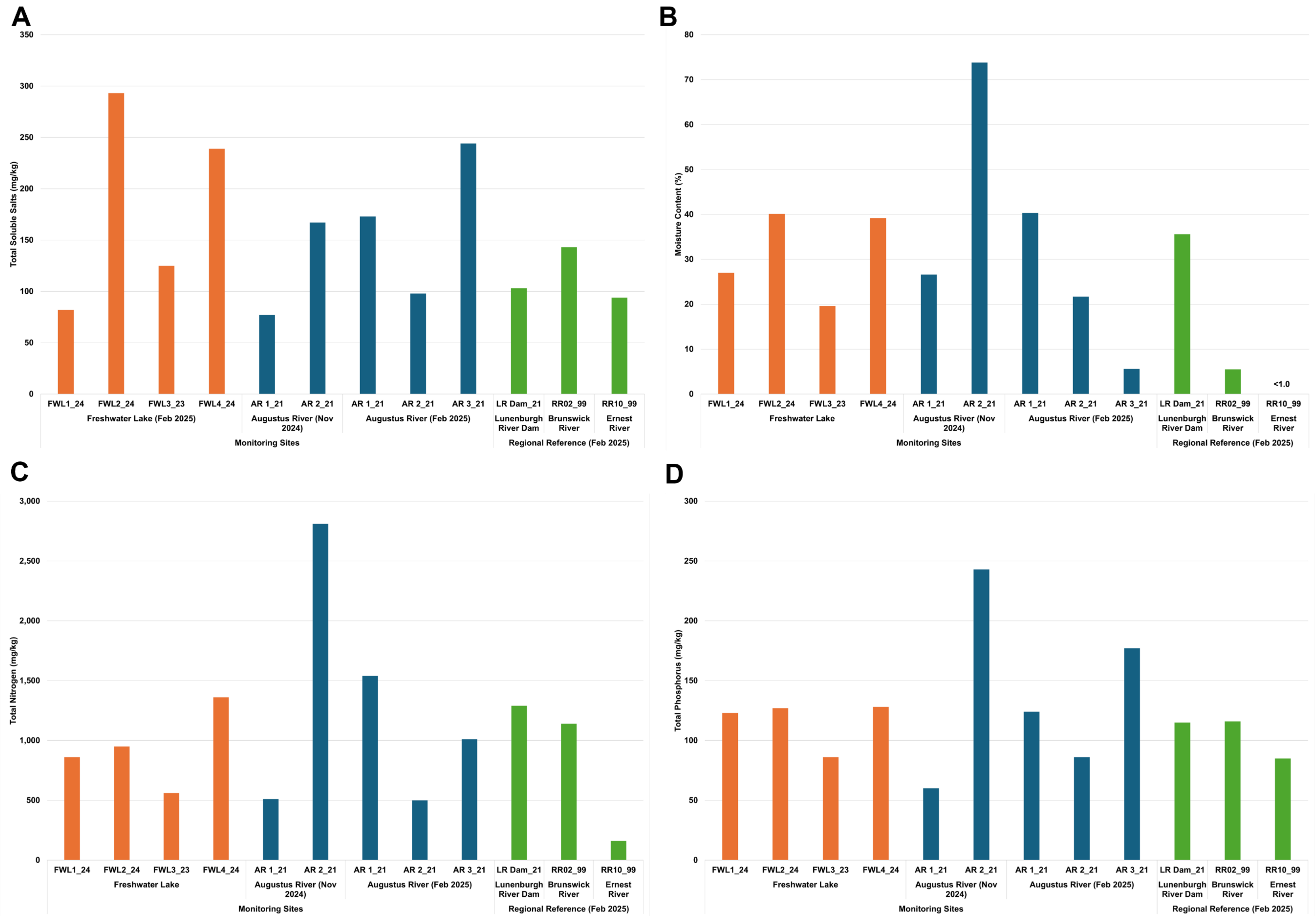

Figure 4-8: Sediment quality parameters from Freshwater Lake, the Augustus River, the Lunenburgh River Dam, the Ernest River and the Brunswick River, November 2024 and February 2025. A) Total Soluble Salts, B) Moisture Content, C) Total Nitrogen, D) Total Phosphorus.

4.5 Carter’s Freshwater Mussel Ecology

4.5.1 Occurrence and Abundance

A total of 199 Carter’s Freshwater Mussel individuals was recorded from AR1_21 and AR2_21, within the Augustus River, during November 2024 and a total of 334 Carter’s Freshwater Mussel individuals was recorded from seven sites during February 2025 (**Table 4-3**). Both live and dead Carter’s Freshwater Mussel individuals were present at deep-water Freshwater Lake sites, the Augustus River sites and the Lunenburgh River Dam (**Table 4-3**) but were not observed at the other two regional reference sites (Ernest River (RR02_99) or Brunswick River (RR02_99)) or shallow-water sites at Freshwater Lake in February 2025. Although empty shells were observed on the dry shores of Freshwater Lake, similarly to the 2023 monitoring program (Stantec 2024), they were not counted as they were outside of the targeted survey area and, due to the highly bleached nature of most of the shells, had probably been dead for a considerable period of time (likely years). Within Freshwater Lake, Carter’s Freshwater Mussel individuals were found to a maximum depth of 4.4 m and were limited by substrate type and potentially dissolved oxygen. Sampling sites were considerably drier during the 2024 survey than the 2023 monitoring program (Stantec 2024) and this was due to a combination of the differences in timing and flow conditions. During the 2023 monitoring program (Stantec 2024) where the field survey was undertaken in November 2023, the Augustus River, Brunswick River and Ernest River were flowing, whereas flow had ceased in February 2025. The lack of water may have resulted in non-detectability of Carter’s Freshwater Mussel in the Brunswick River reference site (RR10_99). Their rarity within that site could be attributed to the propensity of Carter’s Freshwater Mussel to burrow to escape drying (Lymbery *et al.* 2021), meaning they may have gone undetected. Where individuals were present, they were in greatest total abundance in the Augustus River, with a total of 199 and 286 individuals recorded during November 2024 and February 2025, respectively, followed by Freshwater Lake deep-water sites with a total of 48 individuals, and the Lunenburgh River Dam where a single empty shell was recorded (**Table 4-3**). In terms of relative total abundance, a similar trend was observed during the 2023 monitoring program (Stantec 2023), in which a total of 213 individuals was recorded from the Augustus River and 51 were recorded from Freshwater Lake deep-water sites, although no Carter’s Freshwater Mussel individuals were recorded from the Lunenburgh River Dam (LR_Dam_21) during the 2023 monitoring program.

Table 4-3: Total abundance of individuals recorded from each sampling site during the 2024 survey, February 2025.

Classification	Waterway	Site Code	No. Live	No. Dead	Site Total	Mortality (%)
Impact	Freshwater Lake	FWL1_24	0	0	0	-
		FWL2_24	0	0	0	-
		FWL3_23	0	0	0	-
		FWL4_24	0	0	0	-
		FWL_Dive1_21	6	2	8	25.00
		FWL_Dive2_24	15	23	38	60.52
		FWL_Dive3_24	0	2	2	100.00
		Total	***21***	***27***	***48***	***56.25***
	Augustus River (November 2024)	AR1_21	129	31	160	19.38
		AR2_21	30	9	39	23.1
		Total	***159***	***40***	***199***	***20.1***
	Augustus River (February 2025)	AR1_21	121	55	176	31.25
		AR2_21	72	7	79	8.86
		AR3_21	10	21	31	67.74
		Total	***203***	***83***	***286***	***29.02***
Regional Reference	Lunenburgh River Dam	LR_Dam_21	0	1	1	-
	Ernest River	RR02_99	0	0	0	-
	Brunswick River	RR10_99	0	0	0	-

4.5.2 Mortality

Apparent mortality of Carter's Freshwater Mussels should be treated with caution, as the results could represent cumulative mortality over subsequent years. Nevertheless, shells of dead Carter's Freshwater Mussel individuals appeared to be relatively intact, still having brown periostracum, were solid and the nacreous inner layers mostly intact. Over time, shells decay, with the inner and outer layers being lost first ((Cosgrove 2025; Ilarri *et al.* 2015)) and from what little information is available, shells deteriorate within the first 1-2 years and do not generally last more than 5-6 years (Cosgrove 2025). Sampling site mortality ranged from 25% to 100% in Freshwater Lake deep-water sites, with an overall mortality of 56.25% in Freshwater Lake (**Table 4-5**). Sampling site mortality across the Augustus River sites ranged from 8.86% to 67.74%, with an overall mortality of 20.1% for the two sites sampled in November 2024 and 29.02% across the three sites sampled in February 2025 (**Table 4-5**). For seasonal sampling comparison, excluding Site AR3_21 from February 2025, the overall mortality for sites AR1_21 and AR2_21 equated to 24.31% and the difference was significant ($Z = -2.17$, $p=0.03$; **Appendix G**). The increased mortality from November 2024 to February 2025 could have been due to drying of the area downstream of the v-notch weir at AR1_21, although mortality at AR2_21 in November 2024 was much greater than in February 2025, this discrepancy is unexpected given the site maintained water during both sampling events. It is likely though, that the removal of shells from the site in November 2024 could have reduced the mortality rate in subsequent sampling in February 2025. In the Augustus River, February 2025 mortality was significantly greater downstream from the v-notch weir in sites lacking water (AR1 and AR3) compared to the pooled area upstream of the v-notch weir (AR2) ($Z = -4.64$, $p<0.0001$; **Appendix G**). Mortality at sites AR1 and AR3 combined was 36.71% of 207 individuals, compared to a mortality of 8.86% of 79 individuals at the inundated AR2. Further to this, mortality increased significantly with greater drying and increasing distance downstream from the v-notch weir, where mortality at AR3 was 67.74% of 31 individuals compared to 31.25% of 176 freshwater mussels at AR1 ($Z = -3.89$, $p<0.001$; **Appendix G**). Additionally, mortality was significantly greater in Freshwater Lake (56.25% of 48 individuals) compared with the dry sites of the Augustus River (AR1+AR3, 36.71% of 207 individuals; $Z = 2.49$, $p=0.013$; **Appendix G**). This suggests that Freshwater Lake has experienced substantial drying events, likely over subsequent dry seasons, that have led to the mortality of Carter's Freshwater Mussel, consistent with observations of dead individuals on the shore as well as the presence of cracked clay in submerged habitats (**Appendix D**). Carter's Freshwater Mussel mortality differed between Freshwater Lake sites and the inundated Augustus River site (AR2) by more than 40% with 56.25% and 8.86% recorded, respectively ($Z = 5.85$, $p<0.0001$; **Appendix G**), indicating that site AR2 is likely to act as an area of refuge during summer drying events.

4.5.3 Density

Where Carter's Freshwater Mussel was found, quadrat densities ranged from 0 individuals/m^2 to 33 individuals/m^2 in November 2024 (**Table 4-4**, **Figure 4-9**) and 0 individuals/m^2 to 112 individuals/m^2 in February 2025 (**Table 4-5**, **Figure 4-9**). Due to the substantial number of individuals observed at site AR1_21 in the Augustus River during February 2025, only five quadrats were sampled at this site at the time. The increase in density is likely due to the tendency for freshwater mussels to aggregate as water levels recede during drying events (Lymbery *et al.* 2021). Average density of individuals (live and dead combined) was significantly greater at site AR1_21 compared to site AR3_21 during February 2025, with an average of 35.2 individuals/m^2 and an average of 3.1 individuals/m^2, recorded respectively ($U = 46.0$, $p=0.012$; **Appendix G**). However, average densities of Carter's Freshwater Mussel individuals (live and dead) were not significantly different from any other site within the Augustus River. There was significantly greater average density of dead individuals recorded from the dry Augustus River sites (AR1_21, AR3_21; average 5.07 individuals/m^2) compared to the inundated site (AR2_21; average 0.7 individuals/m^2) ($U = 34.50$, $p = 0.022$; **Appendix G**). The highest density of live Carter's Freshwater Mussel individuals was observed at AR1_21, downstream of the v-notch weir **(Table 4-5, Figure 4-9)**. This was consistent with the 2023 monitoring program findings (Stantec 2024). This is likely due to a combination of sediment that is suitable for burrowing, firm enough to facilitate stable filtration activity, and habitat characteristics supportive of both Carter's Freshwater Mussel and host fish. Features comprising intact riparian vegetation, abundant leaf litter, and in-stream habitat complexity (e.g., large woody debris, rocks, logs, etc.). Further, site AR1_21 is well-shaded to buffer against summer temperature extremes (Lymbery *et al.* 2021). Given the close proximity of AR1_21 to pooled water upstream of the v-notch weir, it is also likely that sediment moisture is maintained as a result of leakage or minor flow from the impounded water upstream of the weir. Conversely, site AR3_21, which is further away from the weir, was much drier and this likely contributes to the higher mortality observed at this site.

Table 4-4: Density of live and dead Carter's Freshwater Mussel individuals within each quadrat sampled within the Augustus River, November 2024.

Site Code	Quadrat No.	No. Live Individuals (/m^2)	No. Dead Individuals (/m^2)	Site Total	Mortality (%)
AR1_21	Q1	6	6	12	50.00
	Q2	31	0	31	0.00
	Q3	29	4	33	11.76
	Q4	-	-	-	-
	Q5	9	1	10	10.00
	Q6	10	4	14	28.57
	Q7	10	4	14	28.57
	Q8	7	6	13	46.15
	Q9	15	4	19	21.05
	Q10	12	2	14	14.29
	Total	***129***	***31***	***160***	***19.38***
AR2_21	Q1	-	-	-	-
	Q2	2	0	2	0.00
	Q3	5	3	8	37.50
	Q4	2	1	3	33.33
	Q5	1	0	1	0.00
	Q6	1	0	1	0.00
	Q7	6	2	8	25.00
	Q8	7	3	10	30.00
	Q9	4	0	4	0.00
	Q10	2	0	2	0.00
	Total	***30***	***9***	***39***	***23.08***

Table 4-5: Density of live and dead Carter's Freshwater Mussel individuals within each quadrat sampled within the Augustus River, February 2025.

Site Code	Quadrat No.	No. Live Individuals (/m^2)	No. Dead Individuals (/m^2)	Site Total	Mortality (%)
AR1_21	Q1	16	18	34	52.94
	Q2	3	2	5	40.00
	Q3	9	7	16	43.75
	Q4	93	19	112	16.96
	Q5	0	9	9	100.00
	Total	***121***	***55***	***176***	***31.25***
AR2_21	Q1	0	1	1	100.00
	Q2	13	0	13	0.00
	Q3	1	1	2	50.00
	Q4	1	0	1	0.00
	Q5	28	3	31	9.68
	Q6	15	0	15	0.00
	Q7	1	0	1	0.00
	Q8	1	0	1	0.00
	Q9	10	1	11	9.09
	Q10	2	1	3	33.33
	Total	***72***	***7***	***79***	***8.86***
AR3_21	Q1	0	0	0	-
	Q2	0	1	1	100.00
	Q3	0	2	2	100.00
	Q4	0	0	0	-
	Q5	0	1	1	100.00
	Q6	3	0	3	0.00
	Q7	0	2	2	100.00
	Q8	0	10	10	100.00
	Q9	0	1	1	100.00
	Q10	7	4	11	36.36
	Total	***10***	***21***	***31***	***67.74***

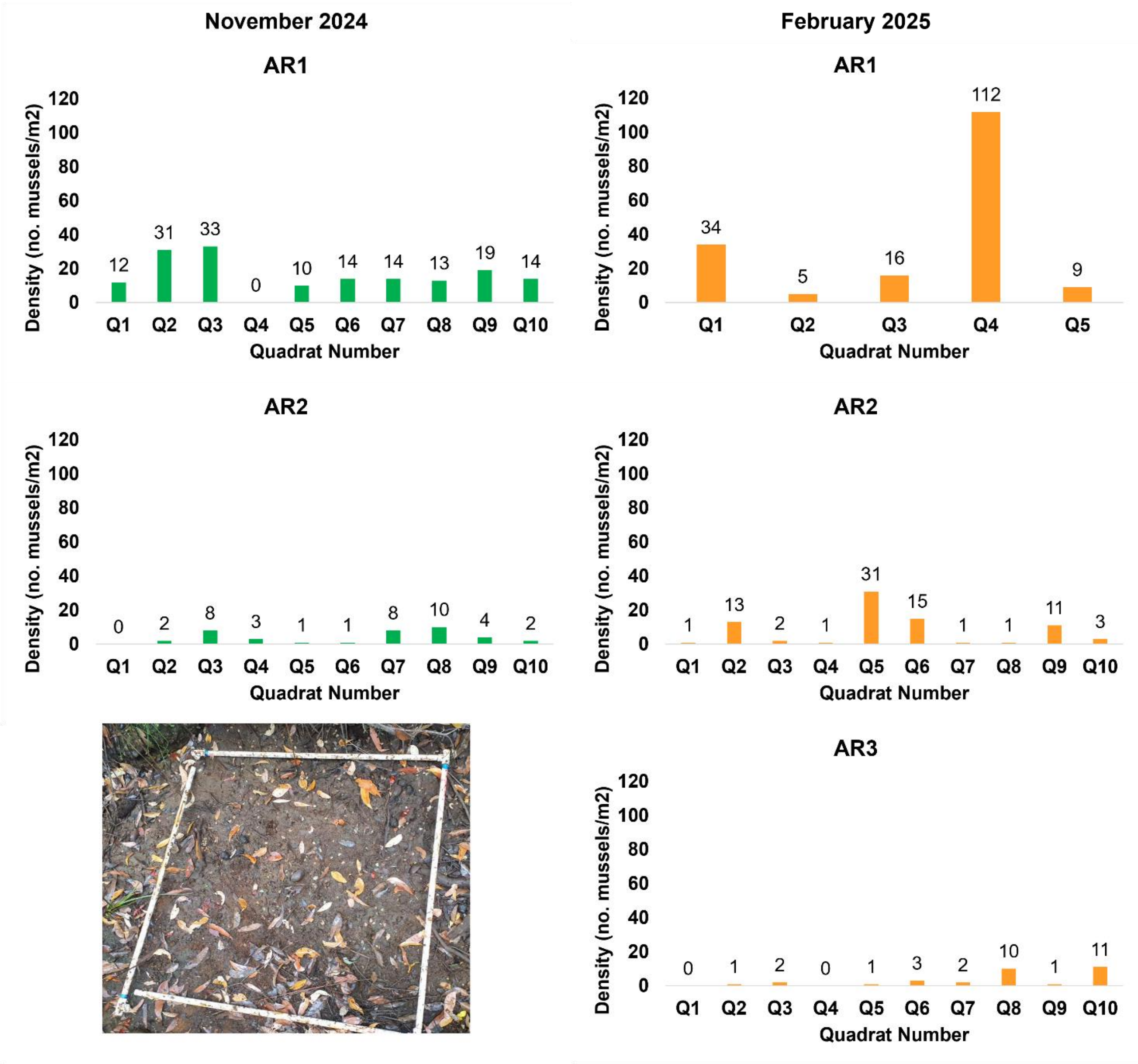

Figure 4-9: Overall (live and dead) density of Carter's Freshwater Mussel densities from the Augustus River sampling sites, November 2024 and February 2025.

4.5.4 Population Structure

Overall shell length of Carter's Freshwater Mussel individuals recorded during the 2024 survey ranged from 20 mm to 82.28 mm (**Table 4-6**). Length-frequency distribution classes from the Augustus River sites and Freshwater Lake for February 2025 are presented in **Figure 4-10**. As indicated by Stantec (2024), Carter's Freshwater Mussel may attain sexual maturity at <30 mm shell length and approximately 4-6 years of age, although age at length is variable depending on environmental conditions affecting growth (Klunzinger *et al.* 2014). Several smaller individuals (<30 mm) were recovered from sampling sites in both Freshwater Lake and the Augustus River, indicating recent recruitment had occurred within the last four to six years, as was the case during the 2023 monitoring program. Although one individual valve was recovered from the Lunenburgh River Dam, it could not be accurately measured due to damage, but it was likely an adult of between approximately 50 mm to 60 mm in length. Detecting smaller size classes less than between 30 mm and 40 mm in length is difficult when tactile searches are employed and it is likely that this size class is underrepresented in Carter's Freshwater Mussel surveys in general (Brainwood *et al.* 2006; Strayer 2008). Assuming most freshwater mussels present within sampling site quadrats were collected, the size class distributions suggest that survival of younger individuals may be lower. The majority of Carter's Freshwater Mussel individuals recorded during the 2024 survey, as was the case during the 2023 monitoring program (Stantec 2024), are likely to be sexually mature and may range in age from 8+ to >20+ years old (Klunzinger *et al.* 2014; Stantec 2024). The precise age of Carter's Freshwater Mussel individuals in Freshwater Lake, Augustus River and regional reference sites is entirely unknown as age estimates have not been undertaken at any of the sampling sites. However, the length-frequency distributions of the freshwater mussels recorded during the current survey program illustrate a pattern of regular recruitment, supported by the findings of the 2023 monitoring surveys which recovered three known host fish species that support the life cycle of Carter's Freshwater Mussel (Klunzinger *et al.* 2012b; Stantec 2024).

Survival of larger Carter's Freshwater Mussel individuals within dry sites (AR1_21 and AR3_21) appears to be lower than at the inundated Augustus River site AR2_21, although whether these sizes are comparable to age remains unknown. This pattern could be related to diet, predation, or other differences in site characteristics. In the two dry Augustus River sites, downstream from the v-notch weir (AR1_21 and AR3_21), the individuals recorded appeared superficially smaller than those from the inundated site AR2, with findings summarised as follows:

- Mean shell length was significantly larger at site AR2_21 (62.43 mm) compared to sites AR1_21 and AR3_21 (46.67 mm) (U = 14,438.5, $p<0.0001$; **Appendix G**).
- Mean shell length was significantly larger at site AR1_21 (48.17 mm) compared to at AR3_21 (38.11 mm) (U = 4,396.5, $p<0.0001$; **Appendix G**).
- Mean shell length was significantly larger at site AR2_21 (62.43 mm) compared to the Freshwater Lake sites (58.42 mm) (U = 1495.5, $p=0.0467$; **Appendix G**).

Differences in shell lengths at inundated sites compared to dry sites suggests that drying may be causing chronic growth cessation (i.e., stunting) during cease to flow periods downstream from the v-notch weir or individuals may be younger in these sites. The former hypothesis is probably more likely. Although similar proportions of live and dead freshwater mussels across all size classes were observed in Augustus River site AR3_21, there was a clear trend in larger numbers of live individuals in the smaller size classes, less than 50 mm in length and a much larger proportion of dead freshwater mussels in the larger size classes measuring 55-65 mm in length in AR1_21. This suggests that even in well-shaded, moist habitats, larger individuals are less resistant to drying than their smaller counterparts, potentially leading to losses in reproductive output for the Augustus River over successive cease to flow periods, noting that larger individuals produce greater numbers of offspring (Byrne 1998; Humphrey and Simpson 1985; Jones *et al.* 1986; Walker 2017).

Table 4-6: Summary of overall shell length for Carter's Freshwater Mussels from the 2024 survey.

Waterway	Site	Date	No. individuals recorded	Average Length (mm)	Minimum Length (mm)	Maximum Length (mm)	Standard Error (mm)
Augustus River	AR1_21	November 2024	160	48.94	20	66	±0.62
	AR2_21		39	63.7	41	76	±1.23
	AR1_21	February 2025	176	48.17	21.18	68.87	±0.69
	AR2_21		79	62.43	36.75	82.28	±1.01
	AR3_21		31	38.11	25.50	51.22	±0.77
Freshwater Lake	Pooled sites		48	59.07	41.00	70.04	±1.04

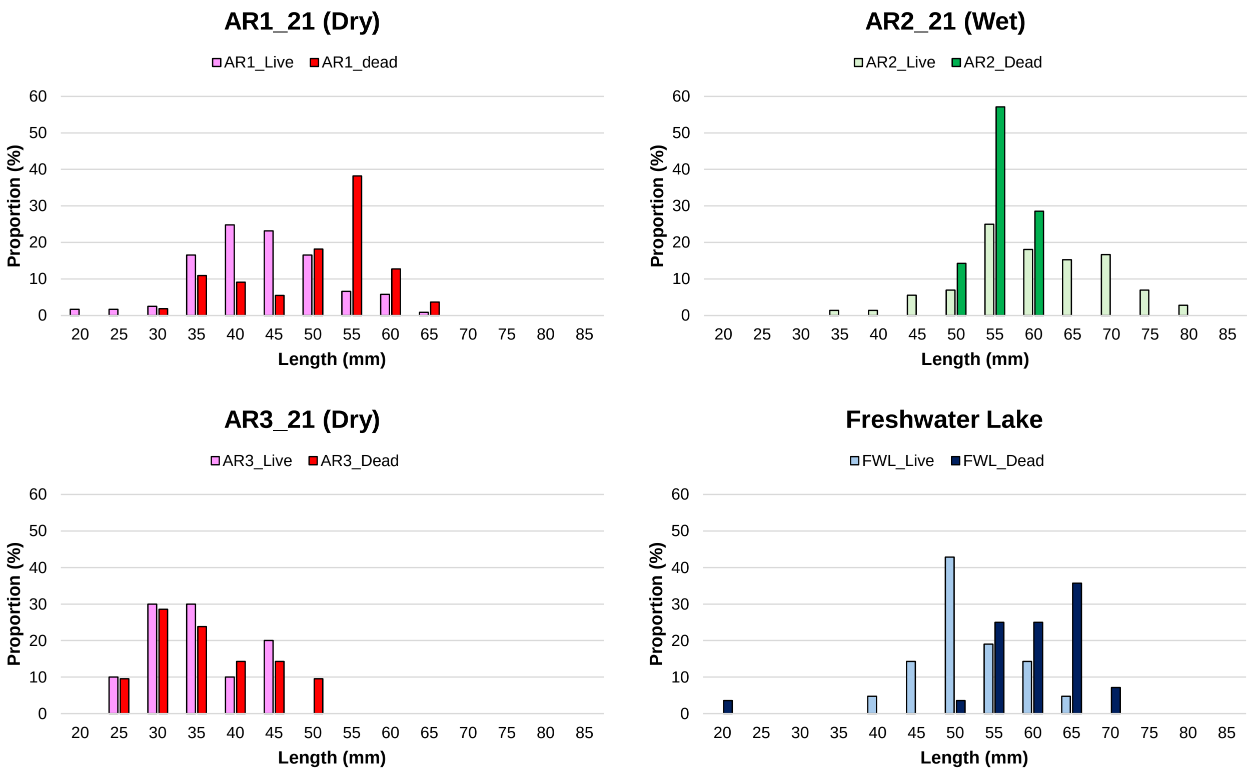

Figure 4-10: Length-frequency histograms of Carter's Freshwater Mussel in 5 mm size classes, from dry (,) and inundated (,) Augustus River sampling sites and Freshwater Lake, February 2025.

5. Summary & Recommendations

The 2024 survey addressed monitoring and reporting requirements outlined in the CFMMPMP (Stantec 2023) in relation to annual monitoring of Carter's Freshwater Mussel, listed as vulnerable on the IUCN Red List, BC Act and EPBC Act. Two sites in Augustus River, consisting of one site upstream from the v-notch weir (AR2_21) and one site downstream from the v-notch weir (AR1_21) were sampled for water and sediment quality and freshwater mussels on 12th November 2024 and a total of 10 sites (seven in Freshwater Lake; three in Augustus River and three regional reference sites) were sampled for water and sediment quality and freshwater mussels between the 9th and the 17th of February, 2025.

Between May 2021 and January 2025, the water level at Freshwater Lake fluctuated between a minimum of 230 m AHD and a maximum of 238 m AHD, noting that minimum water level was lower than had been recorded in the preceding years (2021 - 2023), attributed primarily to low rainfall and increased abstraction rates in mid- to late summer. Peak flow rates of between 23 L/5 mins and 53 L/5 mins were observed between July and September 2024 with a decrease in flow rate below 2.9 L/5 mins occurring between mid-September and mid-October 2024. Flow rate was maintained near the required 2.9 L/5 mins stipulated in SWL6804(4) between mid-September and November 2024 with a decrease below 2.9 L/5 mins after the 26th November 2024, breaching the minimum requirement for maintaining environmental flow in December 2024.

Water quality at Freshwater Lake, the Augustus River, and the regional reference sites during the 2024 Carter's Freshwater Mussel annual monitoring program was characterised by near neutral to slightly alkaline pH and low salinity and was well-oxygenated. The ANZECC & ARMCANZ (2000a) upper trigger value for electrical conductivity (120 µS/cm) in upland rivers was exceeded in the Augustus River sites during both November 2024 and February 2025. The ANZECC & ARMCANZ (2000a) lower trigger value for dissolved oxygen in upland rivers (<90%) was exceeded only in the Augustus River at Site AR2_21 in February 2025 with a dissolved oxygen measurement of 67.9%, but no other exceedances were observed across any other river or lake/dam sites. The ANZECC & ARMCANZ (2000a) upper trigger value for total phosphorus (0.02 mg/L) in upland rivers was marginally exceeded in November 2024 at the two Augustus River sites sampled (AR1_21 and AR2_21) with total phosphorus concentrations of 0.03 mg/L at both sites. No exceedances for Water Quality Australia (2021) DGVs were observed for ammonia or metals and metalloids in any of the sites sampled during the 2024 survey. Despite the observed exceedances of ANZECC & ARMCANZ (2000a) for electrical conductivity, dissolved oxygen and total phosphorus, this does not appear to be limiting to Carter's Freshwater Mussel.

Sediment quality at Freshwater Lake, the Augustus River, and the regional reference sites during the 2024 Carter's Freshwater Mussel annual monitoring program was characterised as slightly acidic in the Augustus River and regional reference sites with pH ranging from 5.6 to 6.6 and near neutral, ranging from 6.4 to 7.0 at Freshwater Lake sites. Sediment salinity was low, ranging from 77 to 293 mg/kg across all sites sampled. The lack of surface water at sites within the Augustus River downstream from the v-notch weir at sites AR1_21 and AR3_21, sampled during February 2025, was also reflected in sediment moisture content, with moisture contents of 40.3% at AR1_21 and 5.6% at AR3_21. Similarly, sediment moisture content at Site AR1_21 (downstream from the v-notch weir) was drier at 26.6% than above the v-notch weir at site AR2_21 (above the v-notch weir) where sediment moisture content measured 73.8% in November 2024. The dryness and lack of surface water at the Brunswick River (RR10_99) and the Ernest River (RR02_99) was also reflected in sediment moisture content, which measured 5.5% and <1.0% in the Brunswick River (RR10_99) and the Ernest River (RR02_99) during February 2025. There were no exceedances in available Water Quality Australia (2021) DGVs for any of the other sediment quality parameters tested for at any of the 2024 survey sites.

Live and dead Carter's Freshwater Mussel individuals were observed in Freshwater Lake and the Augustus River, but unlike the 2023 monitoring program, none were found at Brunswick River (RR10_99), where they had been observed previously. The survey conditions in February 2025 were considerably drier than they had been during the 2023 monitoring program and in November 2023 and November 2024. The patterns emerging from the 2024 survey suggest that water and sediment quality is less of an issue to freshwater mussels in the monitoring areas than drying. Mortalities of freshwater mussels observed during the 2024 survey are most likely a result of drying, particularly given Site AR2_21 with water pooled upstream from the v-notch weir in Augustus River had a substantially lower freshwater mussel mortality rate than sites that had ceased to flow, downstream from the weir. Freshwater mussel abundance and density also had a decreasing gradient with the distance from the v-notch weir in the Augustus River, with abundance and density being greater at AR1_21 than AR3_21, with the latter site being further downstream from the v-notch weir and much drier. Similarly, no freshwater mussels were found in the two regional reference sites at Brunswick River (RR10_99) and Ernest River (RR02_99) that were substantially drier than any of the other sites in February 2025.

In Freshwater Lake, Carter's Freshwater Mussel occupies a band of soft clayey sediment, which occurred at depths of between 1 and about 4 m during the 2024 survey. Drying events and lake level drawdown within Freshwater Lake have clearly resulted in the stranding of Carter's Freshwater Mussels, which has led to mortalities of the species, as evidenced from empty and bleached shells that have baked dry in the summer sun and heat. Nevertheless, Freshwater Lake continues to support the species. Evidence of recruitment was apparent from the recording of small Carter's Freshwater Mussels <30 mm in length (possibly as young as 2-6 years old) in both Freswater Lake and the Augustus River. Although age-at-length estimates of Carter's Freshwater Mussel individuals across the survey sites are not known, maximum shell lengths could represent individuals >20 years old. Additionally, the smaller sized freshwater mussels downstream from the v-notch weir suggests either that successive drying events have stunted growth, although age-at-length estimates for Carter's Freshwater Mussel individuals across survey sites could affirm that this is the case.

5.1 Recommendations

Following completion of the 2024 monitoring program, the following recommendations are provided for consideration by South32:

- Review the adequacy of current environmental flow regimes for maintaining Carter's Freshwater Mussel within Freshwater Lake and the Augustus River.
- Consider amending SWL6804(4) so that a suitable volume remains within Freshwater Lake that cannot be abstracted.
- Establish new regional reference sites in suitable waterways, preferably containing permanent surface water.
- Estimate age-at-length on shells collected during the 2024 monitoring program to inform whether smaller sizes at dry sites represent stunting or actual age in comparison with sites upstream from the v-notch weir.
- Develop a mitigation strategy to reduce mortality in Freshwater Lake (e.g., mussel relocation as water recedes).
- Implement a tracking program to monitor survival more closely between years and ensure mortality is from the previous season and not earlier. This will better inform management and monitoring programs.

6. CFMMPMP (Stantec 2023) Outcome-based Management Provisions

An address of the trigger and threshold criteria outlined in the outcome-based management provisions within the CFMMPMP are provided in **Table 6-1**.

Table 6-1: Address of CFMMPMP (Stantec 2023) outcome-based management provisions.

Outcome-based Management Objectives		Trigger Criteria	Trigger Criteria Exceeded?	Threshold Criteria	Threshold Criteria Exceeded?
IW1	**Minimise adverse impacts to CFM due to project-related land clearing surrounding Freshwater Lake or Augustus River.**	• Clearing occurs without an authorised internal permit within the CBME, but outside the 50 m buffer zone of Freshwater Lake.	• Not applicable to this scope of work	• Unauthorised clearing or disturbance within the 50 m buffer zone of Freshwater Lake.	• Not applicable to this scope of work
IW1		• Clearing occurs without an authorised internal permit within the CBME, but outside the 200m buffer zone of Augustus River.	• Not applicable to this scope of work	• Unauthorised clearing or disturbance within the 200m buffer zone of Augustus River.	• Not applicable to this scope of work
IW2	**Avoid adverse impacts to Carter's Freshwater Mussel from decreased water levels below minimum caused by excessive water abstraction within Freshwater Lake.**	• Water levels recorded below 231 m AHD in Freshwater Lake.	• ✕ Trigger criteria exceeded within Freshwater Lake (<231 m AHD from 10 April 2024 to 29 May 2025)	• Water levels recorded below 225 m AHD for a period of three months in Freshwater Lake.	• Threshold criteria not exceeded within Freshwater Lake
IW3	**Avoid adverse impacts to Carter's Freshwater Mussel from changes in suspended solids due to Project-related sedimentation.**	• Isolated occurrence of overtopping of sediment trap(s) into Freshwater Lake.	• Not applicable to this scope of work	• Continued occurrence / or overtopping of multiple sediment trap(s) into Freshwater Lake.	• Not applicable to this scope of work
IW3	**Avoid adverse impacts to Carter's Freshwater Mussel from changes in suspended solids due to Project-related sedimentation.**	• Total Suspended Soilds: >8 mg/L in the surface water of Freshwater Lake and Augustus River in a single monitoring event.	• Not monitored during 2024	• Total Suspended Soilds: >15 mg/L in the surface water of Freshwater Lake and Augustus River in a single monitoring event.	• Not monitored during 2024
IW4	**Avoid adverse impacts to Carter's Freshwater Mussel from elevated mercury (Hg) levels in the surface water of Freshwater Lake or Augustus River and in the sediment of Freshwater Lake.**	• Dissolved Mercury: >0.00006 mg/L in the surface water of Freshwater Lake and Augustus River, in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or Augustus River	• Dissolved mercury: >0.0006 mg/L in the surface water of Freshwater Lake and Augustus River, in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or Augustus River
IW4		• Total Mercury: 0.15 mg/kg in the sediment of Freshwater Lake and Augustus River, in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or Augustus River	• Total Mercury: 1.0 mg/kg in the sediment of Freshwater Lake and Augustus River, in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or Augustus River
IW5	**Avoid adverse impacts to Carter's Freshwater Mussel from elevated aluminium, cadmium, copper, lead, and zinc concentrations in the surface water of Freshwater Lake or Augustus River.**	• Dissolved Aluminium: >0.027 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or Augustus River	• Dissolved Aluminium: >0.055 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or Augustus River
IW5		• Dissolved Cadmium: >0.00006 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or Augustus River	• Dissolved Cadmium: >0.0002 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or Augustus River
IW5		• Dissolved Copper: >0.001 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or Augustus River	• Dissolved Copper: >0.0014 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or Augustus River
IW5		• Dissolved Lead: >0.001 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or Augustus River	• Dissolved Lead: >0.034 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or Augustus River
IW5		• Dissolved Zinc: >0.0024 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or Augustus River	• Dissolved Zinc: >0.008 mg/L in the surface water of Freshwater Lake and Augustus River, recorded in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or Augustus River
IW6	**Minimise adverse impacts to Carter's Freshwater Mussel from salinisation of the surface water of Freshwater Lake and Augustus River.**	• Salinity >1.6 g/L in the surface water of Freshwater Lake and/or Augustus River in a single monitoring event.	• Trigger criteria not exceeded within Freshwater Lake or the Augustus River	• Salinity >3 g/L in the surface water of Freshwater Lake and/or Augustus River in a single monitoring event.	• Threshold criteria not exceeded within Freshwater Lake or the Augustus River
IW6		• Individual mortality recorded of Carter's Freshwater Mussel at Freshwater Lake.	• ✕ Trigger criteria exceeded within Freshwater Lake with 37 dead Carter's Freshwater Mussel individuals recorded from deep-water sites	• 50% reduction in Carter's Freshwater Mussel known population size (individuals) in Freshwater Lake.	• ✕ Threshold criteria exceeded with mortality at 56.25%
IW6		• Reduction in density (per square metre) of Carter's Freshwater Mussel by >20% recorded at Augustus River.	• Trigger criteria not exceeded within Augustus River	• 50% reduction in Carter's Freshwater Mussel known density (per square metre) in Augustus River.	• Trigger criteria not exceeded within Augustus River

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Appendices

Appendix A Licenses & Permits

Appendix B Historical Surveys, Sites & Sampling Components, 1999-2024

Table B-1: Historical surveys, sites and sampling components implemented within Freshwater Lake, the Augustus River, and regional reference sites in the Lunenburgh River, Brunswick River and Ernest River (1999-2024).

Date Sampled	Survey	Type	Waterway	Sampling Site	Methods
March 1999 December 1999	Hale *et al.* (2000)	Potential Impact	Freshwater Lake	FWL5_99	• Shallow-water mussel transect
		Regional Reference	Brunswick River	RR10_99	• Shallow-water mussel transect
			Ernest River	RR02_99	• Shallow-water mussel transect
October 2004	WRM (2005)	Potential Impact	Augustus River	AR3_21	• Sediment quality
May 2021	Stantec (2021)	Potential Impact	Freshwater Lake	FWL_Dive1_21	• Diving
			Freshwater Lake	FWL03_21	• Quantitative mussel sampling (shoreline) • Sediment quality • Targeted mussel inspection (shoreline) • Water quality
			Freshwater Lake		
			Freshwater Lake		
			Freshwater Lake		
			Freshwater Lake	FWL4_21	• Quantitative mussel sampling (shoreline) • Sediment quality • Targeted mussel inspection (shoreline) • Water quality
			Freshwater Lake		
			Freshwater Lake		
			Freshwater Lake		
			Freshwater Lake	FWL_Dive2_21	• Diving
			Freshwater Lake	FWL_Dive3_21	• Diving
			Augustus River	AR3_21	• Shallow-water mussel transect
		Regional Reference	Lunenburgh River Dam	LRDam_21	• Shallow-water mussel transect
May 2021 July 2021	Stantec (2021)	Potential Impact	Freshwater Lake	FWL1_21	• Quantitative mussel sampling (shoreline) • Sediment quality • Targeted mussel inspection (shoreline) • Water Quality
				FWL2_21	• Quantitative mussel sampling (shoreline) • Sediment quality • Targeted mussel inspection (shoreline) • Water quality

Date Sampled	Survey	Type	Waterway	Sampling Site	Methods
				FWL05_21	• Quantitative mussel sampling (shoreline) • Sediment quality • Targeted mussel inspection (shoreline) • Water quality
			Augustus River	AR1_21	• Shallow-water mussel transect
				AR2_21	• Shallow-water mussel transect
July 2021	Stantec (2021)	Potential Impact	Freshwater Lake	FWL6_21	• Quantitative mussel sampling (shoreline) • Sediment quality • Targeted mussel inspection (shoreline) • Water Quality
November 2023	Stantec (2024)	Potential Impact	Freshwater Lake	FWL03_23	• Shallow-water mussel transect • Water quality • Sediment quality • Shallow-water mussel transect • Fish sampling
				FWL07_23	• Fish sampling • Sediment quality • Shallow-water mussel transect • Water quality
				FWL08_23	• Sediment quality • Shallow-water mussel transect • Water quality
				FWL09_23	• Sediment quality • Shallow-water mussel transect • Water quality
				FWL5_99	• Sediment quality • Shallow-water mussel transect • Water quality
				FWL_Dive1_21	• Snorkeling/free-diving mussel transects
				FWL_Dive2_24	• Snorkeling / free-diving mussel transects

Date Sampled	Survey	Type	Waterway	Sampling Site	Methods
				FWL_Dive3_24	• Snorkeling/free-diving mussel transects
			Augustus River	AR1_21	• Sediment quality • Water quality • Shallow-water quantitative mussel transect
				AR2_21	• Fish sampling • Shallow-water quantitative mussel transect • Sediment quality • Water quality
				AR3_21	• Sediment quality • Water quality • Shallow-water quantitative mussel transect
		Regional Reference	Brunswick River	RR10_99	• Sediment quality • Water quality • Shallow-water quantitative mussel transect
			Ernest River	RR02_99	• Sediment quality • Water quality • Shallow-water quantitative mussel transect
			Lunenburgh River Dam	LRDam_21	• Sediment quality • Water quality • Shallow-water quantitative mussel transect
			Augustus River	AR1_21	• Sediment quality • Water quality • Shallow-water quantitative mussel transect
				AR2_21	• Sediment quality • Water quality • Shallow-water quantitative mussel transect
February 2025	Stantec (2025)	Impact	Freshwater Lake	FWL1_24	• Water quality • Sedimetn quality • Shallow-water quantitative mussel transect
				FWL2_24	• Water quality

Date Sampled	Survey	Type	Waterway	Sampling Site	Methods
					• Sedimetn quality • Shallow-water quantitative mussel transect
				FWL3_23	• Water quality • Sedimetn quality • Shallow-water quantitative mussel transect
				FWL4_24	• Water quality • Sediment quality • Shallow-water quantitative mussel transect
				FWL_Dive1_21	• Deep-water targeted mussel searches
				FWL_Dive2_24	• Deep-water targeted mussel searches
				FWL_Dive3_24	• Deep-water targeted mussel searches
			Augustus River	AR1_21	• Water quality • Sedimetn quality • Shallow-water quantitative mussel transect
				AR2_21	• Water quality • Sedimetn quality • Shallow-water quantitative mussel transect
				AR3_21	• Water quality • Sedimetn quality • Shallow-water quantitative mussel transect
		Regional Reference	Lunenburgh River	LR_Dam_21	• Water quality • Sedimetn quality • Shallow-water quantitative mussel transect
			Ernest River	RR02_99	• Water quality • Sedimetn quality • Shallow-water quantitative mussel transect
			Brunswick River	RR10_99	• Water quality • Sedimetn quality • Shallow-water quantitative mussel transect

Appendix C Habitat Characterisation

Table C-1: Habitat characterisation of shallow-water sampling sites.

Classification	Waterbody	Site ID	Description
Impact	Freshwater Lake	FWL1_24	Dominant substrate comprising abundant cobble over hard clay; some chyrophytes, little to no woody debris and riparian vegetation non-existent
		FWL2_24	Dominant substrate comprising clay with an approximate 5° slope; little to no woody debris and riparian vegetation non-existent
		FWL3_23	Dominant substrate comprising approximately 75% cobble and 25% compacted clay; little to no woody debris and riparian vegetation non-existent
		FWL4_24	Dominant substrate comprising rocky sandy clay; little to no woody debris and riparian vegetation non-existent
	Augustus River	AR1_21	Dominant substrate comprising rocky sand with abundant large and small woody debris and leaf litter; riparian vegetation abundant with a canopy cover of about 40-50% and thick under- to mid- storey except in the main channel of the river; no standing water, but sediment remaining moist
		AR2_21	Dominant substrate comprising silty/sandy mud with occasional leaf litter and some woody debris; emergent sedges abundant along the water's edge and relatively open waterway with occasional shrubs and trees; site inundated with standing water and little flow, upstream from v-notch weir
		AR3_21	Dominant substrate comprising rocky sand with abundant large and small woody debris, logs and leaf litter; riparian vegetation abundant with a canopy cover of about 40-50% and thick under- to mid- storey; no standing water and riverbed mostly dry, except for moist pockets
Regional Reference	Lunenburgh River	LR_Dam_21	Dominant substrate comprising clayey sand, some small woody debris, leaf litter and macrophytes; occasional fringing vegetation and some woody debris
	Ernest River	RR02_99	Dominant substrate comprising sandy silt with boulders and cobble; woody debris and leaf litter was patchy ranging from occasional to common; channel completely dry with no standing water; riparian vegetation relatively abundant with flooded gums, sedges and rushes along the banks
	Brunswick River	RR10_99	Dominant substrate comprising sandy cobble; no water and channel was very dry; stream banks mildly undercut; canopy cover abundant, up to 80%, jarrah woodland

Table C-2: Habitat characterisation of deep-water sampling sites.

Depth (m)	Temperature (°C)	Visibility (cm)	FWL_Dive1_21	FWL_Dive2_24	FWL_Dive3_24
1	23	>10	Compacted clay with cobble	Compacted clay with cobble	Compacted, cracked clay
2	23	>10	Compacted clay with cobble	Compacted clay with cobble	Compacted, cracked clay
3	23	>10	Compacted clay	Compacted clay	Soft clay
4	23	>10	Compacted clay	Soft clay	Soft clay
5	23	>10	Soft clay	Soft clay	Soft mud/silt
6	Thermocline	>10	Soft clay	Soft clay	
7	17	<10	Soft mud/silt	Soft mud/silt	
8	17	<10	Soft mud/silt	Soft mud/silt	
9	17	<10		Soft mud/silt	

Table C-3: ***In situ*** **surface water quality data recorded from Freshwater Lake, the Lunenburgh River Dam, Ernest River and Brunswick River, February 2025.**

Water Quality Parameters	Impact									Regional Reference			ANZECC & ARMCANZ (2000)				Carter's Freshwater Mussel (Klunzinger *et al.* 2015; Perera 2023)	
	Freshwater Lake				Augustus River					Lunenburgh River Dam	Ernest River	Brunswick River	Upland River Trigger		Wetlands Trigger			
	February 2025				November 2024		February 2025			February 2025								
	FWL1_24	FWL2_24	FWL3_23	FWL4_24	AR1_21	AR2_21	AR1_21	AR2_21	AR3_21	LR Dam_21	RR02_99	RR10_99	Lower	Upper	Lower	Upper	LD_{50}	LD_{95}
pH (unit)	8.1	7.9	8.1	8.1	-	-	dry	6.9	dry	8.0	dry	dry	6.8	8.0	7.0	8.5	-	-
Electrical Conductivity (µS/cm)	253.30	266.50	256.00	254.83	216.9	239.0	dry	263.60	dry	294.87	dry	dry	120	300	300	1500	-	-
Salinity (g/L)	0.12	0.13	0.12	0.12	-	-	dry	0.13	dry	0.14	dry	dry	-	-	-	-	1.6	3
Dissolved Oxygen (mg/L)	9.50	9.11	8.70	9.05	-	-	dry	5.43	dry	7.65	dry	dry	-	-	-	-	-	-
Dissolved Oxygen (% Saturation)	113.74	112.31	105.46	109.02	99.9	100.6	dry	67.91	dry	92.67	dry	dry	90	-	90	120	-	-
Temperature (C°)	24.43	26.00	25.10	24.77	-	-	dry	22.63	dry	26.93	dry	dry	-	-	-	-	32.8	33.4

Note: all units are mg/L unless otherwise specified; red shading indicates exceedance of the ANZECC & ARMCANZ (2000a; 2000b) trigger values for upland rivers in southwest Western Australia; basic water quality and nutrient concentrations in bold font indicates exceedance of the Water Quality Australia (2021) DVGs for the protection of 99% of species in pristine freshwater systems; purple shading indicates the use of a Water Quality Australia (2021) DVG with an unknown species protection percentage. Given laboratory pH was analysed outside the maximum holding time of 6 hours, values presented are indicative only.

Appendix D Site Photos

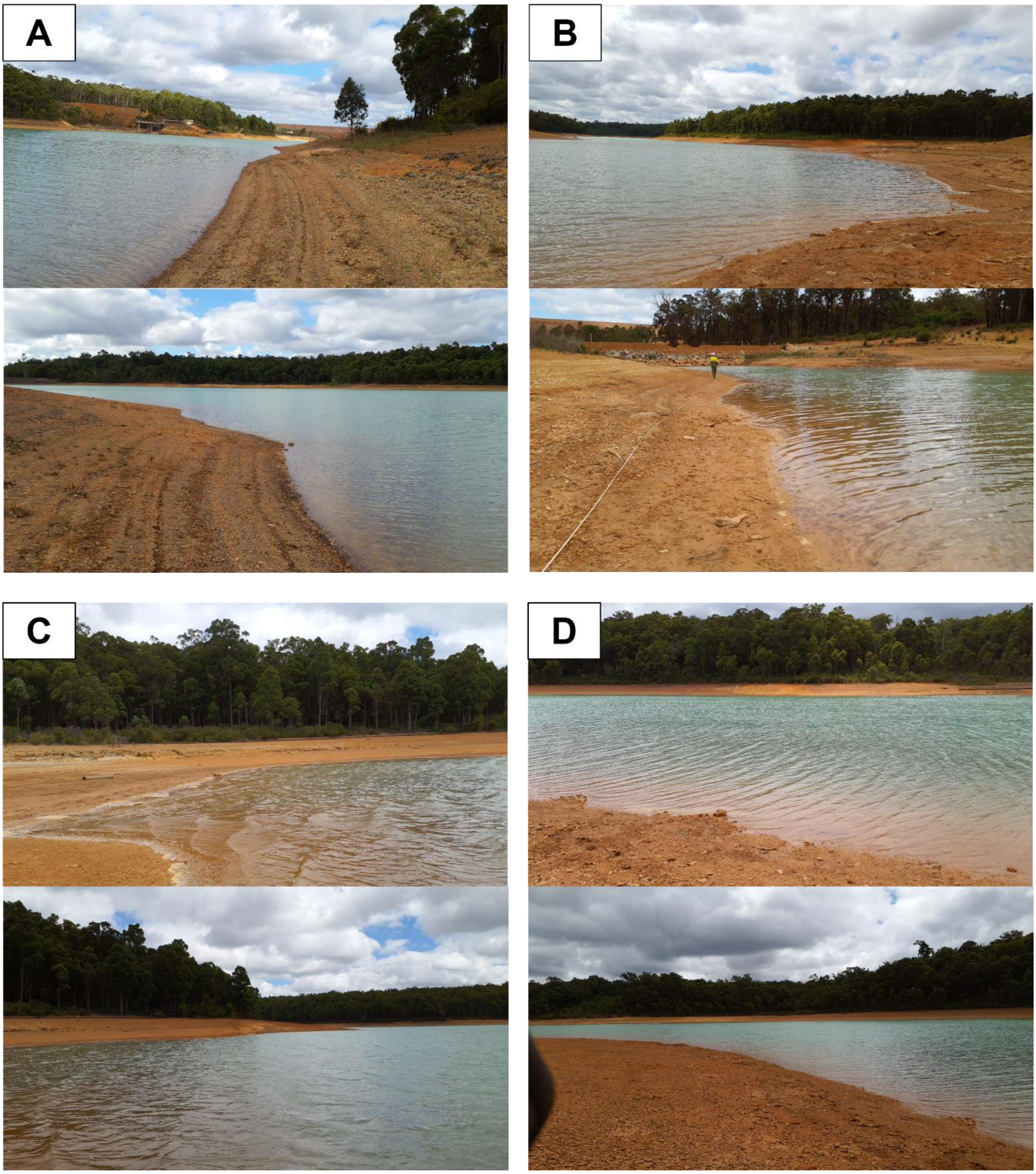

Figure D-1: Freshwater Lake shallow-water sampling sites, February 2025: A) Site FWL1_21; B) Site FWL2_24; C) Site FWL3_23; D) Site FWL4.

Figure D-2: Freshwater Lake deep-water sampling sites, February 2025.

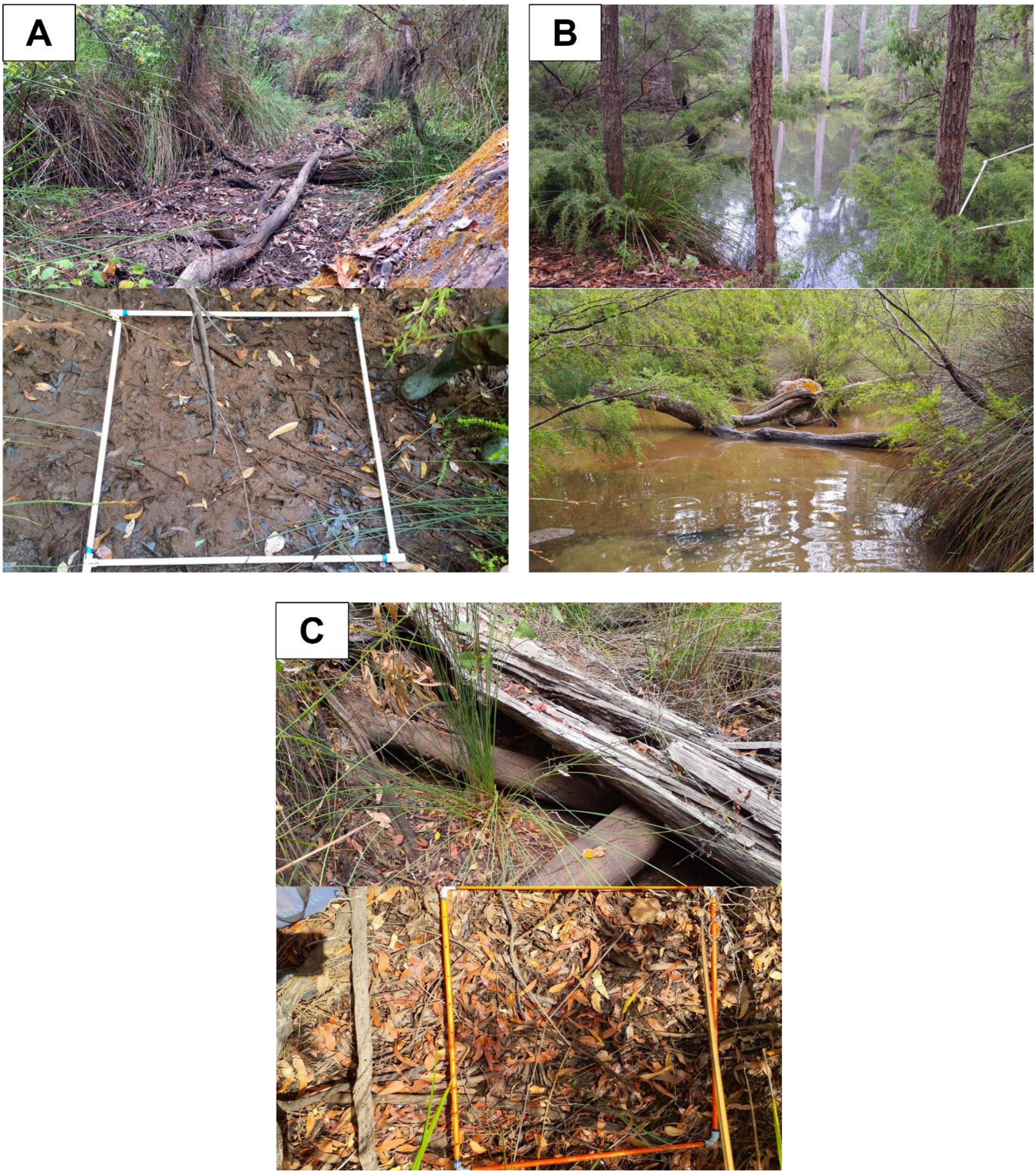

Figure D-3: Augustus River sampling sites, February 2025: A) Site AR1_21; B) Site AR2_21; C) Site AR3_21.

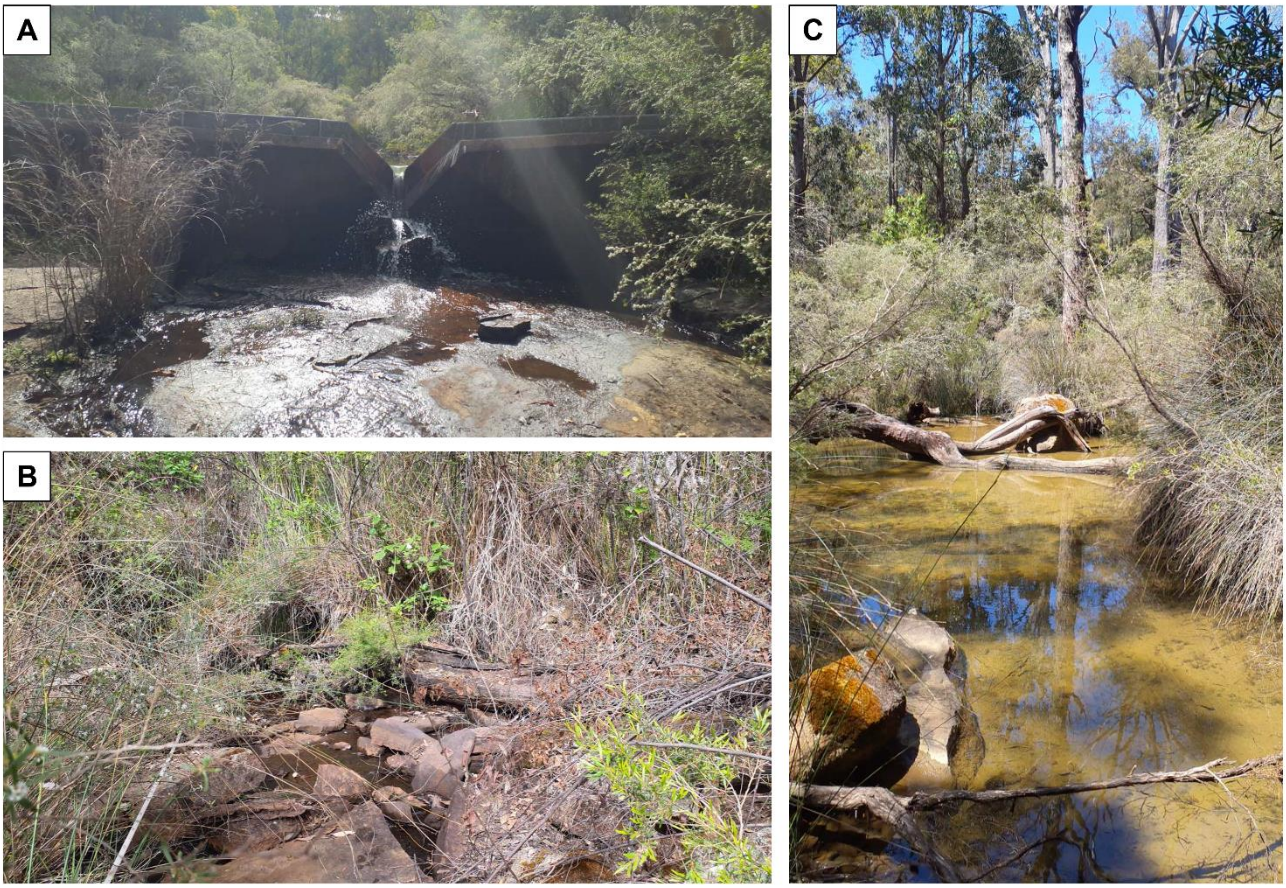

Figure D-4: Augustus River sampling sites, November 2024: A-B) Site AR1_21; C) Site AR2_21.

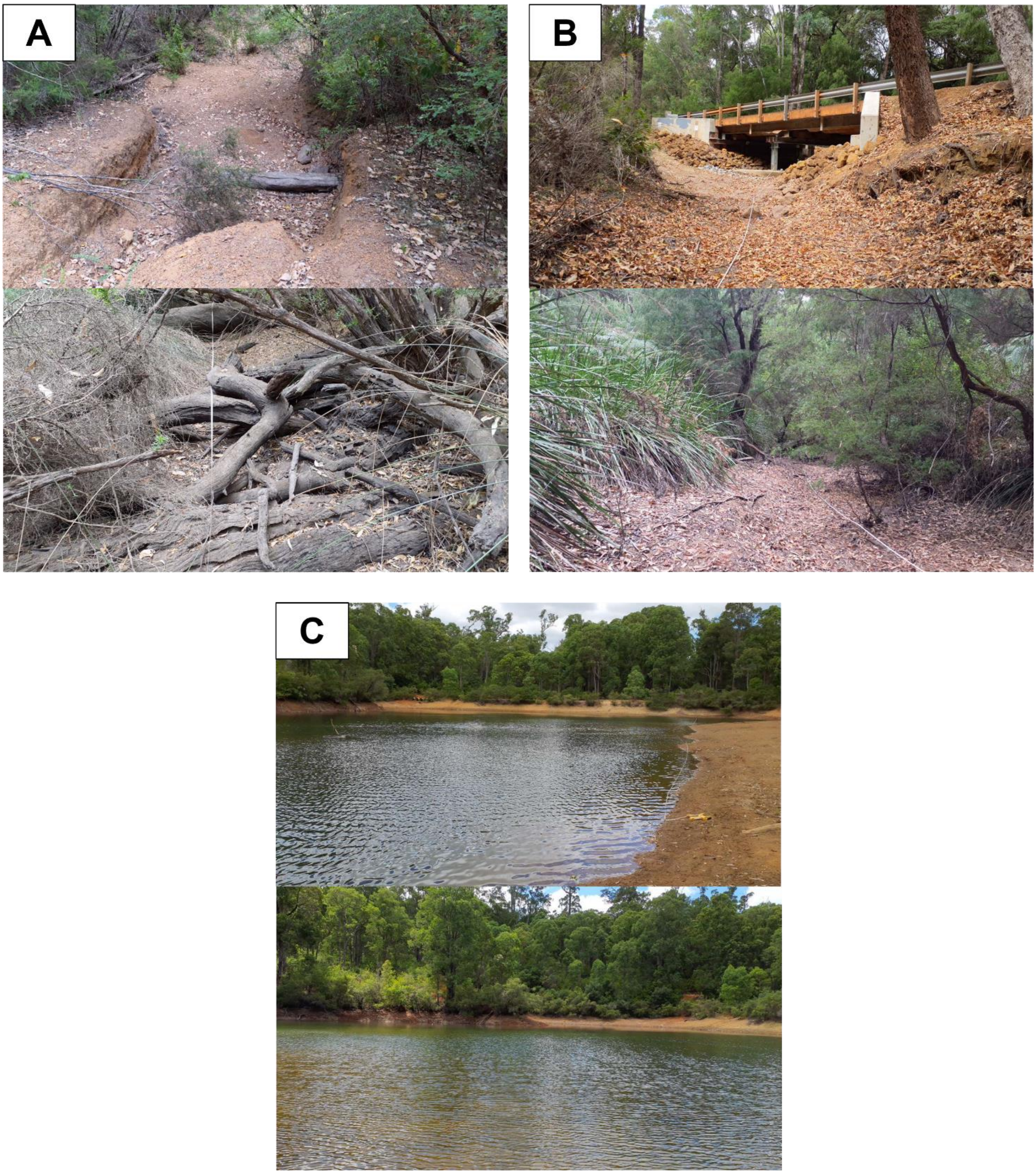

Figure D-5: Regional reference sampling sites, February 2025: A) Ernest River (RR02_99); B) Brunswick River (RR10_99); C) Lunenburgh River Dam (LR_DAM_21).

Appendix E Carter's Freshwater Mussel Shell Measurement Data

Table E- 1: Carter's Freshwater Mussel shell measurement data from 2023 and 2024.

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	60	Live
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	61	Live
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	56	Live
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	62	Dead
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	68	Dead
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	66	Live
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	49	Dead
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	63	Dead
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	59	Dead
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	70	Dead
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	55	Dead
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	65	Dead
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	73	Dead
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	71	Dead
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	68	Dead
November 2023	Freshwater Lake	FWL_Dive1_21	N/A	71	Dead
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	61	Live
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	74	Dead
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	60	Dead
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	63	Live
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	65	Dead
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	68	Live
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	66	Dead
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	71	Dead
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	68	Dead
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	56	Dead
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	64	Live
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	66	Dead
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	52	Live
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	59	Live
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	59	Live
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	78	Dead
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	64	Dead
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	74	Live
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	49	Live
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	63	Dead

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	62	Dead
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	69	Dead
November 2023	Freshwater Lake	FWL_Dive2_24	N/A	66	Dead
November 2023	Freshwater Lake	FWL_Dive3_24	N/A	63	Dead
November 2023	Freshwater Lake	FWL_Dive3_24	N/A	70	Dead
November 2023	Freshwater Lake	FWL_Dive3_24	N/A	62	Dead
November 2023	Freshwater Lake	FWL_Dive3_24	N/A	58	Dead
November 2023	Freshwater Lake	FWL_Dive3_24	N/A	61	Dead
November 2023	Freshwater Lake	FWL_Dive3_24	N/A	58	Dead
November 2023	Freshwater Lake	FWL_Dive3_24	N/A	71	Dead
November 2023	Freshwater Lake	FWL_Dive3_24	N/A	51	Live
November 2023	Freshwater Lake	FWL_Dive3_24	N/A	62	Live
November 2023	Freshwater Lake	FWL_Dive3_24	N/A	67	Dead
November 2023	Freshwater Lake	FWL_Dive3_24	N/A	65	Dead
November 2023	Freshwater Lake	FWL_Dive3_24	N/A	71	Dead
November 2023	Augustus River	AR1_21	1	52	Live
November 2023	Augustus River	AR1_21	1	51	Live
November 2023	Augustus River	AR1_21	1	49	Live
November 2023	Augustus River	AR1_21	1	51	Live
November 2023	Augustus River	AR1_21	1	47	Live
November 2023	Augustus River	AR1_21	2	48	Live
November 2023	Augustus River	AR1_21	2	48	Dead
November 2023	Augustus River	AR1_21	2	46	Live
November 2023	Augustus River	AR1_21	2	48	Live
November 2023	Augustus River	AR1_21	2	50	Live
November 2023	Augustus River	AR1_21	3	54	Live
November 2023	Augustus River	AR1_21	3	54	Live
November 2023	Augustus River	AR1_21	3	51	Live
November 2023	Augustus River	AR1_21	3	62	Live
November 2023	Augustus River	AR1_21	3	35	Live
November 2023	Augustus River	AR1_21	3	53	Live
November 2023	Augustus River	AR1_21	3	43	Live
November 2023	Augustus River	AR1_21	3	60	Live
November 2023	Augustus River	AR1_21	3	26	Live
November 2023	Augustus River	AR1_21	3	37	Live
November 2023	Augustus River	AR1_21	3	37	Live
November 2023	Augustus River	AR1_21	3	41	Live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
November 2023	Augustus River	AR1_21	3	41	Live
November 2023	Augustus River	AR1_21	3	41	Live
November 2023	Augustus River	AR1_21	3	41	Live
November 2023	Augustus River	AR1_21	3	41	Live
November 2023	Augustus River	AR1_21	3	41	Live
November 2023	Augustus River	AR1_21	3	46	Live
November 2023	Augustus River	AR1_21	3	46	Live
November 2023	Augustus River	AR1_21	3	46	Live
November 2023	Augustus River	AR1_21	3	46	Live
November 2023	Augustus River	AR1_21	3	46	Live
November 2023	Augustus River	AR1_21	3	46	Live
November 2023	Augustus River	AR1_21	3	46	Live
November 2023	Augustus River	AR1_21	3	46	Live
November 2023	Augustus River	AR1_21	3	46	Live
November 2023	Augustus River	AR1_21	3	50	Live
November 2023	Augustus River	AR1_21	3	50	Live
November 2023	Augustus River	AR1_21	3	50	Live
November 2023	Augustus River	AR1_21	3	50	Live
November 2023	Augustus River	AR1_21	3	50	Live
November 2023	Augustus River	AR1_21	3	50	Live
November 2023	Augustus River	AR1_21	3	50	Live
November 2023	Augustus River	AR1_21	3	50	Live
November 2023	Augustus River	AR1_21	3	54	Live
November 2023	Augustus River	AR1_21	3	54	Live
November 2023	Augustus River	AR1_21	3	54	Live
November 2023	Augustus River	AR1_21	3	61	Live
November 2023	Augustus River	AR1_21	3	61	Live
November 2023	Augustus River	AR1_21	4	63	Live
November 2023	Augustus River	AR1_21	4	58	Live
November 2023	Augustus River	AR1_21	4	66	Dead
November 2023	Augustus River	AR1_21	4	51	Live
November 2023	Augustus River	AR1_21	4	50	Live
November 2023	Augustus River	AR1_21	4	35	Live
November 2023	Augustus River	AR1_21	4	31	Live
November 2023	Augustus River	AR1_21	5	62	Live
November 2023	Augustus River	AR1_21	5	57	Live
November 2023	Augustus River	AR1_21	5	60	Live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
November 2023	Augustus River	AR1_21	5	52	Dead
November 2023	Augustus River	AR1_21	5	55	Live
November 2023	Augustus River	AR1_21	5	53	Live
November 2023	Augustus River	AR1_21	5	41	Live
November 2023	Augustus River	AR1_21	5	40	Live
November 2023	Augustus River	AR1_21	5	50	Live
November 2023	Augustus River	AR1_21	5	47	Live
November 2023	Augustus River	AR1_21	5	53	Dead
November 2023	Augustus River	AR1_21	5	32	Live
November 2023	Augustus River	AR1_21	5	34	Live
November 2023	Augustus River	AR1_21	6	62	Live
November 2023	Augustus River	AR1_21	6	56	Live
November 2023	Augustus River	AR1_21	6	59	Live
November 2023	Augustus River	AR1_21	6	50	Live
November 2023	Augustus River	AR1_21	6	44	Live
November 2023	Augustus River	AR1_21	6	42	Live
November 2023	Augustus River	AR1_21	6	41	Live
November 2023	Augustus River	AR1_21	6	66	Dead
November 2023	Augustus River	AR1_21	7	65	Dead
November 2023	Augustus River	AR1_21	7	64	Live
November 2023	Augustus River	AR1_21	7	61	Live
November 2023	Augustus River	AR1_21	7	53	Live
November 2023	Augustus River	AR1_21	7	49	Live
November 2023	Augustus River	AR1_21	7	44	Live
November 2023	Augustus River	AR1_21	7	47	Live
November 2023	Augustus River	AR1_21	7	45	Live
November 2023	Augustus River	AR1_21	7	49	Live
November 2023	Augustus River	AR1_21	7	49	Live
November 2023	Augustus River	AR1_21	7	47	Live
November 2023	Augustus River	AR1_21	7	47	Live
November 2023	Augustus River	AR1_21	7	47	Live
November 2023	Augustus River	AR1_21	7	47	Live
November 2023	Augustus River	AR1_21	7	36	Live
November 2023	Augustus River	AR1_21	8	66	Dead
November 2023	Augustus River	AR1_21	8	70	Live
November 2023	Augustus River	AR1_21	8	63	Live
November 2023	Augustus River	AR1_21	8	63	Live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
November 2023	Augustus River	AR1_21	8	53	Live
November 2023	Augustus River	AR1_21	8	58	Dead
November 2023	Augustus River	AR1_21	8	50	Live
November 2023	Augustus River	AR1_21	8	60	Live
November 2023	Augustus River	AR1_21	8	61	Live
November 2023	Augustus River	AR1_21	8	61	Live
November 2023	Augustus River	AR1_21	8	60	Live
November 2023	Augustus River	AR1_21	8	63	Live
November 2023	Augustus River	AR1_21	8	55	Live
November 2023	Augustus River	AR1_21	8	55	Live
November 2023	Augustus River	AR1_21	8	55	Live
November 2023	Augustus River	AR1_21	8	60	Live
November 2023	Augustus River	AR1_21	8	60	Live
November 2023	Augustus River	AR1_21	8	55	Live
November 2023	Augustus River	AR1_21	8	55	Live
November 2023	Augustus River	AR1_21	8	50	Live
November 2023	Augustus River	AR1_21	8	50	Live
November 2023	Augustus River	AR1_21	8	50	Live
November 2023	Augustus River	AR1_21	8	50	Live
November 2023	Augustus River	AR1_21	8	42	Live
November 2023	Augustus River	AR1_21	8	42	Live
November 2023	Augustus River	AR1_21	8	42	Live
November 2023	Augustus River	AR1_21	8	40	Live
November 2023	Augustus River	AR1_21	8	40	Live
November 2023	Augustus River	AR1_21	8	40	Live
November 2023	Augustus River	AR1_21	8	40	Live
November 2023	Augustus River	AR1_21	8	37	Live
November 2023	Augustus River	AR1_21	8	37	Live
November 2023	Augustus River	AR1_21	8	37	Live
November 2023	Augustus River	AR1_21	8	37	Live
November 2023	Augustus River	AR1_21	8	35	Live
November 2023	Augustus River	AR1_21	8	35	Live
November 2023	Augustus River	AR1_21	8	43	Dead
November 2023	Augustus River	AR1_21	9	60	Dead
November 2023	Augustus River	AR1_21	9	60	Live
November 2023	Augustus River	AR1_21	9	60	Live
November 2023	Augustus River	AR1_21	9	60	Live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
November 2023	Augustus River	AR1_21	9	60	Live
November 2023	Augustus River	AR1_21	9	60	Live
November 2023	Augustus River	AR1_21	9	60	Live
November 2023	Augustus River	AR1_21	9	57	Live
November 2023	Augustus River	AR1_21	9	57	Live
November 2023	Augustus River	AR1_21	9	57	Live
November 2023	Augustus River	AR1_21	9	57	Live
November 2023	Augustus River	AR1_21	9	57	Live
November 2023	Augustus River	AR1_21	9	57	Live
November 2023	Augustus River	AR1_21	9	50	Live
November 2023	Augustus River	AR1_21	9	50	Live
November 2023	Augustus River	AR1_21	9	50	Live
November 2023	Augustus River	AR1_21	9	50	Live
November 2023	Augustus River	AR1_21	9	50	Live
November 2023	Augustus River	AR1_21	9	42	Live
November 2023	Augustus River	AR1_21	9	42	Live
November 2023	Augustus River	AR1_21	9	42	Live
November 2023	Augustus River	AR1_21	9	42	Live
November 2023	Augustus River	AR1_21	9	42	Live
November 2023	Augustus River	AR1_21	9	42	Live
November 2023	Augustus River	AR1_21	9	40	Live
November 2023	Augustus River	AR1_21	9	40	Live
November 2023	Augustus River	AR1_21	10	52	Dead
November 2023	Augustus River	AR2_21	1	57	Dead
November 2023	Augustus River	AR2_21	1	61	Dead
November 2023	Augustus River	AR2_21	1	65	Dead
November 2023	Augustus River	AR2_21	1	66	Live
November 2023	Augustus River	AR2_21	1	67	Live
November 2023	Augustus River	AR2_21	1	70	Live
November 2023	Augustus River	AR2_21	1	71	Live
November 2023	Augustus River	AR2_21	1	71	Live
November 2023	Augustus River	AR2_21	1	71	Live
November 2023	Augustus River	AR2_21	2	62	Live
November 2023	Augustus River	AR2_21	2	62	Live
November 2023	Augustus River	AR2_21	2	64	Live
November 2023	Augustus River	AR2_21	3	62	Live
November 2023	Augustus River	AR2_21	3	63	Live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
November 2023	Augustus River	AR2_21	3	66	Live
November 2023	Augustus River	AR2_21	3	67	Live
November 2023	Augustus River	AR2_21	3	72	Dead
November 2023	Augustus River	AR2_21	3	72	Live
November 2023	Augustus River	AR2_21	3	75	Live
November 2023	Augustus River	AR2_21	4	57	Live
November 2023	Augustus River	AR2_21	4	69	Dead
November 2023	Augustus River	AR2_21	4	76	Live
November 2023	Augustus River	AR2_21	5	62	Dead
November 2023	Augustus River	AR2_21	5	63	Live
November 2023	Augustus River	AR2_21	5	66	Live
November 2023	Augustus River	AR2_21	5	70	Live
November 2023	Augustus River	AR2_21	5	71	Live
November 2023	Augustus River	AR2_21	5	73	Live
November 2023	Augustus River	AR2_21	6	38	Dead
November 2023	Augustus River	AR2_21	7	56	Live
November 2023	Augustus River	AR2_21	7	62	Live
November 2023	Augustus River	AR2_21	7	65	Live
November 2023	Augustus River	AR2_21	7	66	Live
November 2023	Augustus River	AR2_21	7	77	Live
November 2023	Augustus River	AR2_21	8	47	Live
November 2023	Augustus River	AR2_21	8	53	Live
November 2023	Augustus River	AR2_21	8	55	Live
November 2023	Augustus River	AR2_21	8	56	Live
November 2023	Augustus River	AR2_21	8	60	Dead
November 2023	Augustus River	AR2_21	8	61	Live
November 2023	Augustus River	AR2_21	9	44	Live
November 2023	Augustus River	AR2_21	9	48	Live
November 2023	Augustus River	AR2_21	9	52	Live
November 2023	Augustus River	AR2_21	9	52	Dead
November 2023	Augustus River	AR2_21	9	60	Live
November 2023	Augustus River	AR2_21	9	61	Live
November 2023	Augustus River	AR2_21	9	62	Live
November 2023	Augustus River	AR3_21	8	26	Live
November 2023	Augustus River	AR3_21	8	41	Live
November 2023	Augustus River	AR3_21	10	25	Live
November 2023	Augustus River	AR3_21	10	25	Live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
November 2023	Augustus River	AR3_21	10	28	Live
November 2023	Augustus River	AR3_21	10	31	Live
November 2023	Augustus River	AR3_21	10	39	Dead
November 2023	Augustus River	AR3_21	10	39	Dead
November 2023	Augustus River	AR3_21	10	44	Live
November 2023	Augustus River	AR3_21	10	45	Dead
November 2023	Brunswick River	RR10_99	3	40	Live
November 2023	Brunswick River	RR10_99	3	50	Live
November 2023	Brunswick River	RR10_99	3	53	Dead
November 2023	Brunswick River	RR10_99	4	50	Live
November 2023	Brunswick River	RR10_99	5	35	Live
November 2023	Brunswick River	RR10_99	8	44	Live
November 2023	Brunswick River	RR10_99	10	33	Live
November 2023	Brunswick River	RR10_99	10	44	Live
November 2024	Augustus River	AR1_21	1	55	dead
November 2024	Augustus River	AR1_21	1	50	dead
November 2024	Augustus River	AR1_21	1	51	dead
November 2024	Augustus River	AR1_21	1	49	dead
November 2024	Augustus River	AR1_21	1	45	dead
November 2024	Augustus River	AR1_21	1	37	dead
November 2024	Augustus River	AR1_21	1	50	live
November 2024	Augustus River	AR1_21	1	54	live
November 2024	Augustus River	AR1_21	1	51	live
November 2024	Augustus River	AR1_21	1	37	live
November 2024	Augustus River	AR1_21	1	36	live
November 2024	Augustus River	AR1_21	1	20	live
November 2024	Augustus River	AR1_21	2	55	live
November 2024	Augustus River	AR1_21	2	56	live
November 2024	Augustus River	AR1_21	2	53	live
November 2024	Augustus River	AR1_21	2	58	live
November 2024	Augustus River	AR1_21	2	58	live
November 2024	Augustus River	AR1_21	2	52	live
November 2024	Augustus River	AR1_21	2	52	live
November 2024	Augustus River	AR1_21	2	64	live
November 2024	Augustus River	AR1_21	2	64	live
November 2024	Augustus River	AR1_21	2	51	live
November 2024	Augustus River	AR1_21	2	51	live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
November 2024	Augustus River	AR1_21	2	51	live
November 2024	Augustus River	AR1_21	2	57	live
November 2024	Augustus River	AR1_21	2	57	live
November 2024	Augustus River	AR1_21	2	51	live
November 2024	Augustus River	AR1_21	2	51	live
November 2024	Augustus River	AR1_21	2	49	live
November 2024	Augustus River	AR1_21	2	52	live
November 2024	Augustus River	AR1_21	2	46	live
November 2024	Augustus River	AR1_21	2	46	live
November 2024	Augustus River	AR1_21	2	45	live
November 2024	Augustus River	AR1_21	2	45	live
November 2024	Augustus River	AR1_21	2	60	live
November 2024	Augustus River	AR1_21	2	60	live
November 2024	Augustus River	AR1_21	2	55	live
November 2024	Augustus River	AR1_21	2	55	live
November 2024	Augustus River	AR1_21	2	58	live
November 2024	Augustus River	AR1_21	2	58	live
November 2024	Augustus River	AR1_21	2	40	live
November 2024	Augustus River	AR1_21	2	40	live
November 2024	Augustus River	AR1_21	2	40	live
November 2024	Augustus River	AR1_21	3	60	dead
November 2024	Augustus River	AR1_21	3	60	dead
November 2024	Augustus River	AR1_21	3	60	dead
November 2024	Augustus River	AR1_21	3	53	dead
November 2024	Augustus River	AR1_21	3	42	live
November 2024	Augustus River	AR1_21	3	42	live
November 2024	Augustus River	AR1_21	3	48	live
November 2024	Augustus River	AR1_21	3	48	live
November 2024	Augustus River	AR1_21	3	55	live
November 2024	Augustus River	AR1_21	3	45	live
November 2024	Augustus River	AR1_21	3	45	live
November 2024	Augustus River	AR1_21	3	63	live
November 2024	Augustus River	AR1_21	3	53	live
November 2024	Augustus River	AR1_21	3	42	live
November 2024	Augustus River	AR1_21	3	46	live
November 2024	Augustus River	AR1_21	3	46	live
November 2024	Augustus River	AR1_21	3	50	live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
November 2024	Augustus River	AR1_21	3	50	live
November 2024	Augustus River	AR1_21	3	56	live
November 2024	Augustus River	AR1_21	3	56	live
November 2024	Augustus River	AR1_21	3	49	live
November 2024	Augustus River	AR1_21	3	49	live
November 2024	Augustus River	AR1_21	3	51	live
November 2024	Augustus River	AR1_21	3	51	live
November 2024	Augustus River	AR1_21	3	52	live
November 2024	Augustus River	AR1_21	3	52	live
November 2024	Augustus River	AR1_21	3	45	live
November 2024	Augustus River	AR1_21	3	45	live
November 2024	Augustus River	AR1_21	3	48	live
November 2024	Augustus River	AR1_21	3	48	live
November 2024	Augustus River	AR1_21	3	48	live
November 2024	Augustus River	AR1_21	3	37	live
November 2024	Augustus River	AR1_21	3	66	live
November 2024	Augustus River	AR1_21	4	-	-
November 2024	Augustus River	AR1_21	5	46	dead
November 2024	Augustus River	AR1_21	5	60	live
November 2024	Augustus River	AR1_21	5	48	live
November 2024	Augustus River	AR1_21	5	48	live
November 2024	Augustus River	AR1_21	5	45	live
November 2024	Augustus River	AR1_21	5	45	live
November 2024	Augustus River	AR1_21	5	42	live
November 2024	Augustus River	AR1_21	5	42	live
November 2024	Augustus River	AR1_21	5	43	live
November 2024	Augustus River	AR1_21	5	36	live
November 2024	Augustus River	AR1_21	6	45	dead
November 2024	Augustus River	AR1_21	6	37	dead
November 2024	Augustus River	AR1_21	6	38	dead
November 2024	Augustus River	AR1_21	6	54	dead
November 2024	Augustus River	AR1_21	6	53	live
November 2024	Augustus River	AR1_21	6	57	live
November 2024	Augustus River	AR1_21	6	43	live
November 2024	Augustus River	AR1_21	6	55	live
November 2024	Augustus River	AR1_21	6	51	live
November 2024	Augustus River	AR1_21	6	41	live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
November 2024	Augustus River	AR1_21	6	43	live
November 2024	Augustus River	AR1_21	6	38	live
November 2024	Augustus River	AR1_21	6	44	live
November 2024	Augustus River	AR1_21	6	36	live
November 2024	Augustus River	AR1_21	7	45	dead
November 2024	Augustus River	AR1_21	7	37	dead
November 2024	Augustus River	AR1_21	7	38	dead
November 2024	Augustus River	AR1_21	7	54	dead
November 2024	Augustus River	AR1_21	7	53	live
November 2024	Augustus River	AR1_21	7	57	live
November 2024	Augustus River	AR1_21	7	43	live
November 2024	Augustus River	AR1_21	7	55	live
November 2024	Augustus River	AR1_21	7	51	live
November 2024	Augustus River	AR1_21	7	41	live
November 2024	Augustus River	AR1_21	7	43	live
November 2024	Augustus River	AR1_21	7	38	live
November 2024	Augustus River	AR1_21	7	44	live
November 2024	Augustus River	AR1_21	7	36	live
November 2024	Augustus River	AR1_21	8	65	dead
November 2024	Augustus River	AR1_21	8	60	dead
November 2024	Augustus River	AR1_21	8	60	dead
November 2024	Augustus River	AR1_21	8	47	dead
November 2024	Augustus River	AR1_21	8	47	dead
November 2024	Augustus River	AR1_21	8	42	dead
November 2024	Augustus River	AR1_21	8	36	live
November 2024	Augustus River	AR1_21	8	40	live
November 2024	Augustus River	AR1_21	8	40	live
November 2024	Augustus River	AR1_21	8	58	live
November 2024	Augustus River	AR1_21	8	53	live
November 2024	Augustus River	AR1_21	8	52	live
November 2024	Augustus River	AR1_21	8	59	live
November 2024	Augustus River	AR1_21	9	65	dead
November 2024	Augustus River	AR1_21	9	55	dead
November 2024	Augustus River	AR1_21	9	48	dead
November 2024	Augustus River	AR1_21	9	48	dead
November 2024	Augustus River	AR1_21	9	56	live
November 2024	Augustus River	AR1_21	9	47	live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
November 2024	Augustus River	AR1_21	9	47	live
November 2024	Augustus River	AR1_21	9	47	live
November 2024	Augustus River	AR1_21	9	47	live
November 2024	Augustus River	AR1_21	9	36	live
November 2024	Augustus River	AR1_21	9	36	live
November 2024	Augustus River	AR1_21	9	48	live
November 2024	Augustus River	AR1_21	9	50	live
November 2024	Augustus River	AR1_21	9	42	live
November 2024	Augustus River	AR1_21	9	42	live
November 2024	Augustus River	AR1_21	9	44	live
November 2024	Augustus River	AR1_21	9	40	live
November 2024	Augustus River	AR1_21	9	40	live
November 2024	Augustus River	AR1_21	9	37	live
November 2024	Augustus River	AR1_21	10	60	dead
November 2024	Augustus River	AR1_21	10	48	dead
November 2024	Augustus River	AR1_21	10	63	live
November 2024	Augustus River	AR1_21	10	65	live
November 2024	Augustus River	AR1_21	10	55	live
November 2024	Augustus River	AR1_21	10	55	live
November 2024	Augustus River	AR1_21	10	53	live
November 2024	Augustus River	AR1_21	10	53	live
November 2024	Augustus River	AR1_21	10	57	live
November 2024	Augustus River	AR1_21	10	57	live
November 2024	Augustus River	AR1_21	10	47	live
November 2024	Augustus River	AR1_21	10	47	live
November 2024	Augustus River	AR1_21	10	43	live
November 2024	Augustus River	AR1_21	10	43	live
November 2024	Augustus River	AR2_21	1	-	-
November 2024	Augustus River	AR2_21	2	75	live
November 2024	Augustus River	AR2_21	2	58	live
November 2024	Augustus River	AR2_21	3	70	dead
November 2024	Augustus River	AR2_21	3	47	dead
November 2024	Augustus River	AR2_21	3	62	dead
November 2024	Augustus River	AR2_21	3	73	live
November 2024	Augustus River	AR2_21	3	65	live
November 2024	Augustus River	AR2_21	3	66	live
November 2024	Augustus River	AR2_21	3	74	live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
November 2024	Augustus River	AR2_21	3	67	live
November 2024	Augustus River	AR2_21	4	67	dead
November 2024	Augustus River	AR2_21	4	74	live
November 2024	Augustus River	AR2_21	4	65	live
November 2024	Augustus River	AR2_21	5	65	live
November 2024	Augustus River	AR2_21	6	76	live
November 2024	Augustus River	AR2_21	7	65	dead
November 2024	Augustus River	AR2_21	7	55	dead
November 2024	Augustus River	AR2_21	7	74	live
November 2024	Augustus River	AR2_21	7	64	live
November 2024	Augustus River	AR2_21	7	70	live
November 2024	Augustus River	AR2_21	7	61	live
November 2024	Augustus River	AR2_21	7	61	live
November 2024	Augustus River	AR2_21	7	69	live
November 2024	Augustus River	AR2_21	8	60	dead
November 2024	Augustus River	AR2_21	8	55	dead
November 2024	Augustus River	AR2_21	8	60	dead
November 2024	Augustus River	AR2_21	8	60	live
November 2024	Augustus River	AR2_21	8	65	live
November 2024	Augustus River	AR2_21	8	62	live
November 2024	Augustus River	AR2_21	8	60	live
November 2024	Augustus River	AR2_21	8	69	live
November 2024	Augustus River	AR2_21	8	57	live
November 2024	Augustus River	AR2_21	8	50	live
November 2024	Augustus River	AR2_21	9	65	live
November 2024	Augustus River	AR2_21	9	71	live
November 2024	Augustus River	AR2_21	9	67	live
November 2024	Augustus River	AR2_21	9	41	live
November 2024	Augustus River	AR2_21	10	57	live
November 2024	Augustus River	AR2_21	10	62	live
February 2025	Freshwater Lake	FWL_Dive1_21	N/A	61.17	Dead
February 2025	Freshwater Lake	FWL_Dive1_21	N/A	62.28	Dead
February 2025	Freshwater Lake	FWL_Dive1_21	N/A	69	Live
February 2025	Freshwater Lake	FWL_Dive1_21	N/A	53	Live
February 2025	Freshwater Lake	FWL_Dive1_21	N/A	47	Live
February 2025	Freshwater Lake	FWL_Dive1_21	N/A	62	Live
February 2025	Freshwater Lake	FWL_Dive1_21	N/A	49	Live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
February 2025	Freshwater Lake	FWL_Dive1_21	N/A	46	Live
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	66.7	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	65.58	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	65.5	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	63.32	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	69.95	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	59.97	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	63.36	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	62.25	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	67.77	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	65.5	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	70.04	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	65.55	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	58.83	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	63.35	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	66.72	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	61.18	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	56.65	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	58.88	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	55.63	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	58	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	66	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	70	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	55	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	20	Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	63	Live
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	50	Live
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	50	Live
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	53	Live
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	51	Live
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	52	Live
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	55	Live
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	56	Live
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	58	Live
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	63	Live
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	58	Live
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	54	Live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	54	Live
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	51	Live
February 2025	Freshwater Lake	FWL_Dive2_24	N/A	41	Live
February 2025	Freshwater Lake	FWL_Dive3_24	N/A	51.2	Dead
February 2025	Freshwater Lake	FWL_Dive3_24	N/A	69.93	Dead
February 2025	Augustus River	AR1_21	Q1	58	Live
February 2025	Augustus River	AR1_21	Q1	59.99	Live
February 2025	Augustus River	AR1_21	Q1	58.86	Live
February 2025	Augustus River	AR1_21	Q1	62.25	Live
February 2025	Augustus River	AR1_21	Q1	57.76	Live
February 2025	Augustus River	AR1_21	Q1	61.16	Live
February 2025	Augustus River	AR1_21	Q1	65.55	Live
February 2025	Augustus River	AR1_21	Q1	59.96	Live
February 2025	Augustus River	AR1_21	Q1	63.37	Live
February 2025	Augustus River	AR1_21	Q1	55.56	Live
February 2025	Augustus River	AR1_21	Q1	54.44	Live
February 2025	Augustus River	AR1_21	Q1	60.05	Live
February 2025	Augustus River	AR1_21	Q1	42.3	Live
February 2025	Augustus River	AR1_21	Q1	43.45	Live
February 2025	Augustus River	AR1_21	Q1	38.85	Live
February 2025	Augustus River	AR1_21	Q1	37.8	Live
February 2025	Augustus River	AR1_21	Q1	37.8	Dead
February 2025	Augustus River	AR1_21	Q1	39.9	Dead
February 2025	Augustus River	AR1_21	Q1	42.26	Dead
February 2025	Augustus River	AR1_21	Q1	43.38	Dead
February 2025	Augustus River	AR1_21	Q1	53.43	Dead
February 2025	Augustus River	AR1_21	Q1	55.53	Dead
February 2025	Augustus River	AR1_21	Q1	56.7	Dead
February 2025	Augustus River	AR1_21	Q1	57.75	Dead
February 2025	Augustus River	AR1_21	Q1	58.88	Dead
February 2025	Augustus River	AR1_21	Q1	58.93	Dead
February 2025	Augustus River	AR1_21	Q1	59.93	Dead
February 2025	Augustus River	AR1_21	Q1	59.97	Dead
February 2025	Augustus River	AR1_21	Q1	60.06	Dead
February 2025	Augustus River	AR1_21	Q1	61.15	Dead
February 2025	Augustus River	AR1_21	Q1	63.27	Dead
February 2025	Augustus River	AR1_21	Q1	63.4	Dead

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
February 2025	Augustus River	AR1_21	Q1	64.48	Dead
February 2025	Augustus River	AR1_21	Q1	65.62	Dead
February 2025	Augustus River	AR1_21	Q2	57.77	Dead
February 2025	Augustus River	AR1_21	Q2	58.92	Dead
February 2025	Augustus River	AR1_21	Q2	54.47	Live
February 2025	Augustus River	AR1_21	Q2	45.5	Live
February 2025	Augustus River	AR1_21	Q2	40.07	Live
February 2025	Augustus River	AR1_21	Q3	39.9	Dead
February 2025	Augustus River	AR1_21	Q3	39.95	Dead
February 2025	Augustus River	AR1_21	Q3	43.4	Dead
February 2025	Augustus River	AR1_21	Q3	45.6	Dead
February 2025	Augustus River	AR1_21	Q3	51.17	Dead
February 2025	Augustus River	AR1_21	Q3	54.47	Dead
February 2025	Augustus River	AR1_21	Q3	56.74	Dead
February 2025	Augustus River	AR1_21	Q3	51.16	Live
February 2025	Augustus River	AR1_21	Q3	48.87	Live
February 2025	Augustus River	AR1_21	Q3	53.4	Live
February 2025	Augustus River	AR1_21	Q3	45.57	Live
February 2025	Augustus River	AR1_21	Q3	40	Live
February 2025	Augustus River	AR1_21	Q3	41.16	Live
February 2025	Augustus River	AR1_21	Q3	39.98	Live
February 2025	Augustus River	AR1_21	Q3	45.56	Live
February 2025	Augustus River	AR1_21	Q3	41.15	Live
February 2025	Augustus River	AR1_21	Q4	31.17	Dead
February 2025	Augustus River	AR1_21	Q4	38.85	Dead
February 2025	Augustus River	AR1_21	Q4	39.97	Dead
February 2025	Augustus River	AR1_21	Q4	44.5	Dead
February 2025	Augustus River	AR1_21	Q4	45.6	Dead
February 2025	Augustus River	AR1_21	Q4	50.02	Dead
February 2025	Augustus River	AR1_21	Q4	50.06	Dead
February 2025	Augustus River	AR1_21	Q4	51.18	Dead
February 2025	Augustus River	AR1_21	Q4	53.38	Dead
February 2025	Augustus River	AR1_21	Q4	53.4	Dead
February 2025	Augustus River	AR1_21	Q4	53.4	Dead
February 2025	Augustus River	AR1_21	Q4	55.6	Dead
February 2025	Augustus River	AR1_21	Q4	58.85	Dead
February 2025	Augustus River	AR1_21	Q4	58.87	Dead

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
February 2025	Augustus River	AR1_21	Q4	58.9	Dead
February 2025	Augustus River	AR1_21	Q4	59.93	Dead
February 2025	Augustus River	AR1_21	Q4	59.95	Dead
February 2025	Augustus River	AR1_21	Q4	63.35	Dead
February 2025	Augustus River	AR1_21	Q4	68.87	Dead
February 2025	Augustus River	AR1_21	Q4	47.85	Live
February 2025	Augustus River	AR1_21	Q4	52.28	Live
February 2025	Augustus River	AR1_21	Q4	64.44	Live
February 2025	Augustus River	AR1_21	Q4	40.1	Live
February 2025	Augustus River	AR1_21	Q4	38.85	Live
February 2025	Augustus River	AR1_21	Q4	49.95	Live
February 2025	Augustus River	AR1_21	Q4	53.44	Live
February 2025	Augustus River	AR1_21	Q4	45.6	Live
February 2025	Augustus River	AR1_21	Q4	47.75	Live
February 2025	Augustus River	AR1_21	Q4	39.94	Live
February 2025	Augustus River	AR1_21	Q4	46.72	Live
February 2025	Augustus River	AR1_21	Q4	53.4	Live
February 2025	Augustus River	AR1_21	Q4	50.04	Live
February 2025	Augustus River	AR1_21	Q4	41.2	Live
February 2025	Augustus River	AR1_21	Q4	45.54	Live
February 2025	Augustus River	AR1_21	Q4	60.04	Live
February 2025	Augustus River	AR1_21	Q4	38.95	Live
February 2025	Augustus River	AR1_21	Q4	50.1	Live
February 2025	Augustus River	AR1_21	Q4	57.8	Live
February 2025	Augustus River	AR1_21	Q4	43.37	Live
February 2025	Augustus River	AR1_21	Q4	46.67	Live
February 2025	Augustus River	AR1_21	Q4	35.6	Live
February 2025	Augustus River	AR1_21	Q4	41.2	Live
February 2025	Augustus River	AR1_21	Q4	42.26	Live
February 2025	Augustus River	AR1_21	Q4	53.4	Live
February 2025	Augustus River	AR1_21	Q4	45.54	Live
February 2025	Augustus River	AR1_21	Q4	43.4	Live
February 2025	Augustus River	AR1_21	Q4	60.06	Live
February 2025	Augustus River	AR1_21	Q4	51.2	Live
February 2025	Augustus River	AR1_21	Q4	44.46	Live
February 2025	Augustus River	AR1_21	Q4	40.07	Live
February 2025	Augustus River	AR1_21	Q4	45.55	Live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
February 2025	Augustus River	AR1_21	Q4	53.42	Live
February 2025	Augustus River	AR1_21	Q4	37.8	Live
February 2025	Augustus River	AR1_21	Q4	46.7	Live
February 2025	Augustus River	AR1_21	Q4	44.52	Live
February 2025	Augustus River	AR1_21	Q4	48.9	Live
February 2025	Augustus River	AR1_21	Q4	46.7	Live
February 2025	Augustus River	AR1_21	Q4	50	Live
February 2025	Augustus River	AR1_21	Q4	44.46	Live
February 2025	Augustus River	AR1_21	Q4	51.2	Live
February 2025	Augustus River	AR1_21	Q4	44.5	Live
February 2025	Augustus River	AR1_21	Q4	39.94	Live
February 2025	Augustus River	AR1_21	Q4	39.97	Live
February 2025	Augustus River	AR1_21	Q4	35.6	Live
February 2025	Augustus River	AR1_21	Q4	52.27	Live
February 2025	Augustus River	AR1_21	Q4	45.55	Live
February 2025	Augustus River	AR1_21	Q4	43.37	Live
February 2025	Augustus River	AR1_21	Q4	38.88	Live
February 2025	Augustus River	AR1_21	Q4	40.1	Live
February 2025	Augustus River	AR1_21	Q4	48.85	Live
February 2025	Augustus River	AR1_21	Q4	54.45	Live
February 2025	Augustus River	AR1_21	Q4	38.94	Live
February 2025	Augustus River	AR1_21	Q4	39.9	Live
February 2025	Augustus River	AR1_21	Q4	45.55	Live
February 2025	Augustus River	AR1_21	Q4	46.74	Live
February 2025	Augustus River	AR1_21	Q4	47.84	Live
February 2025	Augustus River	AR1_21	Q4	43.37	Live
February 2025	Augustus River	AR1_21	Q4	52.3	Live
February 2025	Augustus River	AR1_21	Q4	51.2	Live
February 2025	Augustus River	AR1_21	Q4	40.08	Live
February 2025	Augustus River	AR1_21	Q4	35.5	Live
February 2025	Augustus River	AR1_21	Q4	48.85	Live
February 2025	Augustus River	AR1_21	Q4	33.39	Live
February 2025	Augustus River	AR1_21	Q4	35.52	Live
February 2025	Augustus River	AR1_21	Q4	46.75	Live
February 2025	Augustus River	AR1_21	Q4	52.35	Live
February 2025	Augustus River	AR1_21	Q4	43.4	Live
February 2025	Augustus River	AR1_21	Q4	40.06	Live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
February 2025	Augustus River	AR1_21	Q4	46.65	Live
February 2025	Augustus River	AR1_21	Q4	47.82	Live
February 2025	Augustus River	AR1_21	Q4	42.3	Live
February 2025	Augustus River	AR1_21	Q4	44.49	Live
February 2025	Augustus River	AR1_21	Q4	44.48	Live
February 2025	Augustus River	AR1_21	Q4	40.1	Live
February 2025	Augustus River	AR1_21	Q4	46.74	Live
February 2025	Augustus River	AR1_21	Q4	43.45	Live
February 2025	Augustus River	AR1_21	Q4	47.8	Live
February 2025	Augustus River	AR1_21	Q4	21.18	Live
February 2025	Augustus River	AR1_21	Q4	40.05	Live
February 2025	Augustus River	AR1_21	Q4	38.94	Live
February 2025	Augustus River	AR1_21	Q4	49	Live
February 2025	Augustus River	AR1_21	Q4	30.15	Live
February 2025	Augustus River	AR1_21	Q4	40.07	Live
February 2025	Augustus River	AR1_21	Q4	26.7	Live
February 2025	Augustus River	AR1_21	Q4	52.3	Live
February 2025	Augustus River	AR1_21	Q4	32.34	Live
February 2025	Augustus River	AR1_21	Q4	55.64	Live
February 2025	Augustus River	AR1_21	Q4	35.52	Live
February 2025	Augustus River	AR1_21	Q4	37.78	Live
February 2025	Augustus River	AR1_21	Q4	23.42	Live
February 2025	Augustus River	AR1_21	Q4	39.98	Live
February 2025	Augustus River	AR1_21	Q4	25.5	Live
February 2025	Augustus River	AR1_21	Q5	43.4	Dead
February 2025	Augustus River	AR1_21	Q5	45.58	Dead
February 2025	Augustus River	AR1_21	Q5	53.35	Dead
February 2025	Augustus River	AR1_21	Q5	55.58	Dead
February 2025	Augustus River	AR1_21	Q5	56.67	Dead
February 2025	Augustus River	AR1_21	Q5	57.77	Dead
February 2025	Augustus River	AR1_21	Q5	57.78	Dead
February 2025	Augustus River	AR1_21	Q5	57.83	Dead
February 2025	Augustus River	AR1_21	Q5	60.1	Dead
February 2025	Augustus River	AR2_21	Q1	57.82	Dead
February 2025	Augustus River	AR2_21	Q10	61.19	Dead
February 2025	Augustus River	AR2_21	Q10	71.05	Live
February 2025	Augustus River	AR2_21	Q10	66.64	Live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
February 2025	Augustus River	AR2_21	Q2	53.45	Live
February 2025	Augustus River	AR2_21	Q2	62.23	Live
February 2025	Augustus River	AR2_21	Q2	36.75	Live
February 2025	Augustus River	AR2_21	Q2	58.86	Live
February 2025	Augustus River	AR2_21	Q2	58.9	Live
February 2025	Augustus River	AR2_21	Q2	61.16	Live
February 2025	Augustus River	AR2_21	Q2	59.95	Live
February 2025	Augustus River	AR2_21	Q2	47.76	Live
February 2025	Augustus River	AR2_21	Q2	59.97	Live
February 2025	Augustus River	AR2_21	Q2	57.78	Live
February 2025	Augustus River	AR2_21	Q2	48.94	Live
February 2025	Augustus River	AR2_21	Q2	56.67	Live
February 2025	Augustus River	AR2_21	Q2	44.5	Live
February 2025	Augustus River	AR2_21	Q3	53.39	Dead
February 2025	Augustus River	AR2_21	Q3	55.65	Live
February 2025	Augustus River	AR2_21	Q4	66.76	Live
February 2025	Augustus River	AR2_21	Q5	56.65	Dead
February 2025	Augustus River	AR2_21	Q5	59.9	Dead
February 2025	Augustus River	AR2_21	Q5	61.18	Dead
February 2025	Augustus River	AR2_21	Q5	74.48	Live
February 2025	Augustus River	AR2_21	Q5	63.45	Live
February 2025	Augustus River	AR2_21	Q5	75.5	Live
February 2025	Augustus River	AR2_21	Q5	60.04	Live
February 2025	Augustus River	AR2_21	Q5	58.7	Live
February 2025	Augustus River	AR2_21	Q5	60.05	Live
February 2025	Augustus River	AR2_21	Q5	76.64	Live
February 2025	Augustus River	AR2_21	Q5	73.36	Live
February 2025	Augustus River	AR2_21	Q5	65.54	Live
February 2025	Augustus River	AR2_21	Q5	55.53	Live
February 2025	Augustus River	AR2_21	Q5	59.99	Live
February 2025	Augustus River	AR2_21	Q5	56.72	Live
February 2025	Augustus River	AR2_21	Q5	57.82	Live
February 2025	Augustus River	AR2_21	Q5	55.64	Live
February 2025	Augustus River	AR2_21	Q5	46.74	Live
February 2025	Augustus River	AR2_21	Q5	65.53	Live
February 2025	Augustus River	AR2_21	Q5	71.17	Live
February 2025	Augustus River	AR2_21	Q5	56.65	Live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
February 2025	Augustus River	AR2_21	Q5	77.8	Live
February 2025	Augustus River	AR2_21	Q5	62.3	Live
February 2025	Augustus River	AR2_21	Q5	60.06	Live
February 2025	Augustus River	AR2_21	Q5	62.3	Live
February 2025	Augustus River	AR2_21	Q5	71.2	Live
February 2025	Augustus River	AR2_21	Q5	58.88	Live
February 2025	Augustus River	AR2_21	Q5	65.5	Live
February 2025	Augustus River	AR2_21	Q5	61.18	Live
February 2025	Augustus River	AR2_21	Q5	73.35	Live
February 2025	Augustus River	AR2_21	Q5	61.16	Live
February 2025	Augustus River	AR2_21	Q6	71.18	Live
February 2025	Augustus River	AR2_21	Q6	67.75	Live
February 2025	Augustus River	AR2_21	Q6	72.26	Live
February 2025	Augustus River	AR2_21	Q6	68.92	Live
February 2025	Augustus River	AR2_21	Q6	58.94	Live
February 2025	Augustus River	AR2_21	Q6	82.28	Live
February 2025	Augustus River	AR2_21	Q6	60.05	Live
February 2025	Augustus River	AR2_21	Q6	70	Live
February 2025	Augustus River	AR2_21	Q6	62.24	Live
February 2025	Augustus River	AR2_21	Q6	65.64	Live
February 2025	Augustus River	AR2_21	Q6	62.26	Live
February 2025	Augustus River	AR2_21	Q6	51.14	Live
February 2025	Augustus River	AR2_21	Q6	55.5	Live
February 2025	Augustus River	AR2_21	Q6	53.34	Live
February 2025	Augustus River	AR2_21	Q6	48.85	Live
February 2025	Augustus River	AR2_21	Q7	77.73	Live
February 2025	Augustus River	AR2_21	Q8	71.12	Live
February 2025	Augustus River	AR2_21	Q9	55.53	Dead
February 2025	Augustus River	AR2_21	Q9	81.15	Live
February 2025	Augustus River	AR2_21	Q9	72.28	Live
February 2025	Augustus River	AR2_21	Q9	71.2	Live
February 2025	Augustus River	AR2_21	Q9	69.9	Live
February 2025	Augustus River	AR2_21	Q9	56.69	Live
February 2025	Augustus River	AR2_21	Q9	67.79	Live
February 2025	Augustus River	AR2_21	Q9	79.91	Live
February 2025	Augustus River	AR2_21	Q9	69.84	Live
February 2025	Augustus River	AR2_21	Q9	52.31	Live

Date	Waterbody	Site Code	Quadrat	Length	Live/Dead
February 2025	Augustus River	AR2_21	Q9	52.35	Live
February 2025	Augustus River	AR3_21	Q10	34.5	Dead
February 2025	Augustus River	AR3_21	Q10	34.5	Dead
February 2025	Augustus River	AR3_21	Q10	40.09	Dead
February 2025	Augustus River	AR3_21	Q10	46.67	Dead
February 2025	Augustus River	AR3_21	Q10	33.84	Live
February 2025	Augustus River	AR3_21	Q10	31.11	Live
February 2025	Augustus River	AR3_21	Q10	31.2	Live
February 2025	Augustus River	AR3_21	Q10	45.61	Live
February 2025	Augustus River	AR3_21	Q10	39.99	Live
February 2025	Augustus River	AR3_21	Q10	43.36	Live
February 2025	Augustus River	AR3_21	Q10	38.77	Live
February 2025	Augustus River	AR3_21	Q2	49.99	Dead
February 2025	Augustus River	AR3_21	Q3	33.41	Dead
February 2025	Augustus River	AR3_21	Q3	51.22	Dead
February 2025	Augustus River	AR3_21	Q5	25.5	Dead
February 2025	Augustus River	AR3_21	Q6	46.65	Live
February 2025	Augustus River	AR3_21	Q6	38.83	Live
February 2025	Augustus River	AR3_21	Q6	25.6	Live
February 2025	Augustus River	AR3_21	Q7	25.55	Dead
February 2025	Augustus River	AR3_21	Q7	51.13	Dead
February 2025	Augustus River	AR3_21	Q8	30	Dead
February 2025	Augustus River	AR3_21	Q8	32.24	Dead
February 2025	Augustus River	AR3_21	Q8	32.25	Dead
February 2025	Augustus River	AR3_21	Q8	36.74	Dead
February 2025	Augustus River	AR3_21	Q8	37.78	Dead
February 2025	Augustus River	AR3_21	Q8	37.8	Dead
February 2025	Augustus River	AR3_21	Q8	38.94	Dead
February 2025	Augustus River	AR3_21	Q8	40.15	Dead
February 2025	Augustus River	AR3_21	Q8	41.17	Dead
February 2025	Augustus River	AR3_21	Q8	46.69	Dead
February 2025	Augustus River	AR3_21	Q9	39.98	Dead

Appendix F Historical Water & Sediment Quality Data

Table F- 1: Historical surface water quality data recorded from Freshwater Lake and the Augustus River.

Water Quality Parameters		Freshwater Lake										Augustus River					
		FWL1	FWL2	FWL3	FWL4	FWL5	FWL03_23	FWL05_99	FWL07_23	FWL08_23	FWL09_23	AR1	AR2	AR3	AR1_21	AR2_21	AR3_21
		2021	2021	2021	2021	2021	2023	2023	2023	2023	2023	2021	2021	2021	2023	2023	2023
Basic	pH (unit)	7.28	7.15	7.03	7.15	6.91	**8.1**	**7.5**	**7.9**	**7.9**	**7.8**	**6.61**	**6.59**	**6.69**	**7.1**	**7.0**	**6.9**
	Total Dissolved Solids	136	536	132	128	120	148	143	147	154	152	134	137	132	142	139	141
	Electrical Conductivity (µS/cm)	185	84	169.7	184.61	190.7	**242**	**251**	**241**	**242**	**244**	**217.14**	**225.26**	**159.23**	**253**	**253**	**252**
	Dissolved Oxygen (% Saturation)	122.52	128.46	120.25	126.5	124.49	83.2	93.9	92.1	111.3	94.6	108.6	100.93	113.07	82.8	67.8	69.7
	Turbidity (NTU)	24.5	662	28.2	26.5	34.7	**31.0**	**33.0**	**38.0**	**36.0**	**50.0**	**4.5**	**4.4**	**2.3**	**3.9**	**1.5**	**3.1**
	Suspended Solids	<5	577	10	<5	8						<5	<5	<5			
Major Ions	Sodium	34	21	32	32	33	41	42	40	41	40	35	35	36	40	40	41
	Magnesium	4	<1	4	4	4	4	4	4	4	4	5	5	5	4	4	4
	Calcium	5	1	4	4	4	5	5	5	5	5	4	4	3	4	4	4
	Potassium	2	<1	2	2	2	2	2	2	2	1	2	2	2	1	1	2
	Chloride	47	19	46	46	46	55	57	54	47	56	54	54	57	64	64	64
	Bicarbonate	13	10	8	12	12	26	27	26	26	27	13	13	11	22	21	20
	Sulphate	12	11	17	13	12	15	15	14	15	15	10	11	11	11	12	12
	Carbonate	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Nutrients	Total Nitrogen	0.4	1.2	0.4	0.4	0.3	**0.30**	**0.30**	**0.30**	**0.30**	**0.40**	**0.3**	**0.4**	**0.1**	**0.10**	**0.20**	<0.1
	Total Kjeldahl Nitrogen	0.3	0.9	0.3	0.3	0.2	0.10	0.10	0.10	0.10	0.20	0.3	0.3	0.1	0.10	0.20	<0.1
	Nitrite + Nitrate	0.09	0.28	0.14	0.1	0.1	0.17	0.16	0.17	0.17	0.17	0.03	0.06	0.01	<0.01	0.01	0.01
	Total Phosphorus	0.06	0.12	0.01	0.02	0.01	**0.02**	<0.01	<0.01	<0.01	**0.03**	**0.02**	<0.01	**0.01**	<0.01	<0.01	<0.01
Metals & Metaloids	Aluminum	0.02	0.658	0.017	0.024	0.025	0.030	0.030	0.040	0.040	0.030	0.024	0.022	0.015	<0.01	<0.01	<0.01
	Arsenic	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.001	<0.001	<0.001
	Barium	0.008	0.0015	0.0078	0.0079	0.008	0.0060	0.0070	0.0060	0.0060	0.0060	0.0153	0.0156	0.016	0.0120	0.0120	0.0140
	Boron	0.008	0.005	0.007	0.007	0.007	<0.05	<0.05	<0.05	<0.05	<0.05	0.006	0.005	0.005	<0.05	<0.05	<0.05
	Cadmium	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00005	<0.00005	<0.00005	<0.0001	<0.0001	<0.0001
	Chromium	<0.0002	0.0008	<0.0002	<0.0002	<0.0002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.001	<0.001	<0.001
	Cobalt	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	0.0002	<0.0001	<0.001	<0.001	<0.001
	Copper	0.0006	0.0006	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	0.0007	0.0006	<0.0005	<0.001	<0.001	<0.001
	Iron	0.021	0.548	0.018	0.024	0.024	<0.05	<0.05	<0.05	<0.05	<0.05	0.45	0.268	0.27	<0.05	<0.05	<0.05
	Lead	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.0001	<0.001	<0.001	<0.001
	Manganese	0.0008	0.0064	0.0016	0.0032	0.0036	<0.001	0.002	<0.001	<0.001	<0.001	0.0047	0.0275	0.0062	0.014	<0.001	0.017
	Mercury	0.0002	0.0003	0.0002	0.0002	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	Molybdenum	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	0.002	0.002	0.002	0.002	0.002	<0.00004	<0.00004	<0.00004	<0.001	<0.001	<0.001
	Nickel	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	0.0007	0.001	<0.0005	<0.001	<0.001	<0.001
	Selenium	0.0003	0.001	0.0003	0.0003	0.0003	<0.01	<0.01	<0.01	<0.01	<0.01	<0.0002	<0.0002	<0.0002	<0.01	<0.01	<0.01
	Uranium	<0.00005	0.00012	<0.00005	<0.00005	<0.00005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.00005	<0.00005	<0.00005	<0.001	<0.001	<0.001
	Vanadium	<0.0002	0.0017	<0.0002	<0.0002	<0.0002	<0.01	<0.01	<0.01	<0.01	<0.01	<0.0002	<0.0002	<0.0002	<0.01	<0.01	<0.01
	Zinc	0.002	0.001	<0.001	0.004	0.002	<0.005	<0.005	<0.005	<0.005	<0.005	0.02	0.004	0.002	<0.005	<0.005	<0.005

Note: all units are mg/L unless otherwise specified; red shading indicates exceedance of the ANZECC & ARMCANZ (2000a) trigger values for upland rivers in southwest Western Australia; basic water quality and nutrient concentrations in bold font indicates exceedance of the Water Quality Australia (2021) DVGs for the protection of 99% of species in pristine freshwater systems; purple shading indicates the use of a Water Quality Australia (2021) DVG with an unknown species protection percentage. Given laboratory pH was analysed outside the maximum holding time of 6 hours, values presented are indicative only.

Table F- 2: Historical surface water quality data recorded from regional reference sites within the Lunenburgh River, Ernest River and Brunswick River.

Water Quality Parameters		Lunenburgh River	Lunenburgh River Dam		Ernest River	Brunswick River
		LR1	LR Dam	LRDam_21	RR02_99	RR10_99
		2021	2021	2023	2023	2023
Basic	pH (unit)	**6.53**	**6.79**	**7.1**	**6.1**	**6.6**
	Total Dissolved Solids	307	148	145	118	184
	Electrical Conductivity (µS/cm)	**288.59**	**191.98**	**258**	**208**	**249**
	Dissolved Oxygen (% Saturation)	123.95	119.7	77.7	50.5	49.0
	Turbidity (NTU)	**8.5**	**40**	**1.5**	**1.0**	**1.1**
	Suspended Solids	**10**	**8**			
Major Ions	Sodium	71	38	40	31	39
	Magnesium	11	6	6	5	6
	Calcium	8	2	4	3	4
	Potassium	2	2	1	<1	2
	Chloride	149	66	74	55	67
	Bicarbonate	9	6	8	9	18
	Sulphate	12	9	10	4	5
	Carbonate	<1	<1	<1	<1	<1
Nutrients	Total Nitrogen	**0.6**	**0.2**	**0.20**	<0.1	**0.30**
	Total Kjeldahl Nitrogen	0.6	0.2	0.20	<0.1	0.30
	Nitrite + Nitrate	0.04	0.01	<0.01	0.02	<0.01
	Total Phosphorus	**0.04**	**0.01**	<0.01	<0.01	**0.02**
Metals & Metaloids	Aluminum	0.013	0.01	<0.01	<0.01	0.050
	Arsenic	<0.0002	<0.0002	<0.001	<0.001	<0.001
	Barium	0.0248	0.0113	0.0140	0.0080	0.0190
	Boron	0.009	0.009	<0.05	<0.05	<0.05
	Cadmium	<0.00005	<0.00005	<0.0001	<0.0001	<0.0001
	Chromium	<0.0002	<0.0002	<0.001	<0.001	<0.001
	Cobalt	<0.0001	<0.0001	<0.001	<0.001	<0.001
	Copper	<0.0005	<0.0005	<0.001	<0.001	<0.001
	Iron	0.015	0.015	0.0900	<0.05	0.4300
	Lead	<0.0001	<0.0001	<0.001	<0.001	<0.001
	Manganese	0.0034	0.0005	0.004	0.032	0.053
	Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	Molybdenum	<0.00004	<0.00004	<0.001	<0.001	<0.001
	Nickel	<0.0005	<0.0005	<0.001	<0.001	<0.001
	Selenium	<0.0002	<0.0002	<0.01	<0.01	<0.01
	Uranium	<0.00005	<0.00005	<0.001	<0.001	<0.001
	Vanadium	<0.0002	<0.0002	<0.01	<0.01	<0.01
	Zinc	0.002	<0.001	<0.005	<0.005	<0.005

Notes as per Table F-1.

Table F- 3: Historical sediment quality data recorded from Freshwater Lake and the Augustus River.

Sediment Quality Parameters		Freshwater Lake									Augustus River				
		FWL1	FWL2	FWL5	FWL6	FWL03_23	FWL05_99	FWL07_23	FWL08_23	FWL09_23	AR1	AR2	AR1	AR2	AR3
		2021	2021	2021	2021	2023	2023	2023	2023	2023	2021	2021	2023	2023	2023
Basic	pH (Unit)	6.7	5.7	5.9	6.2	6.5	6.8	7.2	7.7	7.2	6.3	6.2	6.1	6.6	6
	Electrical Conductivity (µS/cm)	10	30	11	19	24	22	37	55	21	19	30	47	37	43
	Moisture Content (%)	17.9	46.4	21	25.7	22.1	24.7	43.2	26.6	22.4	29.4	35	46.6	28.6	52.6
Cations and Anions	Sodium	<10	40	10	20	40	20	60	50	20	20	40	110	60	100
	Calcium	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
	Magnesium	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
	Potassium	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
	Chloride	<10	40	<10	10	20	10	30	20	10	20	30	50	30	70
	Sulphate	<10	40	20	30	20	20	30	30	10	20	40	250	20	40
	Bicarbonate	10	7	<5	10	26	27	44	59	25	22	32	36	32	23
	Carbonate	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Nutrients	Total Nitrogen	200	1,950	110	50	200	190	1330	150	100	560	680	1560	440	3400
	Total Phosphorus	71	192	52	70	79	36	134	166	65	70	128	99	67	197
	Total Organic Carbon (%)	0.57	3.06	0.76	0.5	0.37	1.11	0.88	0.42	0.24	2.54	2.61	5.72	-	4.46
	Total Kjeldahl Nitrogen	200	1950	110	50	200	190	1330	150	100	560	680	1560	440	3400
	Nitrite + Nitrate	<0.1	2.1	<0.1	<0.1	0.7	<0.1	0.5	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1
Metals and Trace Elements	Aluminium	20,200	46,400	18,100	20,300	28,600	18,200	38,200	22,600	20,500	6,040	22,300	9,050	17,600	13,700
	Arsenic	<5	<5	<5	<5	<1	<1	<1	<1	<1	<5	<5	<1	<1	<1
	Boron	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
	Cadmium	<1	<1	<1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<1	<0.1	<0.1	<0.1
	Chromium	25	19	8	23	40.9	14.8	30.6	69.4	19.8	6	16	7.5	7	10.6
	Cobalt	<2	5	<2	4	1.2	0.9	6	0.9	0.6	9	10	10.7	4.2	4.5
	Copper	9	6	<5	19	8.5	4.2	7.8	44.8	5.8	<5	14	4	2.1	7.4
	Lead	<5	7	<5	<5	5.6	7.8	13.2	9.6	3	<5	<5	4	8.9	7.8
	Manganese	35	28	<5	37	19	16	188	30	12	182	49	252	45	47
	Mercury	<0.1	<0.1	<0.1	<0.1						<0.1	<0.1			
	Molybdenum	<2	<2	<2	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Nickel	3	5	<2	3	3.1	2.8	6	3.1	1.6	7	8	12	4.6	6.7
	Selenium	<5	<5	<5	<5	0.1	0.1	0.3	0.1	0.1	<5	<5	0.4	0.2	0.7
	Uranium	0.7	2.7	1	1.1	1.4	0.6	2.6	1.5	0.8	0.4	1.2	0.5	0.9	0.8
	Vanadium	71	52	25	83	125	43	83	186	67	17	52	22	23	37
	Zinc	8	15	<5	6	7	3.3	21.5	3.9	3.2	9	16	15	11.1	15.1

Note: all units are mg/L unless otherwise specified; red shading indicates exceedance of the ANZECC & ARMCANZ (2000a) trigger values for upland rivers in southwest Western Australia; basic water quality and nutrient concentrations in bold font indicates exceedance of the Water Quality Australia (2021) DVGs for the protection of 99% of species in pristine freshwater systems; purple shading indicates the use of a Water Quality Australia (2021) DVG with an unknown species protection percentage. Given laboratory pH was analysed outside the maximum holding time of 6 hours, values presented are indicative only.

Table F-4: Historical sediment quality data recorded from regional reference sites in the Lunenburgh River, Brunswick River and Ernest River.

Sediment Quality Parameters		LoR	Lunenburgh River	Brunswick River	Ernest River
			LRDam_21	RR10_99	RR02_99
			2023	2023	2023
Basic	pH (unit)	0.1	5.6	6.0	6.4
	Electrical Conductivity (µS/cm)	1	27	28	23
	Moisture Content (%)	1	27	38	32.6
Cations and Anions	Sodium	10	40	40	50
	Calcium	10	<10	<10	<10
	Magnesium	10	<10	<10	<10
	Potassium	10	<10	<10	<10
	Chloride	10	30	40	30
	Sulphate	10	10	10	10
	Bicarbonate	5	14	19	20
	Carbonate	5	<5	<5	<5
Nutrients	Total Nitrogen	20	1160	2190	410
	Total Phosphorus	2	100	99	58
	Total Organic Carbon (%)	0.02	3.09	3.99	1.21
	Total Kjeldahl Nitrogen	20	1160	2190	410
	Nitrite + Nitrate	0.1	<0.1	<0.1	<0.1
Metals & Metaloids	Aluminum	50	9,730	22,100	7,390
	Arsenic	5	<1	<1	<1
	Boron	50	<50	<50	<50
	Cadmium	0.1	<0.1	<0.1	<0.1
	Chromium	2	9.7	15.5	18.8
	Cobalt	2	5	5.2	6.6
	Copper	5	4.2	7.8	8.8
	Lead	5	11.1	12.1	5.4
	Manganese	5	62	37	37
	Molybdenum	2	<2	<2	<2
	Nickel	2	5.6	6.4	7.8
	Selenium	5	<0.1	0.3	0.2
	Uranium	0.1	0.4	0.9	0.6
	Vanadium	5	33	63	48
	Zinc	5	9.2	8.9	13.5

Note: all units are mg/L unless otherwise specified; red shading indicates exceedance of the ANZECC & ARMCANZ (2000a) trigger values for upland rivers in southwest Western Australia; basic water quality and nutrient concentrations in bold font indicates exceedance of the Water Quality Australia (2021) DVGs for the protection of 99% of species in pristine freshwater systems; purple shading indicates the use of a Water Quality Australia (2021) DVG with an unknown species protection percentage. Given laboratory pH was analysed outside the maximum holding time of 6 hours, values presented are indicative only.

Appendix G Statistical Analyses

Table G-1: Results of Shapiro-Wilk tests for normality on mussel quadrat density data. Density is reported as no./m2. Quadrat sampling sizes were: AR1_21 = 5; AR2_21 = 10; AR3_21 = 10.

Site	River Condition	Mussel status	Average	Median	Minimum	Maximum	σ	S.E.	W	*p*-value	Normality?
AR1_21	Dry	Live	11.0	9	0	93	7.31	0.99	0.6952	**0.02204***	**No**
AR1_21	Dry	Dead	24.2	9	2	19	38.95	3.54	0.9097	0.5851	yes
AR1_21	Dry	Combined	35.2	16	5	112	44.35	3.34	0.7565	0.05457	yes
AR2_21	Wet	Live	7.2	1.5	1	28	9.24	1.09	0.7748	0.01007*	No
AR2_21	Wet	Dead	0.7	0.5	0	3	0.95	0.36	0.7273	0.003552*	No
AR2_21	Wet	Combined	7.9	2.5	1	31	9.83	1.11	0.7576	0.006848*	No
AR3_21	Dry	Live	1.0	0	0	7	2.31	0.73	0.5218	0.00008066*	No
AR3_21	Dry	Dead	2.1	1	0	10	3.03	0.66	0.6978	0.001929*	No
AR3_21	Dry	Combined	3.1	1.5	0	11	4.01	0.72	0.7172	0.002873*	No
AR1_21+AR3_21	Dry	Live	8.73	0	0	93	23.77	2.08	0.4168	0.000000805*	No
AR1_21+AR3_21	Dry	Dead	5.07	2	1	19	6.33	0.73	0.772	0.001641*	No
AR1_21+AR3_21	Dry	Combined	13.80	3	1	112	28.59	1.99	0.5113	0.000004348*	No
AR1_21+AR2_21+AR3_21	Wet and Dry	Live	8.12	1	0	93	19.03	1.34	0.4645	0.00000001699*	No
AR1_21+AR2_21+AR3_21	Wet and Dry	Dead	3.32	1	0	19	5.34	0.59	0.6504	0.000001679*	No
AR1_21+AR2_21+AR3_21	Wet and Dry	Combined	11.44	3	0	112	22.84	1.35	0.5003	0.00000003769*	No

Table G-1: Comparison of average density, measured in no./m^2 between and among live and dead Carter's Freshwater Mussel individuals. Values are means ±standard errors with ranges in brackets. Test statistics and p-values are provided with level of significance of p<0.05.

Mussel status	River condition	Site	Density	Test statistic	*p-value*
Dead	Wet and dry	AR1_21+AR2_21+AR3_21	3.32 ±0.65 (0-19)	U = 302	0.8416
Live	Wet and dry	AR1_21+AR2_21+AR3_21	8.12 ±1.34 (0-93)		
Dead	Wet	AR2_21	0.7 ±0.73 (0-3)	U = 34.5	0.02244
Dead	Dry	AR1_21+AR3_21	5.07 ±0.77 (1-19)		
Live	Wet	AR2_21	7.20 ±1.09 (1-28)	U = 76	0.9776
Live	Dry	AR1_21+AR3_21	8.73 ±0.42 (0-93)		
Dead	Wet	AR2_21	0.7 ±0.73 (0-3)	U = 102.5	0.1209
Live	Wet	AR2_21	7.20 ±1.09 (1-28)		
Dead	Dry	AR1_21	11.0 ±0.99 (2-19)	U = 13.5	0.9166
Live	Dry	AR1_21	24.2 ±3.54 (0-93)		
Dead	Dry	AR3_21	1.0 ±0.52 (0-7)	U = 29	0.08911
Live	Dry	AR3_21	2.1 ±0.70 (0-10)		
Dead	Dry	AR1_21+AR3_21	5.07 ±0.77 (1-19)	U = 81.5	0.1905
Live	Dry	AR1_21+AR3_21	8.73 ±0.42 (0-93)		

Table G-2: Comparison of average density, measured in no./m^2 between and among Carter's Freshwater Mussel individuals. Values are means ± standard errors with ranges in brackets. Test statistics and *p*-values are provided with level of significance of *p*<0.05.

Mussel status	River condition	Site	Density	Test statistic	*p-value*
Combined	Wet	AR2_21	7.9 ±0.76 (1-31)	U = 76	0.9776
Combined	Dry	AR1_21+AR3_21	13.8 ±0.51 (1-112)		
Combined	Wet	AR2_21	7.9 ±0.76 (1-31)	U = 9	0.05542
Combined	Dry	AR1_21	35.2 ±0.76 (5-112)		
Combined	Wet	AR2_21	7.9 ±0.76 (1-31)	U = 67	0.2013
Combined	Dry	AR3_21	3.1 ±0.72 (0-11)		
Combined	Dry	AR1_21	35.2 ±0.76 (5-112)	U = 46	0.01159
Combined	Dry	AR3_21	3.1 ±0.72 (0-11)		

Table G-3: Shell lengths of Carter's Freshwater Mussel individuals in wet vs. dry river reaches and pairwise site comparisons. Values are means ± standard errors with ranges in brackets. Test statistics and *p*-values are provided with level of significance of $p<0.05$.

Site	River condition	n	Length (mm)	Test statistic	*p-value*
AR2_21	Wet	79	62.43 ±1.01 (36.75-82.28)	U = 14,438.5	<0.0001
AR1_21+AR3_21	Dry	286	46.67 ±0.66 (21.18-68.87)		
AR2_21	Wet	79	62.43 ±1.01 (36.75-82.28)	U = 12,027.5	<0.0001
AR1_21	Dry	176	48.17 ±0.69 (21.18-68.87)		
AR2_21	Wet	79	62.43 ±1.01 (36.75-82.28)	t = 14.7609	<0.0001
AR3_21	Dry	31	38.11 ±1.31 (25.50-51.22)		
AR1_21	Dry	176	48.17 ±0.69 (21.18-68.87)	U = 4,396.5	<0.0001
AR3_21	Dry	31	38.11 ±1.31 (25.50-51.22)		
FWL dive sites	Wet	48	58.42 ±1.31 (20.00-70.04)	U = 1,495.5	0.0467
AR2_21	Wet	79	62.43 ±1.01 (36.75-82.28)		
FWL dive sites	Wet	48	58.42 ±1.31 (20.00-70.04)	U = 8,250.0	<0.0001
AR1_21+AR3_21	Dry	286	46.67 ±0.66 (21.18-68.87)		
FWL dive sites	Wet	48	58.42 ±1.31 (20.00-70.04)	U = 6,821.0	<0.0001
AR1_21	Dry	176	48.17 ±0.69 (21.18-68.87)		
FWL dive sites	Wet	48	58.42 ±1.31 (20.00-70.04)	U = 1,429.0	<0.0001
AR3_21	Dry	31	38.11 ±1.31 (25.50-51.22)		

Table G- 4: Comparison of percentage mortality of Carter's Freshwater Mussel individuals. Test statistic and p-value is provided with level of significance of p<0.05.

River condition	Date	Site	n	Mortality (%)	Test statistic	*p-value*
N/A	November 2024	AR1_21+AR2_21	199	20.10	Z = -2.174691	0.0296533
	February 2025	AR1_21+AR2_21	255	29.02		
Wet	February 2025	AR2_21	79	8.86	Z = -4.640723	0.00000347193
Dry	February 2025	AR1_21+AR3_21	207	36.71		
Wet	February 2025	AR2_21	79	8.86	Z = 8.472356	<0.0001
Dry	February 2025	AR1_21	176	31.25		
Wet	February 2025	AR2_21	79	8.86	Z = 2.604578	0.00919876
Dry	February 2025	AR3_21	31	67.74		
Dry	February 2025	AR1_21	176	31.25	Z = -3.886659	0.000101634
Dry	February 2025	AR3_21	31	67.74		
Wet	February 2025	AR2_21	79	8.86	Z = 5.85	0.0000000049603
Wet	February 2025	FWL dive sites	48	56.25		
Dry	February 2025	AR1_21+AR3_21	207	36.71	Z = 2.485805	0.0129259
Wet	February 2025	FWL dive sites	48	56.25		
Dry	February 2025	AR1_21	176	31.25	Z = 3.187057	0.00143728
Wet	February 2025	FWL dive sites	48	56.25		
Dry	February 2025	AR3_21	31	67.74	Z = -1.02125	0.307136
Wet	February 2025	FWL dive sites	48	56.25		
Wet	February 2025	AR2_21	79	8.86	Z = 5.853494	0.00000000481352
Wet	February 2025	FWL dive sites	48	56.25		

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