Appendix D

Carters Freshwater Mussel (CFM) Survey and CFM Management Plan

Appendix D.1: Carters Freshwater Mussel Survey

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Memorandum **Collie River Bridge Replacement - Carter's Freshwater Mussel Management** **13/06/2025**	
TO: [redacted]	FROM: [redacted]

1 Background

Construction works for bridge replacement on Collie River Road are scheduled to commence in late 2025. This work may impact Carter's Freshwater Mussel (CFM) (*Westralunio carteri*) through direct physical disturbance, effects on water quality and alterations to habitat. *Westralunio carteri* is listed as Vulnerable on state (*Biodiversity Conservation [BC] Act 2016*), national (*Environment Protection and Biodiversity Conservation Act 1999*) and international conservation lists (IUCN Red List).

To provide an understanding of the population present in Collie River in the vicinity of the bridge replacement works, a comprehensive survey was completed on 5-6 May 2025. This Memorandum provides a brief summary of the survey outcomes. The outcomes of this survey will be used to guide preparation of a CFM Management Plan to minimise impacts on the species from the bridge works.

2 Survey Methods

The survey involved hand-searching within 1m^2 quadrats at regular (approximately 3m) intervals along both banks and in wadable off-bank habitat within approximately 50m up- and down-stream of the existing bridge. This resulted in completion of 80 quadrats in this area (Figure 1).

In each quadrat, all mussels were counted and all live mussels were measured for shell length. This data provides estimates of population density to inform management. Size frequency distribution provides an understanding of population viability.

Physico-chemical water quality covariates were measured at 3 locations upstream and 3 locations downstream, with measurements at each bank and in the river mid-point. A Hanna HI98194 multiparameter was used to measure pH, salinity, conductivity, dissolved oxygen and temperature. In addition, turbidity was measured using a Hach 2100P Turbidimeter, including samples from banks and mid-points up-and downstream of the bridge.

The survey was completed by Robyn Paice and Georgia Johnsen, and undertaken with the required approvals as follows:

- TFA-2425-0236: Authorisation to Take or Disturb Threatened Species, issued by the Department of Biodiversity, Conservation and Attractions (DBCA) under Section 40 of the BC Act 2016.

- BA27001289: Fauna taking (Biological Assessment Licence), issued by DBCA under Regulation 27 of the Biodiversity Conservation Regulations 2018.
- Exemption 251345825 from provisions of the Fish Resources Management (FRM) Act 1994, issued by Department of Primary Industries and Regional Development (DPIRD).

3 Water Quality

This section of the Collie River is fresh and well-oxygenated and has very high clarity. From the 18 measurements of physico-chemical variables and turbidity readings, there was very little variation. Thus there is no need to report individual site values. Results are presented in Table 1.

Table 1. Water quality at the Collie River survey site May 2025.

Variable	**Mean (± SD)**
pH	7.59 ± 0.1
Dissolved oxygen (%)	118.68 ± 3.2
Dissolved oxygen (mg/L)	11.24 ± 0.3
Conductivity (µS/cm)	2400.71 ± 20.2
Salinity (mg/L)	1.39
Temp (C)	17.85 ± 0.7

4 Survey Findings

Results are summarised for the main sections of the river in relation to the existing bridge, the east and west banks (quadrats within ~2m of the bank) and off-bank habitat (>2m from bank in wadeable depth) (Table 2, Figure 2). The downstream section is north of the bridge in Figure 1 and the upstream reach is south of the bridge. All margins of error reported are standard error of the mean (SE).

A total of 271 live mussels were found in quadrats in the survey area, with an overall mean density of 3.4 ± 0.8 mussels/m^2. In addition, 31 dead mussels were found during the survey (10.3%). Mussels were present along both banks and in off-bank habitat upstream and downstream of the existing bridge, although density was variable, ranging from 0-58 mussels/m^2. No mussels were found in quadrats under the existing bridge or observed in this area. Habitat here is considered too rocky and shallow to support mussel colonisation.

Downstream of bridge

Downstream of the existing bridge mean density was low overall (2.6 ± 1.5 mussels/m^2) and mussels were only present in 35% of quadrats, with most mussels found more than 30m away from the existing bridge. Within 30m downstream of the bridge, mean density was low at 0.5 mussels/m^2. A “hot spot” of very high density was found approximately 35-40m from the bridge on the west bank, where 58 mussels were found in one quadrat (Figure 1). This was the highest density found throughout the survey. As a result, the west bank had a higher mean density (5.2 ± 3.4) than the east bank (0.8 ± 0.4). The lowest density was found in the off-bank habitat (0.3 ± 0.2).

Low density of mussels in the downstream habitat is likely to be related to the prevalence of rocky substrate within riffle habitat, which is not conducive to settlement of mussels. This area is also impacted by informal vehicle access. In addition, this reach of the river is relatively narrow, and thus subject to higher flow rates than upstream.

Upstream of bridge

Upstream mussel density was higher (mean 4.3 ± 0.8) and presence more consistent, with mussels present in 67% of quadrats. However, density was spatially variable, with mussel density ranging from 0-17. Higher density was found along the east bank and in the off-bank habitat (5.8 ± 1.6 and 5.8 ± 1.3 mussels/m^2 respectively), while the west bank had lower density (2.3±0.9) and a greater proportion of empty quadrats (50%).

The upstream reach is partially impounded by shallow rocky habitat under the bridge, creating extensive river pool habitat, which is colonised by mussels throughout its width in the sampled area. Lower mussel density along the west bank may be related to the presence of extensive soft organic sediments, likely to be anoxic as indicated by a hydrogen sulphide smell when disturbed.

Depth and soft organic sediments restricted the extent of the mussel survey in the off-bank habitat to within 20m upstream of the bridge: the maximum depth able to be surveyed using this quadrat method was 0.7m. These conditions also restricted further quadrat sampling upstream along banks.

Population abundance estimates

The survey outcomes enable estimation of the number of mussels that may require relocation during bridge replacement works. These estimates are provided for both 60m and 100m footprints for construction works, relating to 30m and 50m either side of the existing bridge (Table 2). These estimates will be used as the basis for the CFM Management Plan.

Due to the very low density of mussels with 30m downstream of the bridge, and overall lower area, restricting bridge works to within this area would substantially reduce the number of mussels requiring relocation.

Table 2. *Westralunio carteri* density and abundance estimates for the Collie River survey area May 2025.

Location	Downstream of bridge			Upstream of bridge		
	West bank	East bank	Off-bank	West bank	East bank	Off-bank
Mean density (mussels/m^2 ± SE)	5.2 ± 3.4	0.8 ± 0.4	0.3 ± 0.2	2.3 ± 1.4	5.8 ± 1.6	5.8 ± 1.4
	2.6 ± 1.5			4.3 ± 0.8		
Estimated abundance within **30m** of bridge	150 ± 54*			2338 ± 421		
Estimated abundance within **50m** of bridge	1148 ± 662			5044 ± 1363		

*Based on specific density for this section (0.5 ± 0.2) owing to very low observed abundance

5 Relocation Habitat Assessment

Upstream river habitat was assessed for potential relocation areas. It is not recommended to relocate mussels downstream due to greater potential for water quality impacts during construction.

Approximately 90m upstream of the bridge is a rapid riffle zone unsuitable for mussels. There is likely to be additional mussel habitat upstream of the assessed area with an extensive pool in this area observed from aerial photos. However limited access and time prevented further survey.

Between the survey area and this rapid riffle zone is extensive suitable mussel habitat that could be utilised for relocation. Mussels were observed in the area, however quantifying the population in this area is difficult due to depth being greater than that allowing quadrat sampling. Other sediment sampling methods, such as Eckman grabs, are ineffective, and observation excludes mussels buried

under sediments. For management purposes, it can be assumed that the population density would be similar to the surveyed area, due to similar habitat characteristics.

In the wadeable habitat downstream of the rapid riffle zone, mussels were present and substrate was variably sandy and rocky. Five quadrats were assessed here, with a mean mussel density of 2.2 mussels/m^2. Visual assessment indicated that the eastern bank provides the most favourable mussel habitat (mussels were observed but could not be sampled). This habitat was similar to within the surveyed area and mussels were common in this area.

6 Management Implications

Bridge construction works are likely to have direct physical impacts on the local population of *W. carteri*, and therefore relocation of potentially impacted mussels will be required. Estimates of abundance based on the survey results suggest, for example, that:

- a disturbance footprint of 60m would require relocation of ~2,500 mussels.
- a disturbance footprint of 100m would require relocation of ~6,200 mussels.

Removal of mussels for relocation would be difficult in some upstream areas due to soft sediments and depth, and the presence of mussels throughout off-bank habitat.

A Carter's Freshwater Mussel Management Plan will be developed to guide relocation. This will need to be informed by expected construction footprint.





FIGURE 1. CFM PLOTS

COLLIE RIVER BRIDGE, COLLIE

Ref: SW612 CFM
Date: 12/06/2025 Author: SP

CFM density — Major watercourse
0
1-5
6-10
11-15
16-20
50+
Road



A3 @ 1:700

0 5 10 20 m

N

SW Environmental

Source: Base map © Esri and its data suppliers. SLIP Landgate (2025)

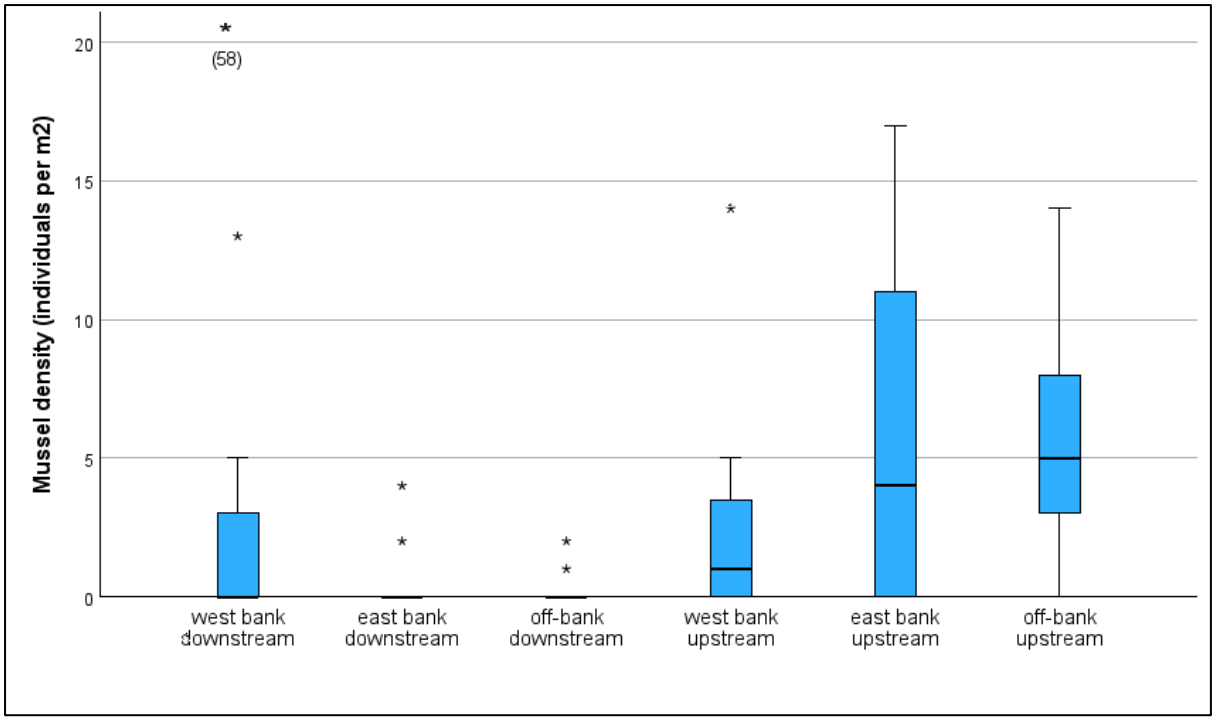


Figure 2. Mussel density estimates in the Collie River survey area May 2025. Lines are median values, boxes represent the 25-75 percentile range, whiskers the 5-95 percentile range, and asterisks are outliers.

Appendix D.2: Carters Freshwater Mussel Management Plan

Carter's Freshwater Mussel (*Westralunio carteri*) Management Plan

Collie River Road Bridge Replacement (4930)

AUGUST 2025

SW Environmental

Version control

Project number:	SW612			
Project file path:	SW612 Collie River Rd Bridge CFMMP			
Client:	GHD			
Revision	Date	Prepared by (name)	Reviewed by (name)	Approved by (name)
Rev 01	18/08/25	Dr Robyn Paice, Ottelia Ecology	SP SW Environmental	SP SW Environmental

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Statement of limitations

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Abbreviations and acronyms

Organisations	
DBCA	Department of Biodiversity, Conservation and Attractions
DCCEEW	Federal Department of Climate Change, Energy, the Environment and Water
DWER	WA Department of Water and Environmental Regulation
EPA	Environmental Protection Authority
Common Terms	
CFM	Carter Freshwater Mussel (*Westralunio carteri*)
Project	The proposed action
SW	Southwest
WA	Western Australia
Legislation	
BC Act	*Biodiversity Conservation Act 2016* (WA)
BC Regs	*Biodiversity Conservation Regulations 2018* (WA)
EP Act	*Environmental Protection Act 1986* (WA)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Federal)
Measurements	
ha	Hectare
km	Kilometre
m	Metre

1 Introduction

1.1 Project Description

Bridge 4930 over the Collie River, at Collie River Road, is scheduled for replacement in late 2026-early 2027. Works will require the construction of a temporary causeway to facilitate demolition and bridge construction. The causeway will span the full river width to enable crane access, with a working width of about 15 m at the crossing point. Following completion of works, the causeway will be removed and the area rehabilitated. The causeway ramp will have a geotextile base to reduce disturbance to the riverbed. Culvert pipes will be incorporated to maintain river flow during works.

This work has potential to impact Carter's Freshwater Mussel (*Westralunio carteri*) mainly through direct physical impacts of the causeway covering mussel habitat. There is also potential for water quality impacts due to sediment disturbance, although this will be managed through the installation of silt curtains.

1.2 Purpose and Scope of this Plan

The purpose of this Carter's Freshwater Mussel Management Plan (CFMMP) is to minimise the impact of bridge construction works on Carter's Freshwater Mussels within the Collie River (Figure 1). To achieve this, the CFMMP provides for temporary relocation of resident mussels during construction works. The approach and methodology are based on a survey of the mussel population at the site in May 2025 (Appendix 1) and prior experience in relocation efforts. The CFMMP includes a risk-based monitoring and reporting program that will measure the success of relocation and guide adaptive management during implementation.



FIGURE 1. CFM AND PROPOSED IMPACTS

COLLIE RIVER BRIDGE, COLLIE

Ref: SW612 CFM
Date: 26/06/2025 Author: SP

CFM density

- 0
- 1-5
- 6-10
- 11-15
- 16-20
- 50+

- Road
- Major watercourse
- Approximate river development footprint (0.16 ha)



A3 @ 1:650

0 5 10 20 m

N

SW Environmental

www.swenvironmental.com.au

Source: Base map © Esri and its data suppliers. SLIP Landgate (2025)

1.3 *Westralunio carteri* – species information

Westralunio carteri is a long-lived, sedentary, large-bodied native freshwater mussel in south-west Western Australia. It plays an important role in river ecology, contributing to nutrient cycling and water clarity through filter-feeding, and its burrowing behaviour aerates sediments, supports benthic invertebrates, and influences nutrient exchange (Daviot et al. 2025). In 2022, genetic studies identified a second species, *Westralunio inbisi* sp. *nov*., with two subspecies. However, most monitoring and conservation literature still uses *W. carteri* in the broader, pre-2022 sense.

1.3.1 Conservation Status

Westralunio carteri is listed as Vulnerable under the Western Australian *Biodiversity Conservation Act 2016*, the national *Environment Protection and Biodiversity Conservation Act 1999*, and internationally on the IUCN Red List (IUCN 2020). Owing to this protected status, management measures are necessary to avoid or mitigate impacts on the species.

Until 2022, *W. carteri* was considered the sole freshwater mussel species occurring in southwest Western Australia. However, recent phylogeographic and DNA-based research (Klunzinger et al. 2021, 2022) confirmed the existence of three distinct evolutionary lineages, leading to the formal recognition of two species: Westralunio carteri (sensu stricto) and *Westralunio inbisi* sp. *nov.*, the latter comprising two subspecies (*W. inbisi inbisi* and *W. inbisi meridiemus*).

In July 2025, the Western Australian Government formally updated the threatened fauna list to reflect these taxonomic changes, retaining *W. carteri* as Vulnerable and listing *W. inbisi inbisi* as Vulnerable and *W. inbisi meridiemus* as Endangered (Department of Biodiversity, Conservation and Attractions [DBCA] 2025). Within the Vulnerable category, *W. carteri* listing was changed from A2c+4c to A2ce; B2ab(ii,iii,iv), recognising that in addition to population declines linked to habitat loss, the species is also threatened by other biological pressures, and has a small, fragmented, and declining geographic range.

Based on the distribution data and genetic assignments in Klunzinger et al. (2022), the Collie River and its tributaries fall entirely within the west coast drainage division — the documented range of *W. carteri* sensu stricto. This area is well north of the Blackwood River, which marks the northern limit of *W. inbisi*. Furthermore, Collie River populations were directly sampled and genetically confirmed as *W. carteri* in the Klunzinger et al. (2022) study. These findings, combined with the absence of *W. inbisi* records in the Collie catchment, provide high confidence that the population addressed by this management plan is *W. carteri*.

1.3.2 Habitat Requirements

The critical habitat requirements for Carter's Freshwater Mussels include the presence of permanent or semi-permanent fresh water (seasonally moist sediments). Water is essential for mussels to breathe, although they can survive out of water in shaded habitat for up to three months (Lymbery et al. 2020). Mussels can migrate further down banks as water levels recede, but this may expose them to reduced shade from riparian vegetation, leaving them unprotected if complete drying occurs.

The species is generally confined to systems with salinity less than 3.0 g TDS L^{-1} (Klunzinger et al. 2015), and secondary salinisation of freshwater systems in south-western Western Australia has already contracted the species' range by about 50 %. Laboratory studies show that sub-lethal effects on burrowing and filtration can occur from about 3 g TDS L^{-1}, with significant feeding suppression above 4 g TDS L^{-1}, and a 96-hour acute LC_{50} for juveniles of 5.9 g TDS L^{-1} (Ma et al. 2022).

Water quality tolerance limits for *W. carteri* are not well defined, and the thresholds in Section 5.6 were based on a precautionary approach consistent with broader aquatic ecosystem protection. The species persists in degraded systems, tolerating very high turbidity and elevated pH; for example, in the lower Vasse River long-term mean autumn turbidity is 25 NTU and summer/autumn mean pH exceed 8.5[1]. Their tolerance for acidic conditions is unknown, warranting caution. Mussels can withstand repeated short-term exposure to temperatures above 30 °C in captivity (Beatty et al. 2020), though prolonged exposure is likely detrimental. While low dissolved oxygen can cause stress, their ability to survive emersion and occurrence in benthic habitats prone to hypoxia suggests some adaptation. For instance, mussels were widespread in the lower Vasse River despite potentially anoxic sediments and mean spring dissolved oxygen of ~2.0 mg/L (City of Busselton 2019).

In addition to these physical habitat requirements, Carter's Freshwater Mussels require the presence of a viable fish population for dispersal. Following spawning by males, larvae (glochidia) are released from females and attach to a fish host, which enables dispersal before detaching and settling in sediments (Klunzinger et al. 2012).

1.3.3 Occurrence of W. carteri *in the Collie River*

Carter's Freshwater Mussel has been recorded in multiple locations along the Collie River and some of its tributaries. Previous monitoring has recorded its presence in both main channel and off-channel habitats, with density influenced by substrate type, flow regime, and salinity. Surveys by Klunzinger et al. (2015) reported that populations in the Collie River were generally restricted to areas with low salinity (< 3 mg/L) and moderate to low flow velocities, often in depositional zones adjacent to vegetated banks. Habitat quality was reduced in reaches subject to secondary salinisation, and densities varied markedly with substrate stability and the extent of fine sediments.

The May 2025 survey around the Collie River Road bridge recorded a total of 271 live mussels in 84 quadrats, with an overall mean density of 3.4 ± 0.8 mussels/m². Mussels occurred along both banks and in off-bank habitat upstream and downstream of the bridge, although density was highly variable (0–58 mussels/m²). No mussels were found beneath the existing bridge where the habitat was shallow and rocky.

Downstream of the existing bridge, mean mussel density was 2.6 ± 1.5 mussels/m², with mussels present in 35% of quadrats. A notable "hot spot" of 58 mussels in one quadrat was located ~35–40 m from the bridge on the west bank. Lower densities elsewhere were associated with coarse, rocky substrates and higher velocities.

Upstream of bridge, mean mussel density was 4.3 ± 0.8 mussels/m², with mussels in 67% of quadrats. East bank and off-bank habitats had the highest densities (both 5.8 mussels/m²), while density along the west bank was lower (2.3 mussels/m²) and had more empty quadrats. Lower densities on the west bank were associated with deep, soft, possibly anoxic sediments.

Survey results show the bridge-site population is dominated by mid-sized individuals (40–50 mm), with few large shells (>60 mm) (Figure 2). Using age–length relationships for *Westralunio carteri* from Klunzinger et al. (2014; $L\infty \approx 61$ mm; $K \approx 0.17$), this size class is typically <10 years old, whereas >60 mm shells may be >20 years old. The scarcity of older individuals suggests a younger, more transient

[1] Data from Water Information Reporting Tool (Department of Environmental Regulation).

cohort compared with stable populations in the Abba and Vasse Rivers. The bridge reach likely acts as a sink habitat, with mussels lost and replaced through high flow scouring, while upstream pools function as source areas for recolonisation.

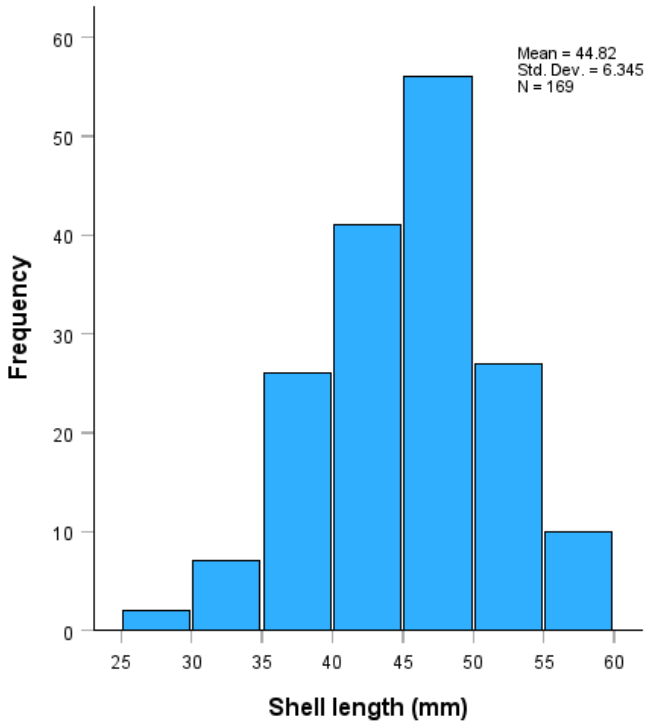


Figure 2. Length-frequency histogram of resident *Westralunio carteri* in the Collie River at the bridge construction site, from May 2025 survey.

1.4 POTENTIAL ENVIRONMENTAL IMPACTS

The bridge construction works, including construction and removal of the temporary causeway, will result in short-term disturbance to the river environment, including bed, banks and water. Without mitigation, the primary impact would be direct physical burial and compaction or displacement of all *W. carteri* within the disturbance area.

Additional potential environmental impacts on the resident mussel population include increased sedimentation and turbidity from bed and bank disturbance, which could smother individuals or clog siphons and interfere with feeding, as well as temporary changes to hydrology and flow patterns resulting from diversion of water through culvert pipes during construction.

1.5 **Direct impacts of works**

The construction footprint extends from 5.0 m downstream of the existing bridge, beneath the bridge itself, across the 15.0 m-wide causeway area. The following assessment of potential impact includes 5.0 m upstream downstream and upstream as a disturbance buffer.

The habitat beneath the bridge is shallow and rocky, unsuitable for mussels, so there will be no impact to mussels or habitat in this section. Estimates of mussel numbers potentially impacted by direct disturbance and requiring relocation, are summarised in Table 1.

1.5.1 Downstream of the bridge

Within 30 m downstream of the bridge, mean mussel density was low (0.5 mussels/m) and distribution patchy. Suitable habitat was confined to near the banks. No mussels were found during survey of off-bank habitat in this section, which was very rocky. Habitat area that may be impacted is 20m^2: including 10.0 m of habitat along each bank with a maximum width of 1.0 m. This provides an estimate of 10 mussels that may be directly impacted if not relocated prior to works.

Permanent alteration of habitat in this section would have minor impact on the availability of habitat for the local resident mussel population.

1.5.2 Upstream of the bridge

The upstream reach is wider (18m) than downstream and is semi-impounded by the shallow rocky sill beneath the bridge, creating a habitat with slower flows and sediment deposition. This habitat is more suitable for mussels, which are present along banks and in off-bank areas with variable density and patchy distribution. Mean density from all upstream sites was considerably higher than downstream, at 4.3 mussels/m², providing an estimate of 1560 that may be directly impacted if not relocated prior to works.

Within 20 m upstream of the bridge, mussels can feasibly be relocated. Beyond the 20 m, deeper off-bank areas become difficult to safely survey and harvest, because water depth and soft sediments prevent hand-foraging without diving[2]. This was the limit of the off-bank survey, however mussels were present (observed) further upstream. Therefore, the disturbance footprint must remain within 20 m of the bridge as currently planned.

Although the causeway is designed for full removal, the habitat within the causeway footprint is likely to be permanently altered by changes in substrate composition and bank morphology. There is a risk that the area may not be suitable for future recolonisation by *W. carteri* or release of relocated mussels, at least in the short term, because sediments could be compacted, unstable, or altered in composition. In addition, the depth of water may not provide suitable, stable conditions for mussel survival.

1.5.3 Population structure and recovery potential

The downstream and under-bridge sections at the site appear to support a relatively young, mobile population that is periodically replenished from upstream. These areas function more like sink habitats, where individuals are regularly lost during high-flow events and replaced by new recruits from more stable upstream pools. Given this dynamic, mussel numbers in these sections are likely to recover through natural redistribution within 1–3 breeding seasons.

Relocating mussels to secure upstream habitats during construction would therefore provide short-term protection, while allowing natural recolonisation and redistribution via flows once works are complete.

[2] Diving or snorkelling during hand foraging for survey and relocation (fishout) exposes personnel to poor water quality due to the disturbance of soft sediments, increasing risk of skin irritation and ear infection.

Table 1. Estimates of *W. carteri* abundance for relocation planning for Collie River Road bridge replacement works.

Zone	Area (m^2)	*W. carteri* density (mussels/m2) (mean ± SE)	Estimated abundance (individuals)
Downstream of existing bridge (0-10m)	20	0.5 ± 0.21	10 ± 4
Upstream of existing bridge (0-20m)	360	4.3 ± 0.78	1560 ± 280
Total	**380**		**1570 ± 284**

1.6 Water Quality and Flow Impacts

Potential impacts on mussels from altered water quality and flow during works include increased turbidity and sedimentation from bed and bank disturbance, as well as temporary flow changes from diversion through culvert pipes. Sediment disturbance, both during mussel relocation and construction, may temporarily increase turbidity and reduce dissolved oxygen through the release of anoxic sediments. However, *W. carteri* is adapted to turbid conditions, can tolerate anoxic sediments, and can temporarily close its shells to avoid adverse conditions. Installation of silt curtains will further limit turbidity in adjacent waters. Flow alterations are expected to be minimal, as works will be conducted during low-flow periods, and mussels rely primarily on the presence of water rather than a specific flow regime, naturally experiencing a range of flow conditions.

2 MANAGEMENT MEASURES

To minimise impacts on *Westralunio carteri* during bridge construction, three complementary management approaches are required:

i. Relocation of mussels from the disturbance footprint to secure upstream habitat.

ii. Installation of a silt curtain to prevent mussels redistributing back into the disturbance area.

iii. Measures to ensure that suitable habitat conditions are maintained or restored following removal of the causeway.

Together, these approaches address both the immediate risk of direct mortality from construction activities and the longer-term requirement for viable habitat to support recolonisation and persistence of the local mussel population.

2.1 Relocation of Mussels

2.1.1 Rationale for the approach

The most effective management measure for minimising impacts on Westralunio carteri during bridge construction is the relocation of mussels from the disturbance footprint to suitable habitat directly upstream. Survey results confirm that upstream areas, particularly along the eastern bank, provide appropriate habitat with established mussel presence. Current densities are relatively low, indicating little risk of overcrowding from additional individuals. Furthermore, timing of works, planned to commence in late 2026, is conducing for immediate relocation with low risk of redistribution into the disturbance area.

Relocating mussels upstream is advantageous because water quality and flow conditions are highly comparable to those within the disturbance footprint, ensuring continuity of environmental conditions. This approach also avoids the risks associated with reintroducing mussels into the construction footprint immediately after causeway removal, when sediment instability or compaction may temporarily limit habitat suitability.

Direct redistribution into upstream sediments provides mussels with the opportunity to burrow and stabilise well before the onset of higher winter flows, reducing the likelihood of downstream displacement into the construction zone. While temporary holding in cages has been shown to be tolerated well by mussels in past relocation work (e.g. Vasse River Eastern Link Bridge: Beatty et al. 2020), immediate resettling in natural sediments is likely to present less stress to mussels, as they can recommence natural behaviors of movement and feeding. Cages will only be used as a contingency measure should monitoring indicate that relocated mussels are being transported downstream despite the use of silt curtains.

2.1.2 Relocation site

All mussels within the disturbance footprint will be relocated to suitable habitat immediately upstream of the bridge, within a reach of approximately 50 m length and >1000 m² in area (river width >20 m). Relocation downstream is not recommended due to a higher risk of water quality impacts during construction.

Survey work in May 2025 confirmed that Westralunio carteri are well established in adjacent upstream habitats. Mussels were recorded along both banks for 30 m upstream of the disturbance footprint and observed throughout bank and off-bank habitats up to 90 m upstream using a bathyscope. Although quadrat sampling was limited by depth, mussels were consistently present across bed and bank habitats, indicating broad habitat suitability. This upstream reach is bounded by a riffle zone (~90 m upstream) that is unsuitable for mussels, effectively containing the relocation area.

In the wadeable section just downstream of the riffle, mean mussel density was 2.2 mussels/m², with a mix of sandy and rocky substrates, suggesting habitat quality comparable to the disturbance site. Upstream of this surveyed area, aerial imagery indicates a larger pool that is also likely to provide additional suitable mussel habitat.

Overall, the reach between the bridge site and the riffle zone provides extensive habitat for relocation. Within this area, the eastern bank is expected to be particularly favourable due to more stable substrates and higher observed mussel abundance.

2.1.3 Relocation methodology

Mussels will be removed from the disturbance footprint by systematic hand foraging to a depth of ~10 cm, using both tactile and visual search. Mussels will be removed from the disturbance footprint by systematic hand foraging to a depth of ~10 cm. Sediments will be searched methodically by raking fingers through the substrate and squeezing handfuls to detect buried mussels by touch. This tactile method is particularly effective for locating individuals concealed beneath the surface.

The disturbance area will be divided into defined sections for systematic hand-searching. Each section will be searched repeatedly, with sediments carefully raked and felt by hand, until no additional mussels are detected for 30 minutes.

Where feasible, finer sediments will be selectively sieved through a 0.5 mm mesh to detect juvenile mussels and assess their occurrence. Full-scale sieving of the disturbance area is not proposed, as it would cause unnecessary sediment disturbance and is unlikely to substantially improve detection given the patchy distribution of juveniles. The selective approach provides confidence that juveniles are considered while minimising habitat impacts.

Collected mussels will be placed in batches into aerated eskis containing river water. To minimise stress, batches will be limited to approximately 100 individuals per esky, with water regularly refreshed. Mussels will be transported immediately to the designated upstream relocation site.

Each mussel will be measured (shell length) and tagged with a unique number using a small, non-toxic sticker affixed to the shell. This will enable future identification and monitoring of growth, health, and survival following relocation.

At the relocation site, mussels will be gently released into suitable habitat along a ~50 m reach, allowing them to settle and rebury naturally. Individuals will be dispersed evenly across available microhabitats (particularly along the eastern bank), with densities kept below 2 mussels per square metre to minimise increases to existing density. The exception will be placement of 50-100 mussels in the designated "check site" (see below).

Any individuals found to be moribund (not closing upon touch) will be recorded and measured but not relocated. Mortality and health condition will be documented during the process.

2.1.4 Relocation timing

Relocation of W. carteri will be scheduled immediately prior to the commencement of bridge replacement works, ensuring mussels are removed from the disturbance footprint before construction begins. Construction is expected to occur over a 4–6 month period from November/December 2026 through early 2027, with completion targeted prior to the onset of winter flows. Undertaking both relocation and construction during the summer–autumn low-flow period will maximise safety, accessibility, and relocation success by providing the most stable hydraulic conditions. The timing of relocation is therefore critical, as low flows are essential to enable effective search, handling, and placement of mussels in the designated relocation area.

2.1.5 Mussel "Check Site"

In addition to dispersing mussels throughout the upstream relocation area, a subset of approximately 50–100 individuals will be placed within a designated check site. This site will comprise a 5–10 m stretch of accessible bank habitat (to be selected in the field based on suitability) that allows repeated

inspection. Mussels will be gently released into the sediment at low density, consistent with the broader relocation strategy, to ensure natural settlement. Establishing this check site will provide a controlled and accessible location for monitoring mussel health and survival during and after the works.

Outcomes from the check site monitoring will be used to verify the success of relocation and inform adaptive management measures (e.g., modifying relocation techniques, considering temporary caging, or alternative relocation sites).

2.2 Silt Curtain Installation

To protect relocated mussels and prevent their redistribution into the disturbance footprint during works, a silt curtain will be installed at the upstream edge of the disturbance buffer. This curtain will act as a physical barrier to fine sediments and drifting mussels, ensuring they are not carried back into the construction zone. It will also serve as a clear visual marker for contractors, delineating the active work area from the adjacent relocation habitat, thereby reducing the risk of inadvertent disturbance to relocated mussels.

2.3 Habitat Suitability Post-Construction

To maximise habitat suitability for recolonisation by W. carteri, contractors should address the key ecological requirements of depth, friable sediment, and bed/bank stability. Practical measures include:

- **Reinstating depth:** Fully remove temporary construction materials to restore natural bed profile and avoid residual mounds or shallow zones that would be unsuitable for mussels.
- **Restoring sediment friability:** Loosen compacted surface sediments (e.g., through light raking/harrowing) to allow mussels to burrow effectively.
- **Stabilising habitat:** Consolidate loose or slumping bank and bed material to reduce erosion and sediment transport after construction.

2.4 Contingency Planning

Although the upstream relocation site has been assessed as suitable habitat, it is possible that monitoring will indicate relocated mussels are not stabilising (e.g. persistent displacement, accumulation against the silt curtain, or failure to rebury at the check site). In such cases, expert judgement and liaison with DBCA will guide the most appropriate response. The aim is to ensure relocated mussels are maintained in secure habitat with minimal stress or mortality, while retaining flexibility to adjust methods as conditions dictate.

Two contingency options are available:

1. **Relocation to the upstream pool (beyond the riffle zone):** This option would only be implemented following further survey confirming suitable habitat conditions (substrate, depth, flow, water quality). Mussels would be distributed at low density across appropriate microhabitats, consistent with methods used at the primary relocation site.
2. **Temporary caging of mussels within the relocation area:** Mussels would be housed in purpose-built cages positioned in flowing water, at a stocking density of up to 100 mussels per cage (m^2). Monitoring of caged mussels would follow the frequency and procedures outlined in

the Monitoring Program (Section 5), with checks on survival, stress, and water quality. Caging would be considered a temporary measure until habitat conditions stabilise and direct release is feasible.

Decisions on contingency measures will not be based on rigid thresholds but on expert assessment of mussel health and stability, in consultation with DBCA. This approach ensures flexibility to adopt the best possible management pathway in response to real-time conditions.

3 RISK ASSESSMENT

Risks associated with this CFMMP are based on current understanding of the nature and timing of construction works, the dynamics of the resident mussel population, available suitable habitat at the site, an understanding on the habitat requirements of the species and outcomes of previous experience in relocation of the species. An outline of risks and their control strategies is provided in (Table 2).

A qualitative risk assessment was applied based on the guidance in Department of the Environment (2014), adapted to specific risks and impacts for this CFMMP (Table 4). Likelihood and consequence were assessed for residual risk (after implementation of control strategies) according to the criteria in Table 3 and Table 4, with the outcomes applied to the risk matrix (Table 5) to determine a final risk rating (Table 6).

All identified risks have a low risk rating with the exception of external events (e.g. fire, flooding, or pollution event), which has a residual rating of medium. This risk is present regardless of the implementation of this CFMMP and it is beyond the scope of this plan to develop risk control strategies for the broader population associated with external factors.

Table 2. Risks identified for implementation of this CFMMP and control strategies for mitigation.

Risk	Control strategies
Smothering/crushing from bridge replacement works	Relocation from disturbance area in accordance with this CFMMP.
Stress or mortality during handling and transport	Minimise handling and keep mussels submerged at all times. Transport in cool, oxygenated river water with aeration. Limit transport time and batch size (≤100 mussels per container). Exclude dead or unresponsive mussels from relocation.
Relocation habitat unsuitable or fails to retain mussels (e.g., washout, failure to rebury, displacement to silt curtain)	Careful selection of relocation site upstream of works with suitable depth and sediment. Works undertaken during low river flow period. Disperse mussels at ≤2 per m² to avoid crowding. Establish check site (50–100 mussels along 5–10 m bank) for systematic monitoring of health and retention. Weekly/monthly inspections of silt curtain to detect displaced mussels. Contingency options (temporary cages or upstream pool relocation) if mussels do not stabilise.

Failure or misplacement of silt curtain (allowing mussel entry into works zone or disturbance of relocation site)	Install curtain within disturbance buffer before works commence. Inspect daily during relocation and fortnightly during works. Repair/adjust immediately if failures detected. Curtain also acts as clear boundary to prevent contractor disturbance in relocation area.
Water quality decline during relocation or works (e.g., low DO, high turbidity, high temperature, salinity changes)	Baseline water quality check prior to relocation. Ongoing monitoring (weekly then monthly) of DO, turbidity, EC, salinity, pH, temperature upstream, within, and downstream of works. Thresholds set on precautionary basis for aquatic ecosystem protection. Adaptive management triggers – suspend relocation or implement corrective actions if thresholds exceeded.
Habitat reinstatement at disturbance footprint inadequate (e.g., compacted sediments, residual mounding, unstable banks)	Contractors to fully remove causeway material and reinstate depth. Loosen compacted sediments to restore friability. Stabilise banks and bed to reduce post-works erosion. Habitat assessment prior to silt curtain removal and post-flow season to confirm suitability for recolonisation.
External events (e.g., major flood, bushfire, pollution incident)	Regular communication with site managers and DBCA. Suspend relocation if acute events elevate risk. Apply adaptive management framework to determine corrective action.
Predation of mussels at relocation site	Maintain low-density dispersal across habitat to reduce attraction of predators.
Public disturbance or interference	Relocation site is upstream of construction and less publicly accessible. Minimise visibility of check site; no signage or markers left in place. Supervision of relocation by qualified personnel.

Table 3. Risk likelihood rating criteria.

Rating	Qualitative measure
Highly likely	Is expected to occur in most circumstances
Likely	Will probably occur during the life of the project
Possible	Might occur during the life of the project
Unlikely	Could occur but is considered unlikely or doubtful
Rare	May occur in exceptional circumstances

Table 4. Risk consequence rating criteria (Paice and Beatty 2022).

Rating	Guideline for qualitative assessment	Interpretation for this CFMTP
Minor	Minor incident of environmental damage that can be reversed	Incident that may affect mussel health temporarily or requires alternative but mortality unlikely or can be avoided through identified adaptive management pathway
Moderate	Isolated but substantial instances of environmental damage that could be reversed with intensive efforts	Isolated incident with temporary impact that may result in death of a small proportion of mussels in the project area
High	Substantial instances of environmental damage that could be reversed with intensive efforts	Incident with temporary impact that may result in death of a large proportion of mussels within the project area
Major	Major loss of environmental amenity and real danger of continuing	Incident that will result in death of mussels in the broader population extending beyond the project area, but impact temporary with recovery possible
Critical	Severe widespread loss of environmental amenity and irrecoverable environmental damage	Incident that will result in death of mussels in the broader population extending beyond the project area with no possibility of recovery due to permanent alteration of conditions

Table 5. Risk assessment matrix.

		Consequence				
Likelihood		Minor	Moderate	High	Major	Critical
	Highly Likely	Medium	High	High	Severe	Severe
	Likely	Low	Medium	High	High	Severe
	Possible	Low	Medium	Medium	High	Severe
	Unlikely	Low	Low	Medium	High	High
	Rare	Low	Low	Low	Medium	High

Table 6. Outcome of risk assessment for identified risks associated with the CFMTP.

Risk	Likelihood (after controls)	Consequence (after controls)	Residual Risk Rating	Rationale
Smothering/crushing from bridge replacement works	Unlikely	Moderate	**Low**	Controlled by relocation prior to works and silt curtain installation; residual risk remains due to possibility of undetected mussels.
Stress or mortality during handling/transport	Unlikely	Moderate	**Low**	Minimized by careful handling; some stress inevitable but mussels resilient.

Risk	Likelihood (after controls)	Consequence (after controls)	Residual Risk Rating	Rationale
Relocation habitat unsuitable or fails to retain mussels	Unlikely	Moderate	**Low**	Habitat selection, low-density dispersal, low flow conditions and contingency reduce risk, but washout may occur.
Failure/misplacement of silt curtain	Unlikely	Moderate	**Low**	Failure unlikely, consequence depends on stabilisation of relocated mussels.
Water quality decline during relocation/works	Possible	Minor	**Low**	Short-term fluctuations possible, but mussels resilient.
Inadequate reinstatement of disturbance footprint	Unlikely	Moderate	**Low**	Requirements achievable but ecological uncertainty remains.
External events (flood, bushfire, pollution)	Rare	Major	**Medium**	Outside project control; contingency measures limited. Consequence high but likelihood rare.
Predation at relocation site	Possible	Minor	**Low**	Natural predation expected at low levels; dispersal reduces concentration of mussels.
Public disturbance/interference	Rare	Moderate	**Low**	Relocation site not publicly accessible; low likelihood with signage/contractor awareness.

4 MONITORING PROGRAM

The monitoring program is designed to verify that relocation and construction activities do not result in unacceptable impacts on *W. carteri* or their habitat. It tracks health and movement of relocated mussels' responses during works, ensures habitat suitability for recolonisation once construction is complete, and assesses recolonisation of the disturbance area. This approach allows for adaptive management, with clear triggers for corrective action if conditions exceed specified thresholds.

4.1 Objectives

Specific objectives of monitoring for implementation of this CFMMP are:

1. Verify water quality remains within tolerances for *W. carteri* during and after works.
2. Ensure relocated mussels remain upstream of the disturbance footprint.
3. Confirm habitat suitability prior to silt-curtain removal.
4. Assess recolonisation and survival of tagged mussels post-works.

4.2 Mussel Monitoring

Mussel checks will occur at several stages to verify the effectiveness of relocation and detect any issues early. A dedicated check site will be established as described in the relocation methodology. Approximately 50–100 mussels will be relocated to this 5–10 m stretch of accessible bank habitat to allow systematic health monitoring.

4.2.1 During bridge works

Following relocation, mussel monitoring will be undertaken weekly for one month, monthly during bridge construction works, and prior to agreed removal of the silt curtain following completion of works and removal of the causeway. This monitoring will include inspection of mussels at the check site, and inspections just upstream of the silt curtain to detect any displaced mussels.

Intensive searching for tagged mussels at the check site will be undertaken for 30 minutes on each monitoring trip, and mussels inspected for:

- Signs of stress (failure to rebury, gaping, mortality).
- Retention in habitat (whether individuals are being washed out or displaced).

4.2.2 After bridge works

Once work is complete and the silt curtain has been removed, resurvey of the disturbance footprint and the check site will be carried, with timing dependent on flow conditions, to assess recolonisation and the distribution of mussels. Ideally this will within three months of completion, and once after cessation of the following season of winter flows.

4.3 Water quality Monitoring

Water quality monitoring is required immediately prior to relocation activities to establish reference conditions. Variables to be included in all monitoring checks are dissolved oxygen (DO), turbidity, electrical conductivity (EC), salinity, pH and temperature. These are to be measured in situ using a suitable water quality meter.

These variables are to be measured within the relocation area, within the construction works area (if safe to do so), and downstream of the construction works area. Measurements should be at the same frequency as mussel monitoring:

- Weekly for one month following relocation
- Monthly for the duration of bridge construction works
- Prior to agreed removal of the silt curtain
- Within three months of completion

4.4 Habitat Assessment

Habitat within the disturbance footprint will be assessed once works are complete and prior to silt-curtain removal to confirm that conditions are suitable for recolonisation by *W. carteri*. The focus is on ensuring that reinstated habitat supports burrowing, stability, and adequate water depth. If deficiencies are identified, corrective actions will be implemented before the removal of the silt curtain to enable natural recolonisation.

Key habitat requirements to be checked include:

- Sediment friability: bed should include some sediments loose enough for mussels to burrow.
- Sediment composition: ensure substrate remains sandy or mixed, avoiding excessive fine silt or coarse rubble that may reduce suitability.
- Bank and bed stability: stabilise loose or slumping material to reduce erosion and sediment transport post-works.
- Water depth: confirm adequate depth across the footprint by fully removing residual construction material and avoiding shallow mounding.

A follow-up assessment will be completed in conjunction with post-works mussel surveys, after cessation of winter flows, to verify longer-term habitat suitability.

4.5 Additional Survey of the Upstream Pool

An additional survey will be undertaken in the large pool located upstream of the riffle zone (as described in the Relocation Methodology). This area was not surveyed during the initial site assessment due to time and access constraints, but it may provide suitable long-term refuge habitat for *W. carteri* and may be useful where a contingency is required.

The survey will focus on confirming mussel presence, estimating relative density, and characterising habitat. A quantitative survey will be completed, using the same methodology used in the May survey (Appendix 1).

Information from this survey will support contingency planning should relocated mussels show evidence of displacement (e.g., repeated accumulation against the silt curtain). If required, the upstream pool may serve as an alternative relocation site, either for temporary holding (caging) or redistribution of individuals.

4.6 Adaptive Management

The monitoring program is supported by an adaptive management framework to ensure timely and effective responses if issues arise. Thresholds for action are based on ecological risk to *W. carteri*, construction impacts, and expert judgement. Where thresholds are exceeded, corrective measures will be implemented in consultation with DBCA, including the contingency options described in the Relocation Methodology (Section 3.4). This flexible approach ensures that mussel welfare and habitat integrity are maintained under changing conditions.

Table 7. Adaptive management thresholds, monitoring triggers and corrective actions.

Monitoring Element	Threshold / Trigger	Corrective Action

Mussel stability and health	Signs of stress at check site: – >5% mortality – persistent displacement – considerable accumulation of mussels against silt curtain	Consult DBCA; implement agreed contingency measures: – relocation to upstream pool – temporary caging
Mussel presence in disturbance footprint	Relocated mussels observed re-entering works area downstream of silt curtain	Reinforce or adjust silt curtain placement; recover and re-release mussels to relocation site or cages as appropriate
Water quality	Exceedance of quantitative thresholds for >24 hours: – DO < 4 mg/L – turbidity > 20 NTU above baseline – pH > 2 units above baseline – Temperature >30 °C	– Investigate source – Halt in-water works if required – Resume only once conditions recover Notify DBCA – Assess contingency
Habitat reinstatement	Disturbance footprint shows excessive compaction, shallow zones, or unstable slumping during post-works assessment	Implement remediation: sediment loosening, contour adjustment, bank stabilisation; re-inspect prior to silt curtain removal
Recolonisation	No evidence of mussel presence in disturbance footprint 6–12 months post-works	Review habitat condition.

5 ROLES AND RESPONSIBILITIES

5.1 Implementation of the Management Plan

Implementation will require approval of a Relocation Licence under Regulation 40 of the *Biodiversity Conservation Regulations 2018* (issued pursuant to the *Biodiversity Conservation Act 2016*). This licence authorises the taking and relocation of *Westralunio carteri* and will provide formal confirmation of the approach outlined in this Carter's Freshwater Mussel Management Plan (CFMMP).

Principal Ecologist Dr Robyn Paice, from Ottelia Ecology, will oversee implementation of the CFMMP. Robyn has a PhD in Freshwater Ecology and substantial experience in ecological surveys, with expertise in water quality, macroinvertebrates and aquatic plants. Robyn has supported and led surveys and management plans for *W. carteri* since 2019. Ottelia Ecology will be responsible for all monitoring and reporting requirements as set out in this CFMMP.

5.2 Reporting

Reporting will provide accountability to regulators and stakeholders, ensuring that monitoring results, any issues encountered, and adaptive management responses are transparently documented throughout implementation of the CFMMP. Requirements are as follows:

- Baseline Report: A short report (or memo) provided within two weeks of completing relocation activities, documenting methods, number of mussels relocated, health at the time of relocation, and baseline water quality.
- Progress Updates: Brief written updates (via email) after monthly monitoring round during works, noting mussel condition, water quality results, and any issues or corrective actions. These can be provided by email to DBCA and the proponent's Environmental Officer.
- Incident Notification: Immediate notification (within 24 hours) to DBCA and the proponent if thresholds are exceeded or if unexpected mortality/displacement is observed.
- Post-Works Report: A short report (or memo) within six weeks of silt curtain removal, summarising monitoring results, habitat condition, and any adaptive management measures implemented.
- Final Monitoring Report: A comprehensive report following the post-winter resurvey, integrating all monitoring data (mussels, water quality, habitat), outcomes of contingency measures (if applied), and recommendations for any further management.

6 References

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7 Appendix 1

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Memorandum **Collie River Bridge Replacement - Carter's Freshwater Mussel Management** **13/06/2025**	
TO: Shane Priddle Principal Consultant South West Environmental +61 (0)437 700 917 shane@swenvironmental.com.au	FROM: Dr Robyn Paice Principal Ecologist Ottelia Ecology +61 (0)417 997 388 robyn@otteliaecology.com.au

1 Background

Construction works for bridge replacement on Collie River Road are scheduled to commence in late 2025. This work may impact Carter's Freshwater Mussel (CFM) (*Westralunio carteri*) through direct physical disturbance, effects on water quality and alterations to habitat. *Westralunio carteri* is listed as Vulnerable on state (*Biodiversity Conservation [BC] Act 2016*), national (*Environment Protection and Biodiversity Conservation Act 1999*) and international conservation lists (IUCN Red List).

To provide an understanding of the population present in Collie River in the vicinity of the bridge replacement works, a comprehensive survey was completed on 5-6 May 2025. This Memorandum provides a brief summary of the survey outcomes. The outcomes of this survey will be used to guide preparation of a CFM Management Plan to minimise impacts on the species from the bridge works.

2 Survey Methods

The survey involved hand-searching within $1m^2$ quadrats at regular (approximately 3m) intervals along both banks and in wadable off-bank habitat within approximately 50m up- and down-stream of the existing bridge. This resulted in completion of 80 quadrats in this area (Figure 1).

In each quadrat, all mussels were counted and all live mussels were measured for shell length. This data provides estimates of population density to inform management. Size frequency distribution provides an understanding of population viability.

Physico-chemical water quality covariates were measured at 3 locations upstream and 3 locations downstream, with measurements at each bank and in the river mid-point. A Hanna HI98194 multiparameter was used to measure pH, salinity, conductivity, dissolved oxygen and temperature. In addition, turbidity was measured using a Hach 2100P Turbidimeter, including samples from banks and mid-points up-and downstream of the bridge.

The survey was completed by Robyn Paice and Georgia Johnsen, and undertaken with the required approvals as follows:

- TFA-2425-0236: Authorisation to Take or Disturb Threatened Species, issued by the Department of Biodiversity, Conservation and Attractions (DBCA) under Section 40 of the BC Act 2016.

- BA27001289: Fauna taking (Biological Assessment Licence), issued by DBCA under Regulation 27 of the Biodiversity Conservation Regulations 2018.
- Exemption 251345825 from provisions of the Fish Resources Management (FRM) Act 1994, issued by Department of Primary Industries and Regional Development (DPIRD).

3 Water Quality

This section of the Collie River is fresh and well-oxygenated and has very high clarity. From the 18 measurements of physico-chemical variables and turbidity readings, there was very little variation. Thus there is no need to report individual site values. Results are presented in Table 1.

Table 1. Water quality at the Collie River survey site May 2025.

Variable	**Mean (± SD)**
pH	7.59 ± 0.1
Dissolved oxygen (%)	118.68 ± 3.2
Dissolved oxygen (mg/L)	11.24 ± 0.3
Conductivity (µS/cm)	2400.71 ± 20.2
Salinity (mg/L)	1.39
Temp (C)	17.85 ± 0.7

4 Survey Findings

Results are summarised for the main sections of the river in relation to the existing bridge, the east and west banks (quadrats within ~2m of the bank) and off-bank habitat (>2m from bank in wadeable depth) (Table 2, Figure 2). The downstream section is north of the bridge in Figure 1 and the upstream reach is south of the bridge. All margins of error reported are standard error of the mean (SE).

A total of 271 live mussels were found in quadrats in the survey area, with an overall mean density of 3.4 ± 0.8 mussels/m^2. In addition, 31 dead mussels were found during the survey (10.3%). Mussels were present along both banks and in off-bank habitat upstream and downstream of the existing bridge, although density was variable, ranging from 0-58 mussels/m^2. No mussels were found in quadrats under the existing bridge or observed in this area. Habitat here is considered too rocky and shallow to support mussel colonisation.

Downstream of bridge

Downstream of the existing bridge mean density was low overall (2.6 ± 1.5 mussels/m^2) and mussels were only present in 35% of quadrats, with most mussels found more than 30m away from the existing bridge. Within 30m downstream of the bridge, mean density was low at 0.5 mussels/m^2. A “hot spot” of very high density was found approximately 35-40m from the bridge on the west bank, where 58 mussels were found in one quadrat (Figure 1). This was the highest density found throughout the survey. As a result, the west bank had a higher mean density (5.2 ± 3.4) than the east bank (0.8 ± 0.4). The lowest density was found in the off-bank habitat (0.3 ± 0.2).

Low density of mussels in the downstream habitat is likely to be related to the prevalence of rocky substrate within riffle habitat, which is not conducive to settlement of mussels. This area is also impacted by informal vehicle access. In addition, this reach of the river is relatively narrow, and thus subject to higher flow rates than upstream.

Upstream of bridge

Upstream mussel density was higher (mean 4.3 ± 0.8) and presence more consistent, with mussels present in 67% of quadrats. However, density was spatially variable, with mussel density ranging from 0-17. Higher density was found along the east bank and in the off-bank habitat (5.8 ± 1.6 and 5.8 ± 1.3 mussels/m^2 respectively), while the west bank had lower density (2.3 ± 0.9) and a greater proportion of empty quadrats (50%).

The upstream reach is partially impounded by shallow rocky habitat under the bridge, creating extensive river pool habitat, which is colonised by mussels throughout its width in the sampled area. Lower mussel density along the west bank may be related to the presence of extensive soft organic sediments, likely to be anoxic as indicated by a hydrogen sulphide smell when disturbed.

Depth and soft organic sediments restricted the extent of the mussel survey in the off-bank habitat to within 20m upstream of the bridge: the maximum depth able to be surveyed using this quadrat method was 0.7m. These conditions also restricted further quadrat sampling upstream along banks.

Population abundance estimates

The survey outcomes enable estimation of the number of mussels that may require relocation during bridge replacement works. These estimates are provided for both 60m and 100m footprints for construction works, relating to 30m and 50m either side of the existing bridge (Table 2). These estimates will be used as the basis for the CFM Management Plan.

Due to the very low density of mussels with 30m downstream of the bridge, and overall lower area, restricting bridge works to within this area would substantially reduce the number of mussels requiring relocation.

Table 2. *Westralunio carteri* density and abundance estimates for the Collie River survey area May 2025.

Location	Downstream of bridge			Upstream of bridge		
	West bank	East bank	Off-bank	West bank	East bank	Off-bank
Mean density (mussels/m^2 ± SE)	5.2 ± 3.4	0.8 ± 0.4	0.3 ± 0.2	2.3 ± 1.4	5.8 ± 1.6	5.8 ± 1.4
	2.6 ± 1.5			4.3 ± 0.8		
Estimated abundance within **30m** of bridge	150 ± 54*			2338 ± 421		
Estimated abundance within **50m** of bridge	1148 ± 662			5044 ± 1363		

*Based on specific density for this section (0.5 ± 0.2) owing to very low observed abundance

5 Relocation Habitat Assessment

Upstream river habitat was assessed for potential relocation areas. It is not recommended to relocate mussels downstream due to greater potential for water quality impacts during construction.

Approximately 90m upstream of the bridge is a rapid riffle zone unsuitable for mussels. There is likely to be additional mussel habitat upstream of the assessed area with an extensive pool in this area observed from aerial photos. However limited access and time prevented further survey.

Between the survey area and this rapid riffle zone is extensive suitable mussel habitat that could be utilised for relocation. Mussels were observed in the area, however quantifying the population in this area is difficult due to depth being greater than that allowing quadrat sampling. Other sediment sampling methods, such as Eckman grabs, are ineffective, and observation excludes mussels buried

under sediments. For management purposes, it can be assumed that the population density would be similar to the surveyed area, due to similar habitat characteristics.

In the wadeable habitat downstream of the rapid riffle zone, mussels were present and substrate was variably sandy and rocky. Five quadrats were assessed here, with a mean mussel density of 2.2 mussels/m^2. Visual assessment indicated that the eastern bank provides the most favourable mussel habitat (mussels were observed but could not be sampled). This habitat was similar to within the surveyed area and mussels were common in this area.

6 Management Implications

Bridge construction works are likely to have direct physical impacts on the local population of *W. carteri*, and therefore relocation of potentially impacted mussels will be required. Estimates of abundance based on the survey results suggest, for example, that:

- a disturbance footprint of 60m would require relocation of ~2,500 mussels.
- a disturbance footprint of 100m would require relocation of ~6,200 mussels.

Removal of mussels for relocation would be difficult in some upstream areas due to soft sediments and depth, and the presence of mussels throughout off-bank habitat.

A Carter's Freshwater Mussel Management Plan will be developed to guide relocation. This will need to be informed by expected construction footprint.



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FIGURE 1. CFM PLOTS

COLLIE RIVER BRIDGE, COLLIE

Ref: SW612 CFM
Date: 12/06/2025 Author: SP

CFM density — Major watercourse
0
1-5
6-10
11-15
16-20
50+
Road



A3 @ 1:700

0 5 10 20 m

N

SW Environmental

Source: Base map © Esri and its data suppliers. SLIP Landgate (2025)

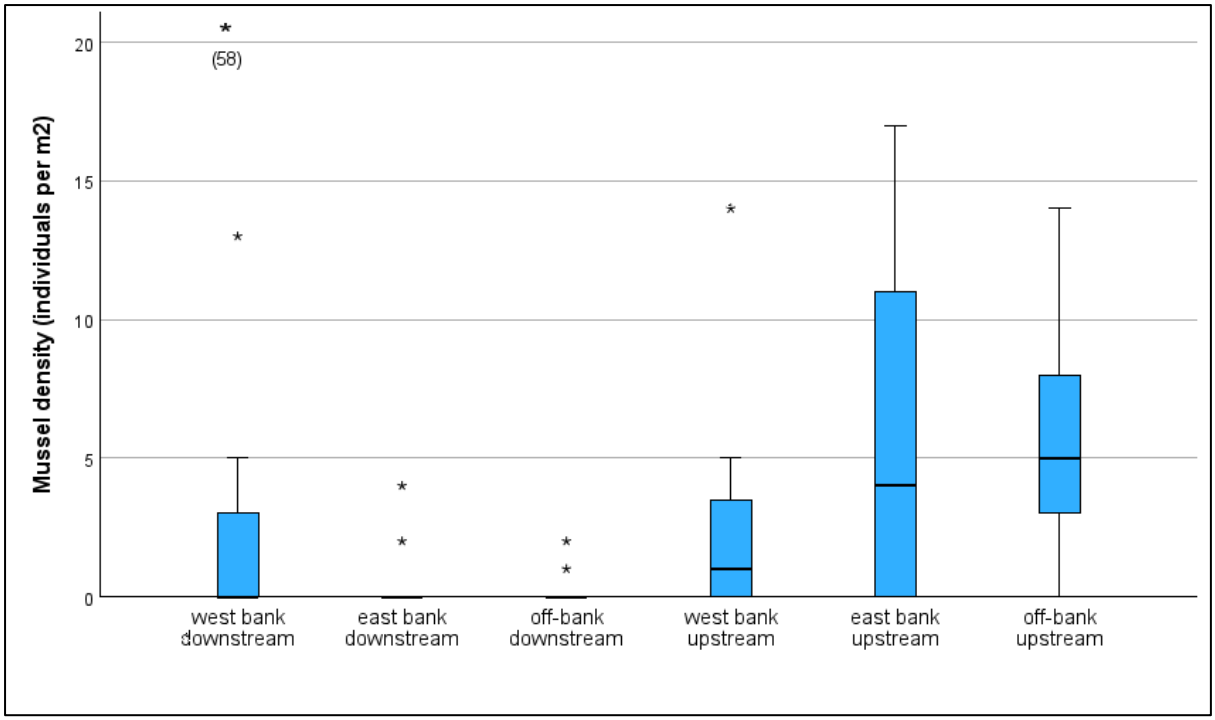


Figure 2. Mussel density estimates in the Collie River survey area May 2025. Lines are median values, boxes represent the 25-75 percentile range, whiskers the 5-95 percentile range, and asterisks are outliers.