



Memorandum

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Copy to	Liezl Bezuidenhout, Principal Directional Studies, South 32		
From	Robert Browne-Cooper, Senior Zoologist, GHD	Tel	+61 8 6222 8338
Subject	Environmental Approvals support for South 32 proposal mine expansion in relation to Carter's Freshwater Mussel	Job no.	6138042

1 Background

South 32 are referring (EPA and EPBC) the Worsley Mine Expansion (WME) under the *Environmental Protection Act 1986* (EP Act) and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The WME is associated with the Boddington Bauxite Mine, comprising the Worsley Mine Development Envelope (WMDE), Bauxite Transport Corridor (BTC), and the Contingency Bauxite Mining Envelope (CBME) located at the Worsley Alumina refinery approximately 50 km south of the WMDE (see Figure 1).

South 32 require additional detail for State and Commonwealth environmental approvals regarding Carter's Freshwater Mussel (*Westralunio carteri*) which is listed as vulnerable under both the *Biodiversity Conservation Act 2016* (BC Act) and EPBC Act.

1.1 Scope and purpose of memorandum

GHD Pty Ltd (GHD) was engaged by South 32 to provide information on the Carter's Freshwater Mussel and likelihood of impact assessment to inform the environmental referrals for the WME. The scope of works included:

- Providing a description of Carter's Freshwater Mussel
- Reviewing database and species distribution, with consideration to local and regional significance in relation to development envelopes
- Completing an assessment of likelihood of occurrence and determining potential for impacts
- Providing advice on the potential likelihood of significant impacts
- Outlining measures to reduce or avoid impacts

The outcome of this scope of works is detailed in this memorandum.

1.2 Approach

The species distribution and assessment of significant impacts provided in this memo is based on spatial data and background documents provided by South 32, and from Department of Biodiversity Conservation and Attractions (DBCA) fauna database.

The following data sources have been used:

- Mine and associated infrastructure development envelope spatial data
- DBCA threatened fauna database, local records of species distribution
- Previous locally relevant aquatic fauna survey and assessment reports
- Matters of National Environmental Significance (MNES). Significant impact guidelines 1.1
- Conservation advice *Westralunio carteri* Carter's freshwater mussel under the EPBC Act
- NatureMap fauna database search of *Westralunio carteri*

1.3 Assumption and limitations

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The opinions, conclusions and any recommendations in this memorandum are based on information reviewed at the date of preparation of the memorandum and on assumptions made by GHD described in this memorandum. GHD has no responsibility or obligation to update this memorandum to account for events or changes occurring subsequent to the date this memorandum was prepared. GHD disclaims liability arising from any of the assumptions being incorrect.

2 Species profile for Carter's Freshwater Mussel

In 2014, the Carter's Freshwater Mussel was listed as Vulnerable under the WA former *Wildlife Conservation Act 1950* (replaced by the BC Act), and listed in 2018 as Vulnerable under the Commonwealth EPBC Act.

Carter's Freshwater Mussel is an elongate-shelled bivalve mollusc that can grow to 100 mm long, but rarely exceeds 90 mm. This species is endemic to southwestern Australia where its current distribution is patchy and extends from around Gingin south to Waychinicup. Formerly its distribution extended into the interior of the south-west, but now it rarely occurs more than 50 km inland. It inhabits freshwater lakes, river systems, and other waterways having favourable sandy or muddy sediments and often associated with woody debris (Klunzinger et.al 2012a).

Newborn mussel larvae are less than 0.5 mm in length and have larval "teeth" used for temporary attaching to host fish gills. This is an important mechanism in the lifecycle that enables the mussel larvae to disperse upstream.

After several weeks the juvenile mussels detach from the host fish and settle into creek bed sediment or other suitable river bed substrate where they begin filter-feeding and growing (Klunzinger et.al 2012b). Mussels burrow into substrate and can move short distances using a muscular foot that is extended from the shell. They can also disperse downstream via water flow. This species can

aestivate by burrowing deep into river beds during natural seasonal cycles when rivers dry. The lifespan is potentially in excess of 50 years.

Carter's Freshwater Mussel is thought to be an important species within the freshwater ecosystem of the Southwest. It is likely to have bio-filtration benefits to water quality by filtering algae, bacteria and other micro-organisms and organic particles (Pusch et al. 2001; Bogan 2008). The mussel also provides a source of food for other invertebrates such as freshwater crayfish, and a variety of vertebrate groups including fishes, turtles, birds and water rats (Walker et al. 2001). Additionally, mussels in general act as a bio-monitor of environmental quality due of their tendency to concentrate and store toxic substances such as heavy metals and pesticides (Walker et al. 2001).

The decline of Carter's Freshwater Mussel in the southwest region has been due to increased salinity within the river systems (Klunzinger et.al 2015). Major river system that have been severely impacted by salinity, and as a result species distribution and number include: Moore, Avon, Blackwood, Murray, Williams, Upper Warren, Upper Kent, Frankland, Bow and Lower Canning Rivers. Widespread increase in river salinity in the southwest has resulted in a 50 percent reduction in this species' range (Klunzinger et.al 2015). Another recognized threat is water extraction causing dehydration and heat stress. This threat is potentially relevant to mining activities in the Southwest where mining activities can alter or divert water flows leading to changed flows.

3 Database review and species distribution

A NatureMap database search identified 393 records of this species within the Southwest region. The spatial data mapped (Figure 1) identifies seven records of Carter's Freshwater Mussel locally relevant to the WME. Figure 2 provides a representation of the species former distribution.

There are few recent records of Carters' Freshwater Mussel of local or regional significance to the WME. Most of the records in the vicinity of the WME range from 1905 to 1971. There are several recent records from the vicinity of the CBME including: Augustus River recorded in 2017 approximately 4 km east north east of the CBME; 8.5 km west of the CBME in 2010, and records from the Collie River and Wellington Dam catchment area approximately 10 km south of the CBME in 2009 to 2011. Hale et.al (2000) recorded the species at two locations within the Worsley Refinery artificial freshwater lake during water quality monitoring. These two mussel localities are not listed within the DBCA database searches. A further record from the Augustus River is documented for a location approximately 1 km northwest of the CBME during a 2004 survey (WRM 2005). Based on the information available on local occurrence, Carter's Freshwater Mussel occurs within the Augustus River in close proximity to the CBME therefore there is a high likelihood that this species occurs in the river systems in proximity of the CBME.

Table 1 provides a summary of previous reports provided by South 32 that are locally or regionally relevant to Carter's Freshwater Mussel and the WME.

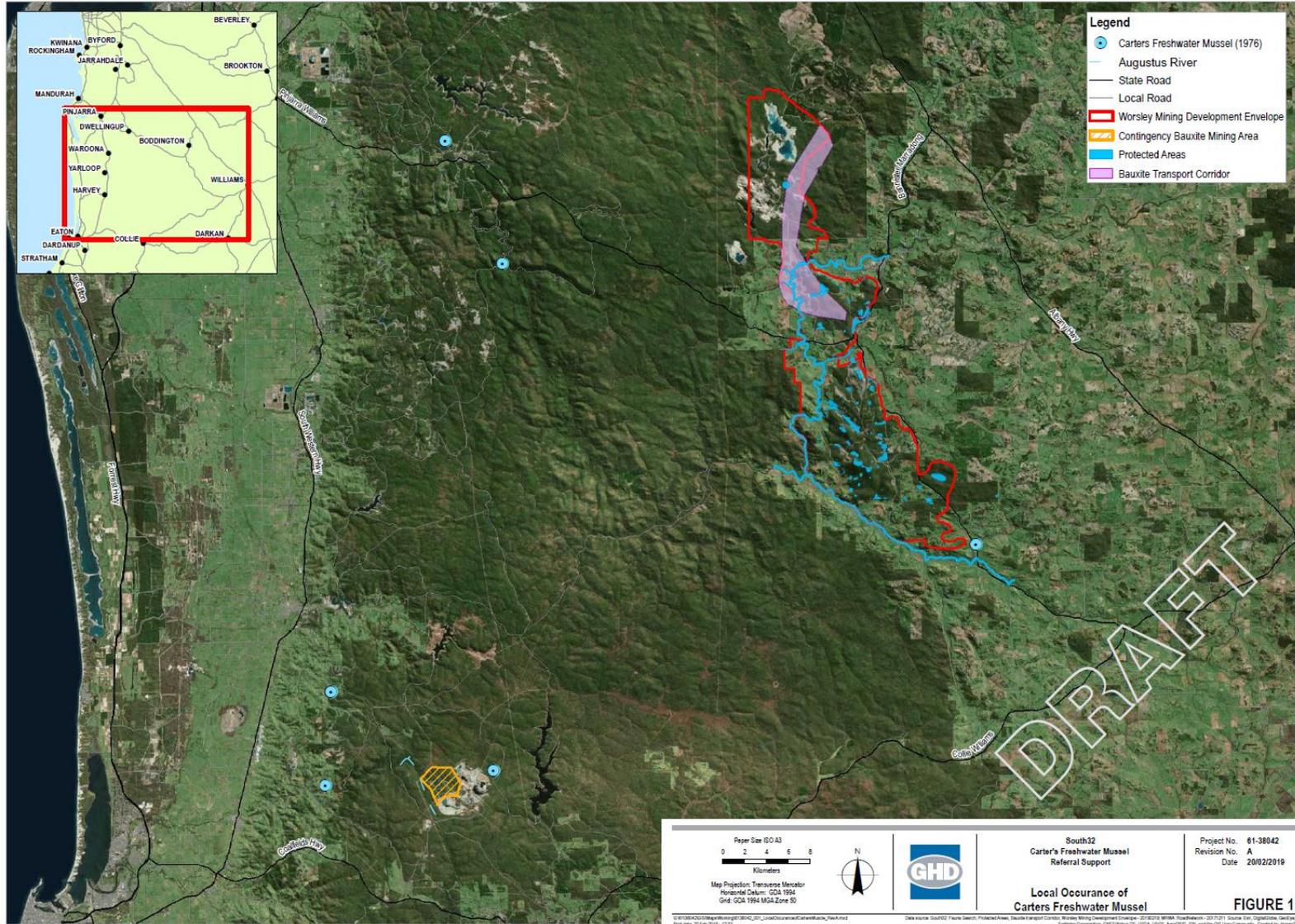


Figure 1. Local Occurrence of Carter's Freshwater Mussel

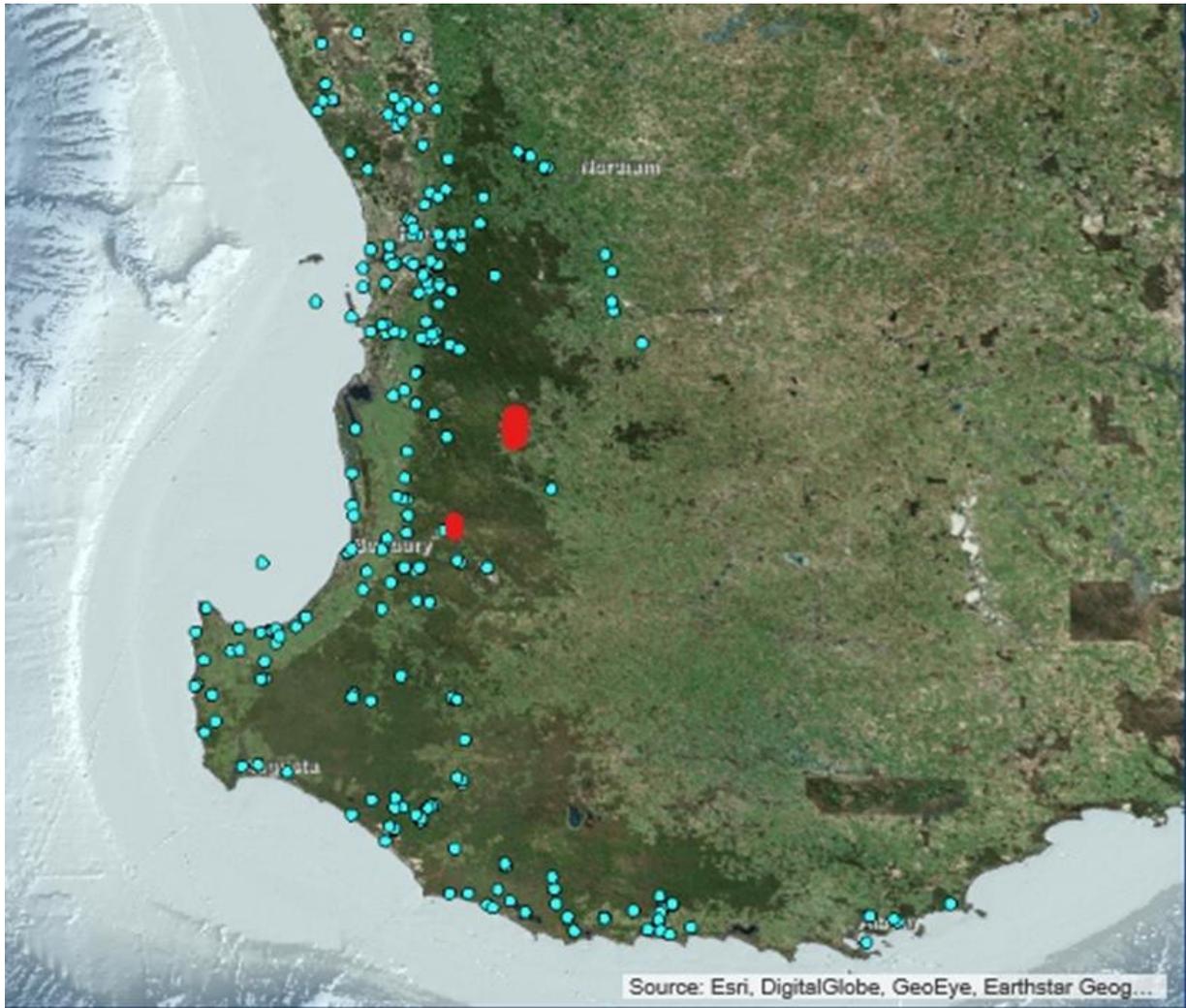


Figure 2. Carter's Freshwater Mussel Distribution¹

¹ Figure 2 shows the historical distribution of Carter's Freshwater Mussel. Database search based on NatureMap (<https://naturemap.dpaw.wa.gov.au/>). This figure is included to provide point locations not available as spatial data. Red areas represent the locations of the WMDE (north) and CBME (south).

Table 1. Summary or reports provided by South 32

Reference	Location of Study	Objective of study	Key findings in relation to Carter's Freshwater Mussel	Conclusions/ Recommendations
<p>Water Quality Aquatic Macroinvertebrate and Fish Monitoring of the Worsley Freshwater Lake and Brunswick River Catchment. March to December 1999. Report to Worsley Alumina Pty. Ltd. by J. Hale, M. McGuire, S. Hambleton, D. Morgan, J. Davis, H. Gill and E. I. Paling. March 2000. Marine and Freshwater Research Laboratory Env Science (Hale et al. 2000)</p>	<p>Worsley Freshwater Lake and Brunswick River Catchment</p>	<p>Water quality, aquatic macroinvertebrates and freshwater fish communities were assessed in the Augustus River downstream of the refinery.</p>	<p>Carter's Freshwater Mussel was recorded in Augustus River and the artificial freshwater lake within Worsley Refinery site. The concentrations of heavy metals in mussel tissue were within the Australian standard (A12) for human consumption, with the exception of mercury within a stream site on the Augustus River. Concentrations of mercury were substantially higher in mussels collected in the freshwater lake and Augustus River than in control streams. Mussel size in the freshwater lake was significantly larger than in Augustus River.</p>	<p>The source of elevated concentrations of mercury in mussel tissue should be investigated further.</p>
<p>Augustus River Ecological Monitoring Program. Report prepared for BHP Billiton Worsley Alumina Pty Ltd. By Wetland Research & Management (WRM 2010)</p>	<p>Augustus River downstream of Worsley Alumina refinery</p>	<p>Establishment of and ecological monitoring program (EMP) downstream of the Worsley Alumina refinery to assess flow variation effects of on aquatic fauna population structure.</p>	<p>The report identifies sampling sites, sampling regimes, value of monitoring parameters proposed for monitoring impacts. No specific reference to Carter's Freshwater Mussel, however this is an applicable species for monitoring as it falls under Tier 3 in the report relevant to macroinvertebrate populations.</p>	<p>Minimum of three years monitoring recommended followed by analysis and review monitoring period and parameters chosen.</p>
<p>Hotham Farm Water Quality and Aquatic Fauna Survey Final Report. January 2013. Report to Newmont Boddington Gold Pty. Ltd. By Wetland Research & Management (WRM 2013)</p>	<p>Newmont Boddington Gold (NBG) approximately 100 km south east of Perth at sites along</p>	<p>A component of ongoing environmental assessments to construct a water storage facility. This study was designed to assess water quality</p>	<p>Overall physico-chemistry not significantly different between sample sites. Macroinvertebrate species richness and assemblage composition not significantly different. Carter's Freshwater</p>	<p>The study shows Junglen Gully to support a higher number of macro-invertebrate endemic species, and sensitive fauna in</p>

Reference	Location of Study	Objective of study	Key findings in relation to Carter's Freshwater Mussel	Conclusions/ Recommendations
	Junglen Gully and 34 Mile Brook	and species composition of aquatic fauna.	Mussel not recorded during the study.	comparison to 34 Mile Brook.
Ecological Water Requirements of Augustus River - Intermediary Assessment. Draft report March 2005. Prepared for Worsley Alumina Pty Ltd. By Wetland Research and Management (WRM 2005)	Augustus River below Worsley Alumina refinery Freshwater Lake	To undertake assessment of ecological water requirements (EWRs) of the Augustus River.	Carter's Freshwater Mussel recorded in the Augustus River at one of three sample sites. Mussel abundance as the record site was 2-10 individuals. Maintenance of water flow throughout year is necessary for breeding and recruitment of aquatic macroinvertebrates, and for nutrient flushing; continued availability of submerged logs, rocks, vegetation etc for habitat; 5-10 cm depth maintained at riffle zones for fauna movement and dispersal, maintenance of permanent freshwater pools; maintain seasonal flooding for native fish life cycles.	Maintain the existing ecological values (i.e. current native fish and macroinvertebrate diversity), with a priority to maintain permanent base flows in summer.
Hotham River - Ecological Water Requirements and Ecological Sustainable Yield Downstream of Tullis Bridge. Unpublished report by Wetland Research & Management to Newmont Boddington Gold. January 2011 (WRM 2011)	Hotham River downstream of Tullis Bridge	Determine the ecological water requirements at areas cross Hotham River. Design an ecologically appropriate flow regime. Define an ecologically sustainable yield for Boddington Gold abstraction licence.	Analyses show there are ecologically critical flow thresholds below 95 L/s, being summer riffle inundation (10 L/s), winter riffle inundation (75 L/s) and small fish passage (80 L/s). Carter's Freshwater Mussel not recorded during the study.	Further studies and monitoring recommended with approach including: Flow objectives, compliance, and ecosystem health.
Thirty-Four Mile Brook Ecological Monitoring: Aquatic Fauna sampling September 2010 and August 2011. Unpublished report by Wetland	Thirty Four Mile Brook	Sampling and assessment of conservation significance	Annual surveys for water quality and aquatic fauna was undertaken at 3 sites located between near mine pit and 5 sites located	No listed species or species considered rare or restricted in

Reference	Location of Study	Objective of study	Key findings in relation to Carter's Freshwater Mussel	Conclusions/ Recommendations
Research & Management to Newmont Boddington Gold Pty Ltd. Final Report August 2012 (WRM 2012)		of aquatic fauna and sampling of water quality	downstream of the pit. Water quality, aquatic macroinvertebrates, crustaceans and fish sampled. Carter's Freshwater Mussel not recorded during the study.	distribution were recorded.

4 Assessment of occurrence and potential for impact

Table 2 presents an assessment of the WME (the action) against significant impact criteria for Carter’s Freshwater Mussel. The criteria are outlined in MNES Significant Impact Guidelines 1.1 (DotE 2013). 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 any of the potential impact criteria listed in Table 2.

The potential impacts criteria below are based on impacts on important populations. An ‘important population’ as defined by DotE (2013) is a population that is necessary for a species’ long-term survival and recovery. It is not known how many, if any subpopulations occur across the range of this species. For the purposes of this assessment, an ‘important population’ is defined as the population of Carter’s Fresh Water Mussel occurring within each major catchment area of the southwest as major catchments will have limited genetic movement and species dispersal between catchments. Therefore two important populations relevant to this species include the Hotham catchment population relevant to the WMDE and Bauxite Transport Corridor, and the Collie catchment population relevant to the CBME.

Table 2. Assessment of Significant Impact Criteria – Carter’s Freshwater Mussel (Vulnerable)

Potential impact criteria	Likelihood of impact
Lead to a long-term decrease in the size of an important population of a species	The species is known to occur within the Augustus River in proximity and downstream of the CBME portion of the WME. It has also been recorded in an artificial freshwater lake within the Worsley Alumina refinery in close proximity to the CBME. The WME is located near the eastern limit of the species current range. Due to salinity, river systems to the east (former habitat) are no longer suitable habitat for this species. Provided measures are in place that avoid water contamination, sedimentation and altered stream flow for the WME, the action is unlikely to lead to long term decrease in the size of an important population.
Reduce the area of occupancy of an important population	The area of occupancy has declined by 49% of its estimated former range largely due to salinity. Whilst salinity is not normally associated with bauxite mining activities, other threatening processes potentially resulting from the action, namely sedimentation and water extraction causing altered flow rates could potentially impact on the species. Provided measures are in place that avoid water contamination, sedimentation and altered stream flow for the WME, the action is unlikely to reduce the area of occupancy of an important population
Fragment an existing important population into two or more populations	The former range of this species included extensive major river systems east of the WME prior to increases in salinity within these river systems. The WME is located near the eastern limit of the species current range. Therefore the WME does not intersect two or more populations, and for this reason, the action is unlikely to fragment an existing important population.
Adversely affect habitat critical to the survival of a species	The species is known to occur within the Augustus River in proximity and downstream of the CBME portion of the WME. Provided measures are in place for the WME to avoid contamination, sedimentation and altered stream flow of the Augustus River and the artificial freshwater lake within the refinery site, the action is unlikely to adversely affect habitat critical to the survival of a species.
Disrupt the breeding cycle of an important population	The species is known to occur within the Augustus River in proximity to and downstream of the CBME portion of the WME. While there is an abundance of other river systems in the southwest region, the occurrence of this species within the Augustus River system represent local habitat in which the species breeds and contributes to recruitment and maintained survival of the population. Assuming there are

Potential impact criteria	Likelihood of impact
	management measures in place to avoid contamination, sedimentation and altered stream flow of the Augustus River downstream of the CBME, the action is unlikely to 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	The occurrence of the species within the Augustus River downstream of the CBME indicates this riparian habitat is of suitable quality for the continued existence of the species in the local area. Potentially activities associated with the action could decrease available habitat including altered stream flows and sedimentation which could lead to species decline. Provided that measures are in place that avoid these potential modifications to local river systems, the action is unlikely to 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	An invasive species, namely feral pig, is listed as a present and future threat to this species. This species currently occurs through the southwest forests including the WME areas. Cattle have also been listed as a current and future threat (TSSC 2018). The action is not expected to increase or facilitate the introduction of invasive species harmful to the Carter's Freshwater Mussel. Measures to control or eradication pig numbers and exclude cattle from waterways would be seen as a positive outcome for this vulnerable species. Feral freshwater fish species are established in the region and four of these species have been confirmed as host fish for Carter's Freshwater Mussel (Krunzinger et.al 2011), aiding the mussel's reproductive cycle and juvenile's dispersal.
Introduce disease that may cause the species to decline, or	Dieback is an established forest pathogen within the southwest and is a potential indirect threat that has the potential to reduce riparian habitat quality and availability. The action is unlikely to increase the current level of threat provide that dieback control measures are enforced.
Interfere substantially with the recovery of the species.	A recovery plan has not been documented for this species. Conservation advice issued by TSSC (2018) provides sufficient direction and management actions that are relevant to the action. Recovery is dependent on avoiding salinity and habitat loss by maintaining freshwater flow and groundwater discharge, avoiding clearing and damage to riparian vegetation and river systems, and pollutant and sediment runoff and contamination into waterway habitat. Provided measures are in place that avoid these potential modifications to local river systems, the action is unlikely to interfere with the recovery of the species.

5 Conclusion on the likelihood of significance of impact

The WME is located at the eastern edge of the current distribution of Carter's Freshwater Mussel. This species occurs in proximity downstream of the CBME area within the Augustus River, and has the potential to occur in other waterways located in proximity of the WME. The occurrence of the species in this area is locally significant due to the estimated 49% reduction in the known historically range. Of the two major catchments it would appear that the Collie catchment has a higher likelihood of impact due the local presence of the species.

Information provided by South 32 for this memo did not specify detailed environmental management and mitigation measures that will be in place to reduce the likelihood of significant impacts. Assuming environmental management and mitigation measures are implemented to avoid salinity increases and habitat loss, the WME is unlikely to have a significant impact on the species. These measures include maintaining freshwater flow and groundwater discharge, avoiding clearing/damage to riparian

vegetation and waterways of local river systems and avoiding pollutant and sediment runoff (contamination) into waterway habitat.

6 Measures to reduce or avoid impacts

The following measures are recommended based on conservation advice for the species (TSSC 2018):

- Maintain freshwater flow and groundwater discharge by minimising stream diversion and surface water extraction from waterways
- Avoid unnecessary water extraction and/or mitigate impacts during rapid drawdowns within reservoirs
- Avoid clearing riparian vegetation and forested areas within catchments
- Revegetate and rehabilitate mine areas cleared of vegetation
- Use effective dieback control measures to minimise spread of this pathogen
- Reduce nutrient runoff and intercept nutrients before they enter the waterways
- Fence cattle out of waterways and actively manage feral pig numbers
- Monitor Carter's Freshwater Mussel local occurrence, density and population age structure during the life of the Worsley Mine

7 References

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