



INDOPACIFIC
Environmental

**VASSE DIVERSION DRAIN UPGRADE PROJECT WESTRALUNIO CARTERI
MANAGEMENT PLAN**

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EXECUTIVE SUMMARY

The Water Corporation proposes to upgrade approximately six kilometres of the Vasse Diversion Drain (VDD) to meet current flood mitigation requirements. The project area extends downstream from the Busselton Golf Course, near Chapman Hill Road, to beyond the Busselton Bypass, with works including the reconstruction and widening of some sections of the levee walls and reconstruction of the diversion dam.

The Vasse River, including the VDD, is known to contain *Westralunio carteri* (Carter's Freshwater Mussel) which is listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* and *Western Australian Biodiversity and Conservation Act 2016*. In order to support project approvals, the Water Corporation commissioned studies investigating the distribution and abundance of *W. carteri* in the sections of the VDD designated for the upgrade. Those studies found live *W. carteri* to be generally confined to the uppermost ~700 metre section of the VDD upgrade project area upstream of the bridge on Chapman Hill Road.

This *W. carteri* Management Plan (WCMP) was drafted to assess the potential for the project to impact upon *W. carteri* present within the project area and the broader population present in the Vasse River catchment. Specific management objectives of the WCMP are to:

- Facilitate compliance with relevant legislation, regulations and approvals;
- Minimise disturbance of known habitat within the project area;
- Minimise disturbance of known habitat and *W. carteri* located upstream and downstream of the project area;
- Minimise mortality of individuals located within the project area as a direct result of earthworks;
- Minimise mortality as a direct result of relocation or translocation; and
- Minimise the risk of disease or infection transmission resulting from the relocation or translocation of *W. carteri* from the project area to an alternative habitat.

In order to support the assessment, a gap analysis was undertaken to enable management options to be definitively considered. As a result, additional survey works were deemed necessary to address the option to relocate *W. carteri* from the project area in line with a management strategy which was previously implemented for *W. carteri* for another project in the lower Vasse River. In particular, the survey aimed to identify whether habitat upstream of the project area was suitable for the relocation of *W. carteri* from the project area. Indeed, results of that survey indicated that extensive suitable habitat existed, and throughout which *W. carteri* was found to be present.

An ecological risk assessment was undertaken as part of this WCMP. As a result, the following preferred relocation methodology was defined to meet the management objectives outlined above:

- In the month(s) prior to construction works, conspicuous mussels will be collected by hand from pools within the project area that will be directly or indirectly affected by earthworks and placed into insulated vessels containing a damp media. In the event the bed within a pool located within the project area will not be subject to earthworks, individuals will be left in-situ.
- *W. carteri* will be relocated to waters upstream of the project area adjacent to, and accessible from, the Busselton Golf Course.
- Insulated vessels will be passed up the banks of the VDD, placed into a vehicle for transfer and immediately driven to relocation sites behind the Busselton Golf Course which is located ~1km away by road.
- Upon arrival at the relocation site, a car topper dinghy will be used to disperse mussels throughout the pool present. Mussel dispersion will be conducted in such a way that densities per m² do not exceed known current maximum densities of the relocation sites.

The relocation of *W. carteri* will be conducted by suitably qualified aquatic ecologists in accordance with requirements set out by the Department of Biodiversity, Conservation and Attractions (Fauna taking (relocation) licence) and Department of Primary Industries and Regional Development (translocation permit issued under the Fish Resources Management Act 1994). Management targets for the relocation will include:

- Less than 5% mortality during relocation from the VDD; and
- Mean rate of mortality in relocated *W. carteri* is not greater than 20% of the rate of mortality in *W. carteri* from the relocation site.

These targets will be assessed via monitoring conducted within one and 14 days from the time *W. carteri* are relocated to determine survival rates of relocated *W. carteri* and those individuals previously present.

A project specific Water Quality Monitoring and Management Plan (WQMMP) will also be implemented and adhered to. The WQMMP will define specific trigger values for various water quality parameters aimed at minimising potential impact to *W. carteri* located upstream and downstream of the project area. In the event trigger values are exceeded, additional management actions and supplementary monitoring will be implemented in accordance with the WQMMP in order to return water quality parameters to tolerable levels of the species.

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1.0 INTRODUCTION

1.1 *Project Description*

The Water Corporation proposes to upgrade approximately six kilometres of the Vasse Diversion Drain (VDD) to meet current flood mitigation requirements, including the capacity to pass a 1 in 100 year flood event (Water Corporation 2020). The project area extends downstream from the Busselton Golf Course, near Chapman Hill Road, to beyond the Busselton Bypass, with works including the reconstruction and widening of some sections of the levee walls and reconstruction of the diversion dam (Figure 1). In order to manage flow and facilitate works on the diversion dam, the current proposal includes the installation of a coffer dam (temporary earth bund) near the upstream extent of the project area, a coffer dam in the Vasse River immediately downstream of its confluence with the VDD, and a temporary bypass pipe to maintain flow to the Vasse River downstream of the diversion dam during construction.

1.2 *Premise*

The Vasse River, including a section of the VDD, is known to contain *Westralunio carteri* (Carter's Freshwater Mussel) (Slack-Smith 2006, Lymbery *et al.* 2008, Ma 2018). *Westralunio carteri* is listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and *Western Australian Biodiversity and Conservation Act 2016* (BC Act). In order to support project approvals, the Water Corporation commissioned studies investigating the distribution and abundance of *W. carteri* in the sections of the VDD designated for the upgrade (Beatty 2019, GHD 2019). Those studies found live *W. carteri* to be generally confined to the uppermost ~700 metre section of VDD upgrade project area (project area) and upstream of the bridge on Chapman Hill Road. As a result of the species presence within the project area and listing under the BC Act, this *W. carteri* Management Plan (WCMP) was drafted to assess the potential for the project to impact upon *W. carteri* present within the project area and the broader population present.

1.3 *Conservation Status*

The conservation advice for *W. carteri* defined by the Threatened Species Scientific Committee (2014), established under the EPBC Act, provides the justification for the listing of the species as Vulnerable. The listing of *W. carteri* as Vulnerable largely relates to the reduction in the extent of occupation (EOO) (i.e. geographical distribution) which is described as historically declining by 49% and which is currently estimated to be 22, 584 km². In particular, the species is described as meeting listing criteria A2c+4c. The guidelines for assessing the conservation

status of native species according to the EPBC Act (and EPBC Regulations 2000) provides the definitions for the listing criteria which in the case of *W. carteri* is based on:

- A2c: Population reduction observed, estimated, inferred or suspected in the past where the causes of the reduction may not have ceased OR may not be understood OR may not be reversible and (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat; and
- A4: The estimated total number of mature individuals is low

The conservation advice also states that the area of extent (AOO) has not been determined and that the current population size is unknown. The criteria for listing of the species as Vulnerable under the BC Act is consistent with the criteria met under the EPBC Act.

1.4 Compliance with Environmental Approvals

The Water Corporation has been granted a Purpose Permit under Part V of the *EP Act* (WA) for project activities. All activities must be undertaken in compliance with conditions set in the Department of Water and Environmental Regulation (DWER) Purpose Permit CPS 8191/1, which are outlined below. Carter's mussels were not listed under the *EPBC Act 1999* [cwth] at the time of referral and were not assessed under EPBC 2017/7932.

Ref	Requirement	Comments
11	<p>Fauna Management – Other approvals</p> <p>Prior to clearing, the Permit Holder must provide to the CEO:</p> <p>a) a copy of the fauna licence(s) obtained under the <i>Biodiversity Conservation Act 2016</i> for the relocation and/or translocation of Carter's freshwater mussel (<i>Westralunio carteri</i>) and the dispersion of western ringtail possum (<i>Pseudocheirus occidentalis</i>) individuals; and</p> <p>b) a copy of the approved exemption from the Department of Primary Industries and Regional Development under the <i>Fish Resources Management Act 1994</i> and <i>Fish Resources Management Regulations 1995</i> for the collection of Carter's freshwater mussel for translocation.</p>	Permits will be obtained by qualified Subject matter experts on behalf of the Corporation.
12	<p>Fauna management – Carter's freshwater mussel</p> <p>a) Prior to commencement of any clearing activities authorised under this Permit, the Permit Holder must submit a Carter's freshwater mussel (<i>Westralunio carteri</i>) Management Plan to the CEO for approval. The management plan must contain the following:</p> <p>(i) Removal, transportation and relocation method, and where required, temporary storage method;</p> <p>(ii) Location of the relocation site, including a field assessment confirming the suitability of the relocation site;</p> <p>(iii) Stocking densities; and</p> <p>(iv) The success rate monitoring plan.</p>	This plan
13, 14,	Fauna management – western ringtail possum	See (Bamford Consulting

Ref	Requirement	Comments
15, 16	Refer to <i>Fauna Management Plan for Vasse Diversion Drain Upgrade</i> (Bamford Consulting Ecologists, 2020) for all conditions relating to Western Ringtail Possums	Ecologists, 2020)

1.5 **Management Approach**

Effective risk management requires the potential impacts of an action to be clearly identified and that existing knowledge of the life history and habitat requirements of listed biota which may be impacted is sufficient to make informed decisions. In order to assess the risk to *W. carteri* and design an effective management strategy, the following steps were followed:

- Clearly define the project;
- Collate background data;
- Define management objectives and identify key risks of the project;
- Identify and address knowledge gaps;
- Define management actions to mitigate the risk;
- Define monitoring to assess management actions;
- Identify roles and responsibilities for implementation; and
- Review the management plan.

1.6 **Previous Management**

In 2018, proposed works by the City of Busselton on the Busselton Eastern Link and Causeway Bridge Duplication Projects resulted in the drafting of a Carter's Freshwater Mussel *Westralunio carteri* Environmental Management Plan (EMP) for *W. carteri* located within that project area on the lower Vasse River (Beatty and Lymbery 2019). While the WA Environmental Protection Authorities (EPA) decision was not to formally assess that project, the EPA advised that an EMP was required to 'design an effective temporary relocation program for the Carter's Freshwater Mussel population to be actioned during the Project'. The subsequent EMP proposed the removal of *W. carteri* from waters within the project area prior to any works being undertaken, temporary relocation of individuals to suitable habitat (or holding facility), and subsequent replacement of individuals back into waters of the project area upon completion of the works.

The draft EMP for that project initially outlined an option for *W. carteri* to be temporarily relocated to waters of the upper Vasse River. This was due to the authors recognising that the 'upper Vasse River, in the vicinity of the junction with the Vasse Diversion Drain, would provide

a suitable site for the temporary relocation because it supports a large, viable population of mussels (Lymbery *et al.* 2008) and is protected from public access.’ However, due to the currently proposed upgrade works of the VDD, the proposed relocation site was not considered suitable. As a result, an alternative site for the temporary relocation of *W. carteri* from the lower Vasse River was identified, that being in Taylors Lake in Capel. This management strategy was subsequently reflected in the final of the EMP in April 2019.

1.7 **Management Objectives**

The overarching aim of the VDD upgrade project WCMP is to manage potential impacts of the works to mitigate a population level effect of *W. carteri* in the Vasse River. Specific management objectives of this WCMP to achieve this overarching aim include:

- Facilitate compliance with relevant legislation, regulations and approvals;
- Minimise disturbance of known habitat within the project area;
- Minimise disturbance of known habitat and *W. carteri* located upstream and downstream of the project area; and
- Minimise mortality of individuals located within the project area as a direct result of earthworks.

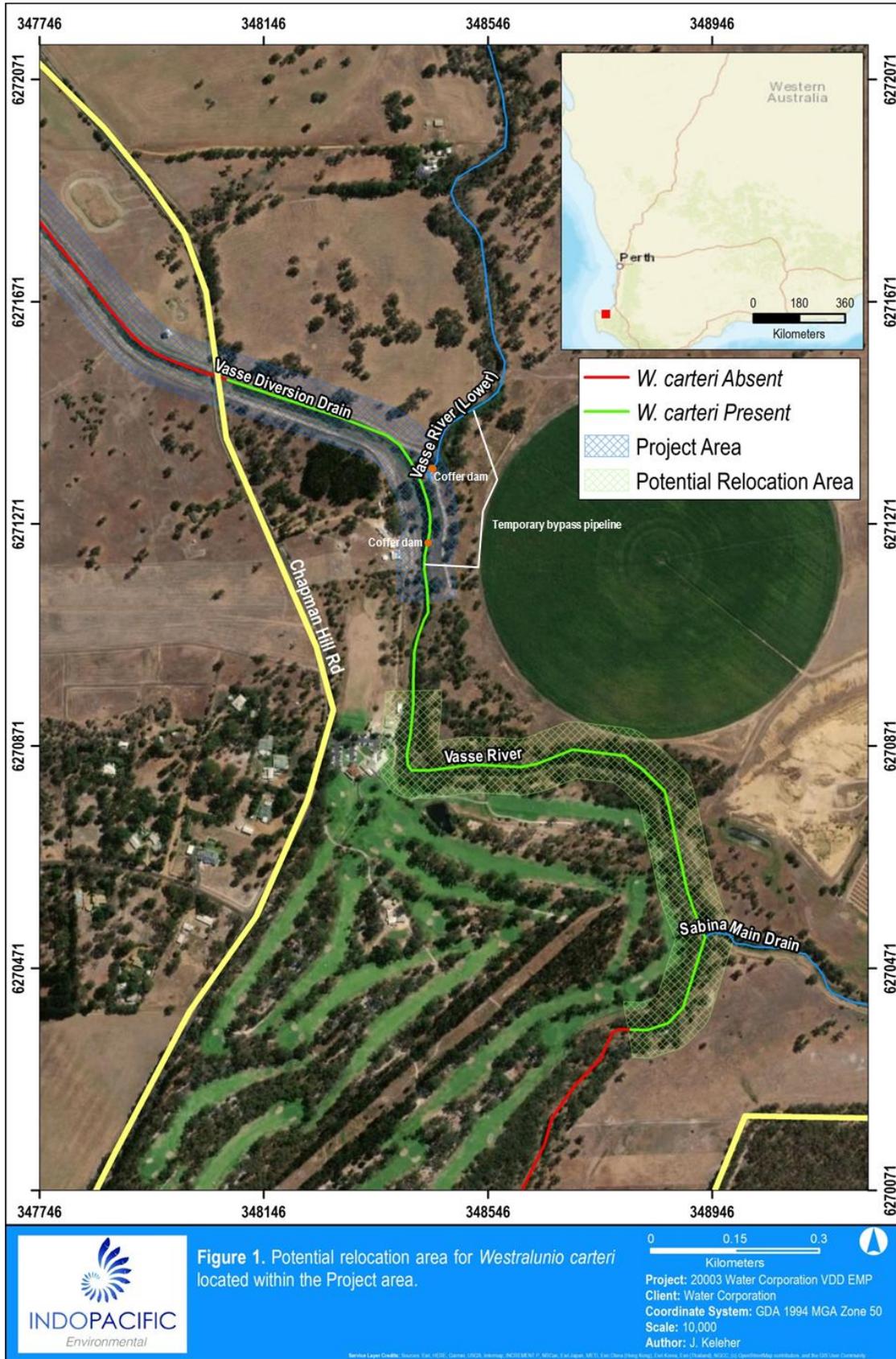
In relation to the VDD upgrade project WCMP, the DWER and the Department of Biodiversity, Conservation and Attractions (DBCA) had stated that the Water Corporation should assess whether the same strategy and relocation site utilised in the Busselton Eastern Link and Causeway Bridge Duplication Projects EMP outlined in Section 1.5 was applicable. In recognition of this request, and the previously employed management strategy for *W. carteri*, additional objectives of this WCMP include:

- Minimise mortality as a direct result of relocation or translocation; and
- Minimise the risk of disease or infection transmission resulting from the relocation or translocation of *W. carteri* from the project area to an alternative habitat.

1.8 **Knowledge Gaps**

While the presence of *W. carteri* within the project area has been well documented during previous surveys conducted by the authors outlined in Section 1.2, additional survey work was undertaken in March 2020 to provide supplementary data on the distribution of *W. carteri* upstream of the project area and the habitat present (Indo-Pacific Environmental 2020). The reason for the collection of supplementary data was due to the fact that none of the previous surveys had formally investigated the presence of *W. carteri* immediately upstream of the

project area or the species upstream extent. Works conducted in 2020 included an assessment of the *W. carteri* habitat present within the project area to understand the species requirements and assist in identifying potential relocation or translocation sites through the comparison of habitat attributes. Sites immediately upstream of the project area were also assessed to identify whether *W. carteri* were present. This information would be subsequently used to aid in identifying whether waters upstream of the project area would provide a suitable relocation site for *W. carteri* should relocation be considered necessary. The results of that survey can be found in Appendix 1.



2.0 WESTRALUNIO CARTERI RISK ASSESSMENT

2.1 Risk Identification and Assessment

Table 1 outlines the key risks, risk limiting factors, management actions and a qualification of the residual risk as they relate to the Management Objectives. The risk assessment aims to consider a practical range of management options and ultimately identify a preferred management strategy based on the residual risk of these options. In order to increase the relevance of the assessment specifically to *W. carteri*, the attributes which lead to the species listing as Vulnerable outlined in the conservation advice of the Threatened Species Scientific Committee (2014) were also considered. Furthermore, relevant to the species listing under the EPBC Act, the risk assessment considered the factors defined in the 'Significant Impact Criteria' for a Vulnerable species outlined in the Significant Impact Guidelines (Department of Environment 2013), which states the following:

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

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

Table 1. Risk Assessment for *Westralunio carteri*. Residual outcomes highlighted in green represent lowest risk to *W. carteri* and subsequently the preferential management action to be adopted.

	Management Objective	Key Risk	Risk Limiting Factors	Management Action	Residual Outcome
1	Minimise disturbance of known habitat within the project area.	<ul style="list-style-type: none"> - Direct removal of bed and bank sediment will result in mortality of <i>W. carteri</i> present through crushing or desiccation once removed from aquatic habitat. - Increased water turbidity resulting from disturbed sediments may lead to liberation of sediment analytes which are detrimental to <i>W. carteri</i>. - Mechanical excavation of beds and banks leads to smothering of <i>W. carteri</i> with sediment. 	<ul style="list-style-type: none"> - Project area containing <i>W. carteri</i> is limited to ~700 m section at upstream extent of project area. - Project will not result in habitat loss leading to a reduction of known area of extent (EOO), any measurable loss in area of occupation (AOO), or affect conservation listings. - <i>W. carteri</i> is distributed throughout the Vasse River. The project area does not represent a significant portion of known habitat. - <i>W. carteri</i> extensively distributed throughout waters immediately upstream of the project area in comparable densities. 	<ul style="list-style-type: none"> - Minimise disturbance to bed and banks in the upstream section of the project area where <i>W. carteri</i> is known to occur. - Identification of specific bed and bank areas requiring sediment removal through bathymetric assessment. - Targeted removal of bed and bank sediments where required. - Mechanical excavation of bed will not occur upstream of the coffer dam located near the upstream extent of the project area (Figure 1) where <i>W. carteri</i> is known to occur. <p>And</p> <ul style="list-style-type: none"> - Proposed timing of the project is summer when water levels are contracted and VDD exists as a series of pools in the project area. - Dry sections between pools in VDD will limit the spatial spread of disturbed sediment and waters. <p>And</p> <ul style="list-style-type: none"> - Progress works in the project area where <i>W. carteri</i> is present in an upstream direction - Reduce the duration of plume exposure to <i>W. carteri</i> located downstream when affected by flow. 	<p>Moderate risk to individuals within the project area.</p> <p>Very low risk of a population level effect.</p>
2	Minimise disturbance of known habitat and <i>W. carteri</i> located upstream and downstream of the project area.	<ul style="list-style-type: none"> - Increased water turbidity resulting from disturbed sediments leads to travel of plume downstream into the VDD. - Diversion dam works disrupts or ceases flow in the Vasse River leading to temporary drying of habitat downstream. - Diversion dam works causes increased water turbidity or sediment transfer downstream in the Vasse River. - Increased water turbidity resulting from disturbed sediments results in reduced water quality in waters upstream of the project area. - Excavation of bed results in surface or sub-surface flow from pools upstream of the project area resulting in pool draw down. 	<ul style="list-style-type: none"> - Project area containing <i>W. carteri</i> is limited to ~700 m section at upstream extent of project area. - No live <i>W. carteri</i> found in VDD below Chapman Hill Road. - Cofferdam in the Vasse River immediately downstream of the diversion dam construction site will limit downstream movement of sediment and turbid water. - Cofferdam near upstream extent of the project area will reduce plume travel and maintain water level in pools upstream where <i>W. carteri</i> occur. - Temporary bypass pipeline will maintain flow to the Vasse River downstream of the diversion dam during construction. 	<ul style="list-style-type: none"> - Proposed timing of the project is summer when water levels are contracted and the VDD and Vasse River immediately below the diversion dam exist as a series of disconnected shallow pools in the project area. - Greatly reduced flow or cessation of flow during summer will limited downstream transport of sediment or water. - Dry sections in VDD will limit the spatial spread of disturbed sediment and waters. <p>And</p> <ul style="list-style-type: none"> - Use of silt curtains adjacent coffer dams to reduce transport of sediment upstream and downstream in the Vasse River. - Silt curtains will be installed prior to instillation of the coffer dams. - Silt curtains will be located immediately upstream of the coffer dam upstream of the diversion dam, and in the Vasse River immediately downstream of the coffer dam downstream of the diversion dam construction site. - A silt curtain will also be located below the temporary bypass pipe outlet. <p>And</p>	<p>Low risk to individuals upstream and downstream of the project area.</p> <p>Very low risk of a population level effect.</p>

	Management Objective	Key Risk	Risk Limiting Factors	Management Action	Residual Outcome
				<p>- Pumping rates through the temporary bypass pipe will be sufficient to maintain base flow (or greater) in the Vasse River. Pumping rates will not result in the drawdown of water from pools upstream of the project area where <i>W. carteri</i> occur.</p> <p>And</p> <p>- Implementation of and adherence to a project specific Water Quality Monitoring and Management Plan</p> <p>- The plan will monitor water quality in the Vasse River upstream and downstream of the project area before, during and after construction. Water quality is assessed against parameter trigger values set from pre-construction baseline data, literature and historical data. Exceedances of trigger values will result in implementation of additional management actions which may include, for example, installation of additional silt curtains or temporary cessation of construction works.</p>	
3	Minimise mortality as a direct result of earthworks in the project area.	- Earthworks results in loss of <i>W. carteri</i> from the project area and/or loss from broader catchment.	<p>- <i>W. carteri</i> distributed throughout the Vasse River. Project area does not represent a significant portion of known habitat.</p> <p>- <i>W. carteri</i> extensively distributed throughout waters immediately upstream of the project area in comparable densities.</p> <p>- Total loss of individuals in the project area would not result in any reduction of known extent of occupation (EOO), any measurable loss in area of occupation (AOO), or affect conservation listings.</p>	<p>- Management action for objectives 1 and 2</p> <p>And</p> <p>- No relocation or translocation of <i>W. carteri</i> from the project area.</p> <p>- High mortality of individuals at all life stages present.</p> <p>Or</p> <p>- Relocation or translocation of <i>W. carteri</i> from the project area to suitable habitat.</p> <p>- Reduced rates of mortality in individuals present through relocation of conspicuous <i>W. carteri</i> from works area.</p> <p>- Mortality in some life stages, in particular juveniles. Preservation of stock in later life stages including mature <i>W. carteri</i>.</p>	<p>High risk to individuals within the project area.</p> <p>Low risk of a population level effect.</p> <p>Low risk to individuals within the project area.</p> <p>Very low risk of a population level effect.</p>
4	Minimise mortality as a direct result of relocation or translocation.	<p>- Increased stress or mortality from physical removal, handling and transfer.</p> <p>- Introduction of translocated individuals to a site of differing water or habitat quality leads to stress or mortality.</p>	- <i>Westralunio carteri</i> been successfully relocated during previous programs, including the Busselton Eastern Link and Causeway Bridge Duplication Projects and the Helena River (Klunzinger <i>et al.</i> 2011), indicating some level of resilience to relocation.	<p>- Relocation of <i>W. carteri</i> to sites within the Vasse River catchment with comparable habitat to that within the project area.</p> <p>- Comparative assessment indicated waters upstream of the project area were suitable for the relocation of <i>W. carteri</i>. Water and sediment quality and habitat characters were comparable (if not better) than habitat present within the project area. <i>Westralunio carteri</i> extensively distributed throughout waters upstream of the project area indicating suitability of habitat.</p> <p>- Suitable relocation sites located <1km upstream of the project area would result in minimal transit and out of water time. Ease of access through Busselton Golf Course.</p> <p>- Individuals remain with comparable genetic stock.</p> <p>Or</p>	<p>Low risk to individuals relocated from the project area.</p> <p>Very low risk of population level effect through loss of diversity.</p>

	Management Objective	Key Risk	Risk Limiting Factors	Management Action	Residual Outcome
				<ul style="list-style-type: none"> - Relocation of <i>W. carteri</i> to Taylors Lake. - Varying water quality between the project area and Taylors Lake. - Comparative habitat assessment was not undertaken between VDD project area and Taylors Lake. - Taylors Lake in Capel is at least 30 minutes away by road resulting in vastly increased out of water time. - Carrying capacity of Taylors Lake is unknown. <p>And</p> <ul style="list-style-type: none"> <i>Permanently relocate W. carteri to recieval site.</i> - Removes the need for a second relocation event and any risk of stress or mortality associated with it. - If relocated to waters upstream of the project area, natural dispersal will re-establish <i>W. carteri</i> in the project area post-construction over time and if habitat is suitable. <i>Westralunio carteri</i> extensively distributed in waters immediately upstream of the project area. Downstream dispersal will occur during times of elevated flow rate and through dispersal of fish carrying glochidia. - Permanent relocation to Taylors Lake provides no net benefit to Vasse River population and removes genetic diversity. The EMP outlined an ultimate contingency to relocate individuals from the lower Vasse River project area to the upper Vasse River catchment if habitat was not suitable post-construction. <p>Or</p> <ul style="list-style-type: none"> - Reintroduce <i>W. carteri</i> back into project area post-construction. - Reintroduction of <i>W. carteri</i> represents a second relocation event and attracts risk of stress or mortality. - Habitat will take an extended period to stabilise within the VDD post-construction. - Unknown suitability of VDD as habitat for <i>W. carteri</i> post-construction. - Project area habitat does not represent critical habitat for the Vasse River population and area does not represent a significant portion of known habitat. 	<p>Moderate risk to individuals relocated from the project area due to extended transit time and introduction to differing habitat.</p> <p>Low risk of a population level effect through loss of diversity.</p> <p>Low risk to individuals relocated from the project area.</p> <p>Moderate risk to individuals due to second relocation event.</p>
5	Minimise the risk of disease, infection or parasite transmission resulting from the relocation or translocation of <i>W. carteri</i> .	<ul style="list-style-type: none"> - Transmission of disease, infection or parasites between translocated <i>W. carteri</i> and host population. - The Significant Impact Guidelines (Department of Environment 2013) states that the introduction of a 'disease that may cause the species to decline' is an action which is likely to have a significant impact on a vulnerable species. 		<ul style="list-style-type: none"> - Relocation of <i>W. carteri</i> to waters upstream of the project area. - Negates any risk associated with disease, infection or parasite transmission between individuals from differing catchments. - Negates any risk to sympatric species within the Vasse River catchment. <p>Or</p> <ul style="list-style-type: none"> - Relocation of <i>W. carteri</i> to waters outside the Vasse River catchment, in particular Taylors Lake, Capel - Risk of disease, infection or parasite transmission 	<p>No risk to relocated individuals.</p> <p>Moderate risk to individuals due to second relocation event.</p>

	Management Objective	Key Risk	Risk Limiting Factors	Management Action	Residual Outcome
				<p>between translocated individuals and Taylors Lake host population.</p> <ul style="list-style-type: none"> - Risk of disease, infection or parasite transmission between translocated individuals and Vasse River population upon subsequent return of translocated individuals 	

3.0 MANAGEMENT APPROACH

Outlined below is the proposed relocation methodology for the management of *W. carteri* from the VDD project area, relevant management targets and proposed monitoring. The methods, including the relocation sites, were determined from the risk assessment in Section 2.1 to meet the management objectives outlined in Section 1.6.

3.1 Exemptions and Permits

Any relocation of *W. carteri* will require various licences and exemptions and submission of information. From the DBCA this will include:

- Submission of a Translocation Proposal (incorporated within this WCMP); and a
- Fauna taking (relocation) licence.

In addition, a translocation permit issued under the *Fish Resources Management Act 1994* (FRMA) by the Department of Primary Industries and Regional Development (DPIRD) will be required.

3.2 Relocation Methodology

The relocation of *W. carteri* will be managed by suitably qualified aquatic ecologists and adhere to the following procedure:

- Suitable relocation sites have been identified in waters upstream of the project area adjacent to, and accessible from, the Busselton Golf Course. Relocation sites will be those recommended in the reconnaissance survey which can be found in Appendix 1. A majority of individuals collected from the project area will be relocated to the large pool accessible from the site referred to as VDD11. This is due to:
 - The extent and quality of the suitable habitat available;
 - The volume of water present and thus the ability to buffer seasonal variation in water levels and temperature;
 - The close proximity to the project area (i.e. ~1km by road) meaning transit time will be minimised; and
 - The ease of bank access into waters of the relocation site which will further minimise out of water time.
- In the month(s) prior to construction works, conspicuous mussels will be collected by hand from pools within the project area that will be directly or indirectly affected by earthworks. Each side of the bank will be searched by two people progressing in an

upstream direction which will assist in maintaining water clarity if some flow is present. Collected mussels will be placed in an insulated vessel containing a damp media. *Westralunio carteri* in the insulated vessels will not exceed five individuals depth to avoid crushing and ensure weights of the insulated vessels to be carried are manageable by personnel.

- In the event the bed within a pool located within the project area will not be subject to earthworks, individuals will be left in-situ. This aims to:
 - Negate any risk of stress or mortality associated with removal and relocation;
 - Maintain a continued presence of *W. carteri* within the project area; and
 - Assist with future colonisation of individuals into areas impacted by earthworks.
- Insulated vessels will be passed up the banks of the VDD, placed into a vehicle for transfer and immediately driven to VDD11 behind the Busselton Golf Course which is located ~1km away by road. Noting the short transfer distance, insulated vessels will not be topped up with water. This aims to:
 - Avoid stress due to a reduction in water quality of transfer water through the build-up of released toxins, for example, ammonia; and
 - Reduce the likelihood of spawning in transfer water. It is well understood that spawning in bivalve molluscs can be initiated through the repeated removal and immersion in water (Helm *et al.* 2004) which results in a stress related spawning event. The proposed methodology aims to achieve a single removal from waters of the project area and single replacement in the pool accessed from VDD11.
- Upon arrival at VDD11, a car topper dinghy will be used to disperse mussels throughout the pool present. Stocking densities will not exceed the maximum density recorded within the pool accessible from VDD11. Depending upon the number of individuals removed from the project area, limited numbers of *W. carteri* will be relocated to VDD4 and VDD8 outlined in Appendix 1.

3.3 **Water Quality Monitoring and Management Plan**

A project specific Water Quality Monitoring and Management Plan (WQMMP) will be implemented and adhered to. The WQMMP identifies key environmental receptors, including *W. carteri*, present in the VDD and Vasse River which may be affected by the project. The WQMMP will be developed in consultation with DWER by addressing the following:

- Identify relevant surface water quality parameters for each key environmental receptor to monitor and determine tolerance values, beyond which impact is considered likely to occur. Tolerance values will be determined through review of published literature, historical data and the collection of baseline data from the VDD and Vasse River prior to construction. Tolerance values will be used to define surface water quality parameter 'trigger values' whereby any exceedance of these values will result in the implementation of management actions to reduce water quality parameters to within respective tolerable levels of *W. carteri*;
- Establish monitoring locations in the VDD and Vasse River. This may include, for example, one site upstream of the project area in the Vasse River, one site downstream of the temporary bypass pipe outlet in the Vasse River, and two sites downstream of Chapman Hill Road Bridge in the VDD;
- Collection of water quality data through the installation of data loggers, in-situ measurements and/or analysis of water samples before, during and after construction works. Data will be regularly reviewed during construction to detect any exceedance of a trigger value; and
- Defining management actions (and supplementary monitoring) to reduce water quality parameters to within respective tolerable levels in the event trigger values are exceeded.

3.4 **Management Targets and Monitoring**

Proposed monitoring aims to inform the success of Management Objectives 2 and 4, noting that Management Objectives 1, 3 and 5 will be achieved if management actions outline in Table 1 are implemented and adhered to. Table 2 subsequently defines Management Targets and the proposed Monitoring method aimed at measuring the success of the Management Approach. Corrective actions should Management Targets fail to be met are also described.

3.5 **Roles and Responsibilities for Implementation**

The WCMP will be managed on behalf of the Water Corporation by a suitably qualified aquatic ecologist. The ecologist will ensure adherence to the management actions outlined in the WCMP, including the relocation of *W. carteri* from the project area, and associated monitoring. The ecologist will also be responsible for the application, management and reporting of all permits and licences required by the DBCA and the DPIRD for the relocation.

3.6 ***Management Plan Review.***

A report will be produced within eight weeks of the relocation of *W. carteri* from the VDD project area. The report will discuss the effectiveness of the management proposed in this WCMP and adherence to the management approach. Results of monitoring and any corrective actions will be outlined. The report will be submitted to the Water Corporation who will provide it to relevant Commonwealth and State departments in accordance with any legislative, permit or licence requirements.

Table 2. Management objective, management targets, proposed monitoring and correction actions for the relocation of *W. carteri*.

	Management Objective	Management Target	Monitoring	Corrective Action
2	Minimise disturbance of known habitat and <i>W. carteri</i> located upstream and downstream of the project area.	No prolonged exceedance of water quality assessment criteria set out in the WQMMP during construction.	<ul style="list-style-type: none"> - Monitoring will be conducted in accordance with the WQMMP. - Water quality parameters relevant to <i>W. carteri</i> will be monitored using loggers, in-situ measurements and/or analysis of water samples before, during and after construction works at sites upstream and downstream of the project area in the Vasse River and VDD. - Relevant water quality parameters to <i>W. carteri</i> are likely to include (but not limited to) electrical conductivity, salinity, water temperature and turbidity. - Data will be frequently reviewed to identify whether trigger values for <i>W. carteri</i> are exceeded. 	<ul style="list-style-type: none"> - Management actions and supplementary monitoring will be implemented in accordance with the WQMMP when trigger values are exceeded. Management actions will aim to reduce water quality parameters to within respective tolerable levels (trigger values) for <i>W. carteri</i>. - Management actions may include, for example, the instillation of additional silt curtains or temporary cessation of works.
4	Minimise mortality as a direct result of relocation or translocation.	Less than 5% mortality during relocation from the VDD.	<ul style="list-style-type: none"> - The number of <i>W. carteri</i> removed from the VDD and placed in each insulated vessel will be recorded. - <i>Westralunio carteri</i> will be inspected prior to release and the number which have perished in each insulated vessel during the relocation will be recorded. This will include <i>W. carteri</i> found to be damaged (e.g. crushed or cracked shell). - The mean ratio of live to perished <i>W. carteri</i> will be calculated on the movement of every 10 insulated vessels. 	<ul style="list-style-type: none"> - In the event >5% mortality, the relocation method will be revised and the driver behind the high rate of mortality identified and the methodology adapted. For example, if crushing is the main driver during the relocation, the number of mussels per insulated vessel may be reduced. In the event heat is found to be the driver, insulated vessels will be cooled. - Subsequent to a change in methodology, the mean ratio of live to perished <i>W. carteri</i> will continue to be calculated on the movement of every 10 insulated vessels.

	Management Objective	Management Target	Monitoring	Corrective Action
		<p>Mean rate of mortality in relocated <i>W. carteri</i> is not greater than 20% of the rate of mortality in <i>W. carteri</i> from the relocation site.</p>	<ul style="list-style-type: none"> - At VDD11, three temporary 1m² pens will be established in the pool. Pens will be constructed from fine mesh driven ~10cm into the river bed and rising at least 20 cm up from it. - Ten relocated individuals from the VDD and ten individuals from the relocation site will be identified with a distinguishing marker and placed in each pen. - Each individual will be inspected one day and 14 days after the relocation and the ratio of dead to live mussels recorded. 	<ul style="list-style-type: none"> - In the event >20% mortality is observed in relocated <i>W. carteri</i> at VDD11 one day after relocation, any subsequent <i>W. carteri</i> removed from the VDD will be relocated to alternative pools located further upstream including VDD4 and VDD8 at reduced stocking densities and potential drivers of mortality will be investigated. - In the event >20% mortality is observed in relocated <i>W. carteri</i> at VDD11 14 days after relocation, potential drivers of mortality will be investigated and used to inform any future relocation programs for <i>W. carteri</i>.

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APPENDIX 1



INDOPACIFIC

Environmental

**VASSE DIVERSION DRAIN UPGRADE PROJECT WESTRALUNIO CARTERI
SCOPING STUDY**

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1 INTRODUCTION

1.1 Purpose

This report provides the findings of a reconnaissance survey to identify potential relocation sites for *Westralunio carteri* in the Vasse Diversion Drain (VDD).

1.2 Background

The Water Corporation is proposing upgrade works to the VDD to meet current flood mitigation requirements. The project area extends downstream from the Busselton Golf Course to beyond the Busselton Bypass, with works including the reconstruction of some sections of the levee walls and the diversion dam. In order to support project approvals, the Water Corporation commissioned several studies investigating the distribution and abundance of *W. carteri* in the sections of the VDD which were designated for the upgrade. Those studies found *W. carteri* to be confined to the uppermost section of project area and upstream of the bridge on Chapman Hill Road (Beatty 2019, GHD 2019).

In 2018, proposed works by the City of Busselton on the 'Busselton Eastern Link and Causeway Bridge Duplication Projects' resulted in the drafting of an EMP for the management of *W. carteri* located within that project area on the lower Vasse River (Beatty and Lymbery 2019). While the WA Environmental Protection Authorities (EPA) decision was not to formally assess that project, the EPA advised that an EMP was required to 'Design an effective temporary relocation program for the Carter's Freshwater Mussel population to be actioned during the Project'. The subsequent EMP proposed the removal of *W. carteri* from waters within the project area prior to any works being undertaken, temporary relocation of individuals to suitable habitat (or holding facility), and subsequent replacement of individuals back into waters of the project area upon completion of the works. The draft 'Busselton Eastern Link and Causeway Bridge Duplication Projects Carter's Freshwater Mussel *Westralunio carteri* Environmental Management Plan' (WCMP) initially outlined an option for *W. carteri* to be temporarily relocated to waters of the upper Vasse River. This was due to the authors recognising that the 'upper Vasse River, in the vicinity of the junction with the Vasse Diversion Drain, would provide a suitable site for the temporary relocation because it supports a large, viable population of mussels (Lymbery et al. 2008) and is protected from public access.' However, due to proposed upgrade works in the VDD, the proposed relocation site was not considered suitable. As a result, an alternative site for the temporary relocation of *W. carteri* from the lower Vasse River was identified, that being in Taylors Lake in Capel. This management strategy was subsequently reflected in the final of the WCMP in April 2019.

In relation to the VDD upgrade project EMP, the Department of Water and Environmental Regulation (DWER) and the Department of Biodiversity, Conservation and Attractions (DBCA) discussed with the Water Corporation that proposed management should consider whether the same strategy and

relocation site (i.e. Taylors Lake) utilised in the WCMP was applicable. However, upon review of the WCMP, it was recognised that a key risk of the relocation of *W. carteri* to Taylors Lake was the transmission of disease or infection between individuals from two distinct catchments. As the option of relocating *W. carteri* to waters immediately upstream of the project area (i.e. to remain within the same catchment) would largely eliminate the key risk of disease or infection transmission, the Water Corporation expressed a desire to scope opportunities to relocate *W. carteri* to waters immediately upstream of the VDD project area. In addition, this option would vastly reduce handling and transport timeframes, and therefore reduce the risk of mortality associated with relocation. Indo-Pacific Environmental was subsequently engaged to assist with investigating this option.

2 FIELD RECONNAISSANCE

2.1 Approach

A survey of aquatic habitat within the project area where *W. carteri* was identified as being present, and waters upstream of the project area, was undertaken on the 18th and 19th of March 2020. The aim of this investigation was to identify whether sites for relocation of *W. carteri* existed upstream of the VDD upgrade works area adjacent the Busselton Golf Course and beyond. If identified, the suitability of a potential relocation site would subsequently be assessed on the following criteria:

- Presence of perennial water with salinity of no greater than 1.5 ppt (g/L);
- Aquatic habitat of the relocation site has comparable (or better) habitat characteristics of that present within the project area where *W. carteri* was identified (including fine sediments, woody debris and overhanging riparian vegetation);
- The presence and abundance of *W. carteri*;
- The presence of host fish species, noting larvae of *W. carteri* are obligate parasites of fish (Klunzinger 2012); and
- Ease of access to a potential relocation site to facilitate relocation.

Figure 1 indicates the area investigated during March 2020. The entire survey area was traversed by foot in order to identify the extent of water and all potential sites for relocation. While notes on the habitat and presence of *W. carteri* were taken throughout the entire survey area, habitat characterisation and a density estimate of *W. carteri* was undertaken at three sites within the project area (i.e. VDD1 to VDD3) and at eight sites where water was present upstream of the project area (i.e. VDD4 to VDD11) in order to facilitate a habitat comparison and assess the suitability of potential relocation sites. Water quality parameters and habitat characters assessed can be seen in Tables 1 and

2. A qualitative density range estimate of *W. carteri* was also made at these sites with the use of a bathyscope. Observed fish and crayfish species were also documented.

Additional areas located much further upstream including those accessible from Queen Elizabeth Road and Don Road were also inspected as potential relocation sites. These sites were however found to be dry or when water was present its quality was not favourable for the species. There was also no evidence of *W. carteri* being present at these sites in the form of live or dead shell.

3 Findings

3.1 Habitat Characterisation

A continuous series of pools was found to be present upstream of the project area which bordered the Busselton Golf Course. These pools extended for ~1.2 kilometres upstream of the downstream survey area boundary (i.e. near VDD11) before the river bed becomes dry. This figure does not include that area between the downstream survey boundary and the proposed works area which has been designated as a buffer. While water was found to be present in one rocky pool further upstream of VDD5, water quality measurements and a lack of any aquatic biota indicated this was recently accumulated rain water. The largest pool present in the broader area originated upstream of VDD2 (within the project area) and continued for ~800 metres beyond VDD10. Pools located further upstream were up to 100 metres in length with several having some surface water connectivity and flow between them.

Table 1 indicates that mean water temperatures and dissolved oxygen were broadly comparable between sites within the project area and potential relocation sites upstream. However, mean salinity, electrical conductivity and total dissolved solids were higher at sites within the project area than at potential relocation sites. This result was largely due to values attained from VDD1 within the project area, where salinity and electrical conductivity was vastly higher than all other sites assessed. In relation to salinity at VDD1, water was found to be 1.27 ppt which is approaching the upper tolerance limit of 1.5 ppt for the species in rivers of the south-western Australia (Klunzinger 2012). Total dissolved solids was also highest at VDD1. Furthermore, pH was far lower at VDD1 and outside the range stipulated in the Australian and New Zealand Guidelines (ANZG) (2018) for lakes, reservoirs and wetlands in south-western Australia.

Table 2 and 3 provide the results of sediment and water sample analysis collected at four sites within the project area. Nutrient, metal and metalloid concentrations in sediment and water samples from sites within the project area were broadly comparable to concentrations found upstream. While trigger values concentrations for orthophosphate (ortho-P) and total phosphate were found to be exceeded, this result is not unexpected considering the surrounding land use.

Table 4 provides details of the habitat characterisation collected at the eleven sites assessed. While mean values of most habitat parameters were consistent between sites within the project area and

potential relocation sites upstream, several key parameters were seen to vary. Although water depth was generally comparable between sites (ranging from 0.4 to 0.7 m), mean channel width varied between sites within the project area (which ranged from 5 to 6 metres) and potential relocation sites upstream where widths of up to 10 (VDD5) and 12 metres (VDD11) were recorded. Greater amounts of bedrock were observed in a number of potential relocation sites upstream representing up to 40% of the mineral substrate.

Mean vegetation cover (shade) values were seen to be broadly comparable between sites within the project area and potential relocation sites upstream. However, closer inspection of values for individual sites within the project area showed a notable difference was recorded in the riparian vegetation cover (shade) and the percentage cover of trees along the banks at those individual sites. VDD1 and VDD2 had limited (if any) shading of the river due to the lack of trees. Banks at these sites had also slumped and much of the ground above the bank was bare. This was considered likely to be due to the fact these sites were located within the constructed section of the VDD downstream of the diversion dam. In contrast, VDD3, whilst in the project area, was above the diversion dam and had riparian cover values and morphology closer to those of the potential relocation sites upstream.

3.2 Presence of *Westralunio carteri* and other biota

Westralunio carteri were found to be extensively distributed throughout the entire survey area, including the pools located upstream of the project area. Individuals were observed in both sandy and rocky substrates and were generally concentrated towards the water edge along the bank as opposed to occurring in the middle of the pools. Table 4 provides a density estimate of mussels at each of the sites surveyed and notes on the habitat present. Density estimates were seen to vary greatly between the sites surveyed. The highest estimated density was found to be present in VDD1 within the project area with up to 80 to 100 individuals being present per square metre. It was speculated that the high density present was the result of the site being a contracted isolated pool. Furthermore, this was close to the downstream extent of the distribution where individuals may have accumulated after being washed down during flow events. Estimated densities at the other sites within the project area were vastly lower having three to four individuals per square metre at VDD2 and up to ten individuals per square metre at VDD3.

The highest density of *W. carteri* at potential relocation sites was recorded at the downstream survey area boundary (VDD11) having an estimated 50 to 80 individuals present per square metre. VDD5 which was the uppermost pool assessed was estimated to have up to 50 individuals per square metre, however, the density was seen to vary greatly within this pool. These potential relocation sites had the widest channel widths and as such may retain water for longer periods due their greater holding capacities. The lowest density estimate at potential relocation sites was recorded from VDD7 where between one and four individuals per metre were observed. However, it should be noted that this site

was highly turbid due to tannin and as such visual estimates made with the bathyscope may not be reflective of the actual density present (i.e. it may be higher)

Fish were observed free swimming at all sites surveyed. This included the native species *Pseudogobius olorum* (Swan River Goby) and *Galaxias occidentalis* (Western minnow), and the introduced *Gambusia holbrooki* (Eastern Gambusia). Burrows and dried claws of the native freshwater crayfish *Cherax quadricarinatus* (Gilgie) were also observed.

4 SUITABILITY OF POTENTIAL RELOCATION SITES

In consideration of a number of the parameters assessed, the water and habitat quality of potential relocation sites located upstream were considered to be better than a majority of that present within the project area, particularly those in the downstream extent such as VDD1 and VDD2. Although the highest estimated density was found to be present at VDD1, this site was a contracted and isolated pool where individuals would have retreated as water levels contracted. Water quality at this site was far poorer than other sites assessed with, for example, salinity being far higher at 1.27 ppt than elsewhere. As aforementioned, this is approaching the upper tolerance limit of 1.5 ppt for the species in rivers of the south-western Australia (Klunzinger 2012). Furthermore, VDD1 (and VDD2) received no shading from riparian vegetation with a complete absence of large trees and a low percentage of smaller trees. Noting the lack of riparian vegetation and contracted nature of the pool, *W. carteri* located in VDD1 are at a higher risk of thermal stress from elevated water temperatures and potential mortality if evapoconcentration occurs within the pool and results in a salinity which exceeds the 1.5 ppt threshold.

Westralunio carteri density estimates indicated that the species is abundant and widely distributed throughout the upstream survey area. While relocation of individuals could occur throughout the ~1.2 kilometres of pools present, Table 5 identified four sites which were considered suitable relocation sites. However, it should be remembered that the large pool present in the reconnaissance survey area, provides over 350 metres of channel (i.e. between VDD10 and VDD11) throughout which *W. carteri* may be dispersed. Dispersal over a large area should allay concerns over excessive stocking densities at relocation sites. Sites VDD4, VDD8, VDD10 and VDD11 are readily accessible from the Golf Course with VDD11 being accessible from the carpark (i.e. there is no need to transit the Golf Course itself). While VDD5, the uppermost pool, had a high density of *W. carteri* in some sections, was a large pool and unlikely to dry out, access to the site was not as straight forward as others and it would take some time to transit through the Golf Course grounds.

Noting that VDD11 can be accessed from the Golf Course car park and it is the closest site to the project area by road, out of water time between the removal of individuals from the project area to relocation, would be low. For example, the travel distance between VDD1 and VDD11 by road is approximately one kilometre and as such the time in which *W. carteri* would be out of the water during transit would be in the order of a few minutes. One practical option may be to launch a small car topper

dinghy at VDD11 and from which *W. carteri* could be ferried to various parts of the large pool. Benefit may exist in additionally relocating some individuals to VDD4 and VDD8 however these sites should receive fewer individuals due to the physical size of the pools and lower density present.

5 SUMMARY

Noting the presence and abundance of *W. carteri* and habitat quality of potential relocation sites located upstream of the project area, relocation of individuals to these sites vastly reduces any risk of stress or mortality in comparison to the relocation to Taylors Lake in Capel. This is due to individuals being relocated to waters of similar chemistry and environmental condition, and having transit times which are greatly reduced. Furthermore, individuals would remain with the same genetic stock, and the risk of disease or infection transfer from *W. carteri* from another catchment (and vice versa) is negated. The requirement to move relocated individuals back to the project area upon completion of the upgrade works may also not be as necessary due to potential of downstream waters to be populated over time through natural dispersal. This option would remove any risk to *W. carteri* associated with an additional removal, transit and reintroduction.

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Table 1. Physico-chemical water quality parameters of sites assessed within the project area (VDD1-VDD3) and potential *W. carteri* relocation sites located upstream (VDD4-VDD11).

Site	Temperature °C	Dissolved O ₂ %	Dissolved O ₂ (mg/L)	Conductivity (mS/cm)	Practical Salinity (ppt)	TDS (ppm)	pH	ORP (mV)
ANZG TV		90-120		0.3-1.5			7-8.5	
VDD1	20.9	84.7	7.46	2.45	1.27	1278	6.04	74.1
VDD2	19.54	76.8	7.01	1.66	0.95	932	7.4	66.1
VDD3	18.9	80	7.4	1.65	0.84	827	7.84	62
Mean (SE)	19.78 (0.48)	80.5 (1.87)	7.29 (0.12)	1.92 (0.22)	1.02 (0.11)	1012 (111)	7.09 (0.44)	67.4 (2.9)
VDD4	20	91.1	8.2	1.476	0.75	738	7.98	65.6
VDD5	19.24	70.2	6.55	1.756	0.89	878	7.04	58.2
VDD6	19.3	77	7.08	1.59	0.81	798	7.2	54.8
VDD7	17.8	68	6.4	1.269	0.64	635	7.5	56.9
VDD8	19.25	77.9	7.16	1.809	0.92	905	7.25	54.5
VDD9	19.25	77.1	7.09	1.789	0.86	837	7.3	55
VDD10	19.28	82.1	7.56	1.586	0.8	794	7.69	56.8
VDD11	19.5	81	7.35	1.628	0.83	814	7.44	58.2
Mean (SE)	19.2 (0.21)	78.05 (2.37)	7.17 (0.19)	1.61 (0.06)	0.81 (0.03)	799 (27.8)	7.43 (0.10)	57.5 (1.19)

Table 2. Nutrient, metal and metalloid concentrations of fluvial sediment samples collected from sites within the Vasse Diversion Drain project area with ANZG (2018) and Simpson and Batley (2016) toxicant default guideline values (DGV) for sediment quality. Shading indicates an exceedance of the DGV and red shading indicates an exceedance of the GV-High.

	Al mg/kg	Cr mg/kg	Fe mg/kg	Ni mg/kg	Cu mg/kg	As mg/kg	Cd mg/kg	Pb mg/kg	TKN mg.N/g	TOTAL P mg.P/g	TOC % C
Reporting Limit	<10	<0.2	<10	<0.2	<0.2	<0.1	<0.02	<0.1	<0.1	<0.05	<0.1
DGV	-	80	-	21	65	20	1.5	50			
VDD1	1100	2.4	5000	0.4	0.3	0.1	<0.02	3.2	0.3	0.18	0.3
VDD3	910	1.6	1700	0.5	0.3	<0.1	<0.02	1.8	0.2	0.09	0.3
VDD4	760	1.7	2400	0.3	<0.2	<0.1	<0.02	3.2	0.1	0.09	0.2
VDD6	1400	3.7	18000	1.0	<0.2	0.9	<0.02	2.6	<0.1	0.09	0.1

Table 3. Nutrient, metal and metalloid concentrations of water samples collected from sites within the Vasse Diversion Drain project area with ANZG (2018) nutrient guideline trigger values and contaminant trigger values recommended for slightly to moderately disturbed aquatic ecosystems. Shading indicates an exceedance of a trigger value.

	AMMONIA µg.N/L	ORTHO-P µg.P/L	NO3+NO2 µg.N/L	TOTAL-P µg.P/L	TOTAL-N µg.N/L	Filtered Al µg/L	Filtered Cr µg/L	Filtered Fe µg/L	Filtered Ni µg/L	Filtered Cu µg/L	Filtered As µg/L	Filtered Cd µg/L	Filtered Pb µg/L
Reporting Limit	<3	<2	<2	<5	<50	<5	<0.2	<1	<0.3	<0.2	<0.5	<0.1	<0.1
Trigger Values	900	>30	>100	>60	>1500	55	-	-	11	1.4	-	0.2	4.4
VDD1	20	3	3	36	1100	8	<0.2	100	0.5	<0.2	0.9	<0.1	<0.1
VDD3	10	36	2	140	780	9	<0.2	470	0.5	<0.2	<0.5	<0.1	<0.1
VDD4	10	6	5	70	640	<5	<0.2	370	0.3	<0.2	<0.5	<0.1	<0.1
VDD6	24	3	11	120	990	<5	<0.2	140	<0.3	<0.2	<0.5	<0.1	<0.1

Table 4. Estimated density of *W. carteri* and habitat assessment parameters of sites assessed within the project area (VDD1-VDD3) and potential *W. carteri* relocation sites located upstream (VDD4-VDD11).

	VDD1	VDD2	VDD3		VDD4	VDD5	VDD6	VDD7	VDD8	VDD9	VDD10	VDD11	
Estimated Density of <i>W. carteri</i> (per m²) (s: sand, r: rock)													
	80-100	3-4	10	-	10-20 s 1-3 r	2-50	3-6	1-4	15-20	5-15	20-40	50-80	
Water Profile				Mean								Mean	
Velocity (m/sec)	0	0	0	0.0	0	0	0	0	0	0	0	0	0.0
Mean Width (m)	6	5	6	5.7	5	10	8	6	4	3	7	12	6.9
Mean Depth (m)	0.6	0.4	0.6	0.5	0.5	0.6	0.5	0.4	0.5	0.5	0.7	0.7	0.6
Mineral Substrate (%)													
Bedrock %	10	10	0	6.7	10	5	20	45	40	40	0	0	20.0
Boulders > 256 mm	25	10	15	16.7	60	10	20	20	10	10	10	0	17.5
Cobble 64-256mm	10	10	10	10.0	10	10	10	10	10	10	10	5	9.4
Gravel 16-64mm	10	10	25	15.0	5	10	10	5	10	5	10	5	7.5
Pebbles 4-16mm	5	10	10	8.3	0	5	10	5	5	5	10	10	6.3
Sand 1-4mm	35	45	30	36.7	15	50	20	10	15	20	55	75	32.5
Silt/Clay 0.5mm	5	5	10	6.7	0	10	10	5	10	10	5	5	6.9
Instream Habitat Cover (1=<10%, 2=10-35%, 3=35-65%, 4=65-90% and 5=>90%)													
Emergent Macrophytes	0	0	0	0.0	1	0	0	0	1	0	0	1	0.4
Submerged Macrophytes	0	0	0	0.0	0	0	0	0	0	0	0	0	0.0
Floating Macrophyte	0	1	0	0.3	0	0	0	0	0	0	1	0	0.1
Algae	3	2	3	2.7	3	3	2	1	2	1	1	1	1.8
Coarse Woody Debris	2	1	1	1.3	1	3	2	1	2	1	2	2	1.8
Litter/Detritus	2	1	2	1.7	2	3	3	2	2	2	2	2	2.3
Root Mats	1	1	0	0.7	1	3	1	1	1	1	2	2	1.5

Sand/Silt Bed	3	3	2	2.7	2	3	3	1	2	2	3	3	2.4
Gravel/Rock Bed	3	3	3	3.0	4	4	3	4	4	4	1	0	3.0
Riffle	0	0	0	0.0	0	0	0	0	0	0	0	0	0.0
Pool/Unknown	0	0	0	0.0	0	0	0	0	0	0	0	3	0.4
Overhanging Vegetation	1	0	2	1.0	1	2	1	2	1	1	2	2	1.5
Riparian Vegetation													
Vegetation Cover of River (Shade) %	2	0	20	7.3	10	10	5	5	10	5	10	10	8.1
% Cover Trees > 10 m	0	0	0	0.0	20	10	0	0	10	0	10	5	6.9
% Cover Trees < 10 m	5	5	20	10.0	30	30	10	10	30	20	20	15	20.6
% Cover Shrubs/grass	85	90	90	88.3	90	90	90	90	90	90	80	90	88.8
Evidence of fire riparian Zone (Y=Yes, N=No)	N	N	N	N	N	N	N	N	N	N	N	N	N
Water and Sediment Observations													
Water Clarity (m)	>1.5	0.3-1.5	0.3-1.5	0.3-1.5	0.3-1.5	0.1-0.3	0.3-1.5	<0.1	0.1-0.3	0.1-0.3	0.1-0.3	0.3-1.5	0.3-1.5
Water Odour	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Water Oils	None	Globs	None	None	None	None	None	Slick	None	None	None	None	None
Foam/Scum	None	None	None	None	None	None	None	None	None	None	None	None	None
Sediment oils	None	None	None	None	None	None	None	None	None	None	None	None	None
Sediment Odours	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Introduced fauna disturbance													
Bank Disturbance other Feral Animals	None	None	None	None	None	None	None	None	None	None	None	None	None
Erosion Left/Right Bank (Y=Yes, N=No)													
Bare ground above water	Y/Y	Y/Y	Y/Y	Y/Y	N/N	Y/Y	N/N	N/N	N/N	N/N	Y/Y	Y/Y	N/N
Tree roots exposed	Y/Y	N/N	Y/Y	Y/Y	N/N	Y/Y	N/N	N/N	N/N	N/N	Y/Y	Y/Y	N/N
Gully erosion	N/N	N/N	N/N	N/N	N/N	N/N	N/N	N/N	N/N	N/N	N/N	N/N	N/N
Slumping banks	Y/Y	Y/Y	Y/Y	Y/Y	N/N	N/N	N/N	N/N	N/N	N/N	N/Y	Y/Y	N/N
Excessive fallen trees	N/N	N/N	N/N	N/N	N/N	N/N	N/N	N/N	N/N	N/N	N/N	N/N	N/N
Local catchment erosion	Little	Little	Little	Little	None	Little	None	None	None	None	Little	Little	None -Little

Table 5. Assessment of suitability of sites located upstream of the project area for relocation of *W. carteri*. Green shading indicates a site was suitable, orange shading indicates a site was somewhat suitable and red shading indicates a site was not considered suitable.

Site	Water resource and channel	Sediment	Instream organic matter/woody debris	Riparian vegetation	<i>W. carteri</i> (per m2)	Fish	Ease of Access	Summary
VDD4	Equivalent width and depth to project area sites.	Coarse rock with some sand	Comparable to project area sites.	Equivalent or denser than project area sites.	10-20 in sand; 1-3 in rock	Present.	Directly accessible from Golf Course but requires some additional transit time through grounds.	Smaller site but accessible and stable. Suitable for relocation of moderate numbers.
VDD5	Wide channel compared to project area sites. Lower likelihood of drying due to volume	Extensive sand, variable rock fractions	More than project area sites.	Equivalent or denser than project area sites.	2-50 but throughout pool	Present.	Accessible from Golf Course but requires greatest transit time through grounds. Greater distance from Gold Course to water to be traversed by foot. Steep banks and fence line.	Access requires additional travel time across grounds and cartage down banks. Pool is relatively large. Suitable for relocation of moderate numbers.
VDD6	Channel marginally wider than project area sites	Bedrock, variable rock fractions, some sand	More than project area sites.	Equivalent project area sites.	3-6	Present.	Directly accessible from Golf Course but requires some additional transit time through grounds.	Lower abundance of <i>W. carteri</i> likely the result of high proportion of rocky substrate. Junction of two channels and subsequent mixing/water velocities may also contribute to reduced density. Limited carrying capacity.
VDD7	Comparable channel width to project area sites	High proportion of bedrock, coarse rock and limited sand	Comparable to project area sites.	Equivalent project area sites.	1-4	Present.	Directly accessible from Golf Course but requires some additional transit time through grounds.	Lower abundance of <i>W. carteri</i> likely the result of rocky high proportion of rocky substrate. Limited carrying capacity.
VDD8	Marginally narrower channel width to project area sites	High proportion of bedrock, coarse rock and limited sand	More than project area sites.	Equivalent or denser than project area sites.	15-20	Present.	Directly accessible from Golf Course but requires some additional transit time through grounds.	Narrower channel may reduce available space for relocation. Suitable for relocation of lower numbers.

Site	Water resource and channel	Sediment	Instream organic matter/woody debris	Riparian vegetation	<i>W. carteri</i> (per m2)	Fish	Ease of Access	Summary
VDD9	Narrow channel width to project area sites	High proportion of bedrock, coarse rock and some sand	Comparable to project area sites.	Equivalent project area sites.	5-15	Present.	Directly accessible from Golf Course but requires some additional transit time through grounds.	Narrow channel may reduce available space for relocation. Higher water velocities may occur.
VDD10	Upstream end of largest pool in the area which incorporates End' site. Comparable channel width to project area sites	Extensive sand, variable rock fractions	More than project area sites.	Equivalent or denser than project area sites.	20-40	Present.	Directly accessible from Golf Course carpark. Short transit time through grounds.	Large area for relocation. Very accessible and high carrying capacity due to large area. Suitable for relocation of high numbers.
VDD11	Widest and longest pool. Likely to have lower flow velocity. Low likelihood of drying due to volume. Extensive bank habitat.	Extensive sand, smaller rock fractions	More than project area sites.	Equivalent or denser than project area sites.	50-80	Present.	Directly accessible from Golf Course carpark. Shortest distance from project area for transfer. Access to ~350 m continuous channel	Numerous sites for relocation within pool. Very accessible and high carrying capacity due to large area. Suitable for relocation of high numbers.

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