REPORT

DRAFT COLLIE RIVER REVITALISATION STRATEGY
2018 – 2022
FOR
SHIRE OF COLLIE

DATE: July 2018
REFERENCE: Q23062017-004_G
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1 Executive Summary

The Collie River is a major river system flowing through the town of Collie in southwest of Western Australia (Figure 1 and Figure 2). After a major flood event in 1963/64 an 8km stretch of the Collie River which runs through the town, was dredged, deepened, widened and fringing vegetation removed. The river has been impacted by a range of land-uses (CENRM 2008) and significantly modified over the past 120 years. The river has significant environmental and cultural value for the people of Collie.

The vision for the Collie River is to develop and implement strategies to improve the health and amenity of the river including; enhancing community experience, reducing nutrient runoff, increasing biodiversity, managing weed species and improving water quality. These strategies benefit not only the local community but also those accessing water further downstream, whilst increasing public amenity to the river.

The Collie River Revitalisation Plan 2008 (CRRP 2008) was updated to reflect the changes impacting the river and banks since the CRRP2008 and to create a shared vision for the river into the future at a strategic level. This strategy focused on the changes impacting the river since the CRRP 2008 and any anticipated changes over the next 5 years. The strategy included gathering and collation of information from a wide variety of stakeholders, wide community consultation, and field investigations. This strategy particularly focused on the stretch of retrained river within the town just below Lynn Street Bridge to Roberts Rocks.

The Shire of Collie has been successfully managing Nardoo with the herbicide Reglone. Continuing this program will be beneficial in long-term management of Nardoo. In addition, a rehabilitation strategy for the study area is recommended to be established and implemented.

There are several areas within the Shire of Collie where vehicular access is causing erosion of the river bank. It is recommended that the Shire identify and prioritise these areas and implement management strategies to reduce the impact of vehicular access in these areas. It is also recommended that the Shire establish a river monitoring program.

With the cessation of mine dewatering and decreasing rainfall, the river flow is likely to reduce. To ensure existing pools are retained, it is recommended that the Shire consider interventions that assist in retaining water and raising the river levels during dry periods.

A decline in water quality has been an issue in the Collie River study area. There is a lack of a structured quality controlled (QA/QC) monitoring program in the study area. The Shire of Collie have built a biofiltration basin system and network to improve water quality of the river.

In order to manage the water level there are three options available to the Shire. These include construction and use of river gates at Venn Street, construct riffles, or use a ‘living’ river concept to regenerate the river back to a more functioning riverine ecosystem. The cost of construction, operation, and maintenance of all options must be assessed and factored into the final solution.
## 2 Recommendations Summary Table

<table>
<thead>
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<th>Item</th>
<th>Section of the strategy</th>
<th>Area</th>
<th>Category</th>
<th>Action</th>
<th>Timeline</th>
<th>Achieve Vision</th>
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</table>
| 1    | 10.1.1                   | Engineering Options               | Water Level Management          | • In order to manage the water level there are three options available to the Shire. These include construction and use of river gates at Venn Street, construct riffles, or use a ‘living’ river concept to regenerate the river back to a more functioning riverine ecosystem.  
• The cost of construction, operation, and maintenance of the chosen design must be factored into the project consideration. | Completed by 2019          | Improve the health and amenity of the river  
Ensure the identified sections of the river remain aesthetically appealing which recognises and promotes the river as a community asset. |
| 2    |                          | Nutrient Management               | Drainage management             | • Undertake installation of biofiltration basins in accordance with the recommendation from CENRM 2016.  
• Once these have been constructed carry out another review of nutrient and pollutant levels from drains and prioritise actions accordingly. | Completed by June 2020     | Improve the health and amenity of the river |
| 10.3 |                          |                                    |                                 |                                                                        |                           |                                                                                |
| 10.8 |                          | Monitoring                        |                                 | • Monitor nitrogen, phosphorus, salinity, and Reglone spray at Lynn Street Bridge and Roberts Rocks boards (see monitoring table below).  
• Monitor water level in mAHD at the following locations:  
  o Just below Lynn Street bridge  
  o Venn St River Boards  
  o Minningup Pool  
  o Roberts Rocks | Monitoring program to be commenced by March 2019, then ongoing | Improve the health and amenity of the river |
| 3    | 10.2                     | Restoration of Riparian Vegetation| Restoration of Riparian Vegetation | • Continue Nardoo control with Reglone Hydrogel. Renew clearing permit from the DWER for Nardoo control.  
• Develop and implement the Shire rehabilitation strategy for the study area.  
• Integrate the strategy into the Shire five year works programme.  
• Ensure that the section of the river foreshore where weeds are | Annually within the first two weeks of autumn. | Improve the health and amenity of the river  
Develop and implement the Shire river foreshore |
<p>| 10.2 |                          |                                    |                                 |                                                                        |                           |                                                                                |</p>
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<td>6</td>
<td>10.9</td>
<td>Advocate for the health of Collie River</td>
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- Removed are replanted with native seedlings and maintained regularly.  
- is availability.  
- Start once weed removal is completed then ongoing  
- rehabilitation strategy.

**4 10.5** Community engagement and education  
Community engagement and support  
- Support Friends of Collie River group in the implementation of the strategy.  
- Regularly inform the community of the progress of the implementation of the CRRS. This can be achieved by using various communication mediums such as social media, print media, radio interviews, the Shire website and on-site signage.  
- Engage with the indigenous community on progress of the implementation of the CRRP.  
- Completed by June 2019  
- Ongoing, at least once a Quarter  
- Enhancing community experience  
- Recognise and conserve the Aboriginal cultural history associated with the river.

**10.6**  
- It is recommended that the Shire carry out a community education campaign to reduce community nutrient input into the river.  
- Start 2019 and ongoing on a 6 monthly basis  
- Improve the health and amenity of the river including; enhancing community experience.

**10.7**  
- Consideration is required by the Shire to review and reduce fertiliser load into the river. It is recommended that the Shire also work with the Collie Golf Course and other large businesses to reduce nutrient input into the river.  
- Completed by July 2019  
- Improve the health and amenity of the river.

**5 10.4** Access and erosion management  
- Investigate access and erosion issues in the study area such as ‘Sandy’ and Mungalup Bridge.  
- Prioritise and manage issues accordingly.  
- Completed by July 2019  
- Improve the health and amenity of the river.

**6 10.9** Advocate for the health of Collie River  
- The Collie Shire to work with other Local Government Agencies, Industry, Government Agencies, and Community groups on river management issues.  
- Quarterly meetings, ongoing  
- Improve the health and amenity of the river.
- It is recommended that the Shire also advocate to ensure that the values of the river are protected in any future developments.

### Monitoring Frequency

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<th>Methodology</th>
<th>Frequency</th>
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<td>River Flow</td>
<td>Gauging Station installed by DWER</td>
<td>Monthly</td>
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<td>Water Quality:</td>
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| Nitrogen and Phosphorus    | Grab sample
Send to chemical analysis laboratory (P&N)
Portable in situ salinity meter | Quarterly            |
| Salinity                   |                                                                             |                    |
| Potential Impact of Reglone| To be assessed, The Shire should carry this out in partnership with SWCC, DWER, or academic institutions currently studying impacts of herbicide monitoring. | To be assessed     |
3 Introduction

The Collie River is a major river system flowing through the town of Collie in southwest of Western Australia (Figure 1 and Figure 2). After a major flood event in 1963/64 an 8km stretch of the Collie River which runs through the town, was retrained, deepened, widened and fringing vegetation removed. The river has been impacted by a range of land-uses (CENRM 2008) and significantly modified over the past 120 years. The river has significant environmental and cultural value for the people of Collie.

The Shire of Collie (Shire) commissioned GFG Consulting (GFG) to update the Collie River Revitalisation Plan 2008 to a strategic document.

Figure 1: Map showing the location of the upper Collie River catchment.
4 Purpose and Scope

The purpose of the update of the Collie River Revitalisation Plan 2008 (CRRP 2008) was to reflect the changes impacting the river and banks and to create a shared vision for the river into the future. The primary focus of CRRP 2008 was the establishment of environmental flows and management of nardoo. This update focuses on the changes impacting the river since the CRRP 2008 and any anticipated changes over the next 5 years. The update included gathering and collation of information from a wide variety of stakeholders, wide community consultation, and field investigations. The update particularly focuses on the stretch of dredged river within the town just above Lynn Street Bridge to Robert's Rocks, a distance of around 12 km, (referred to as the Study Area hereafter). The reference to the 8km stretch of the river in the CRRP 2008 is from just above the Lynn Street bridge to South of the Collie Golf Club.

The vision and five year strategy was developed in conjunction with stakeholders including the Shire of Collie, Weeds and Waterways Advisory Committee (WWAC), Department of Water and the community of Collie. The development of this strategy consisted of literature review, field investigation, stakeholder engagement as well as extensive public consultation.

**Collie River Study Area - Existing Treatments**

![Figure 2: Layout of Study Area](image-url)
5 Vision
The vision for the Collie River is to develop and implement strategies to improve the health and amenity of the river including: enhancing community experience, reducing nutrient runoff, increasing biodiversity, managing weed species and improving water quality. These strategies benefit not only the local community but also those accessing water further downstream, whilst increasing public amenity to the river.

- Develop and implement the Shire river foreshore rehabilitation strategy.
- Acknowledge and preserve the various recreational pursuits associated with the river (fishing, canoeing etc).
- Ensure the identified sections of the river remain aesthetically appealing which recognises and promotes the river as a community asset.
- Recognise and conserve the Aboriginal cultural history associated with the river.
6 Background

6.1 Catchment Description

The Collie River, upstream from the Wellington Dam, is a Water Resource Recovery Catchment area described in the Western Australian State Salinity Strategy and covers an area of 2827 square km’s (Mauger et al. 2001b). Upper Collie surface water area is within the proclaimed Collie River Irrigation District and includes the main stream of the Collie River, the Collie River south and east branches and the Bingham and Harris rivers. The Collie and Harris rivers have been dammed to create the Wellington and Harris reservoirs (DOW 2009).

The majority of the upper catchment is forested and in the 2002 National Land and Water Resources Audit (NLWRA 2002 in Macgregor et al 2010) the catchment is described as in a ‘moderate’ condition compared with other catchments in Australia (Macgregor et al. 2010).

Land clearing in the eastern and southern portion of the catchment has led to dry land salinity, this has led to increased saline water flowing into streams. As a result, water quality in the Collie River and in the Wellington Reservoir has deteriorated. The Collie River East Branch contributes the highest salt load to the Wellington Reservoir. The Harris and Bingham rivers provide a valuable, seasonal input of fresh water to the Collie River system. Land clearing also increased flows in comparison to fully forested catchments. Higher flows have led to erosion of river channel and the sedimentation of river pools downstream. This is particularly evident along the Collie River East Branch (DOW 2009).

The major mining activity in the catchment is the extraction of coal and power generation. The Collie Coal Basin is a declared Groundwater Management Area and the groundwater from this basin discharges into the Collie River and tributaries (Macgregor et al. 2010).

6.2 Geomorphic Setting

The study area is located in the Collie Coal Basin which lies within the Darling Plateau, a physiographic unit on the Yilgarn Block of Archean age, consisting of extensive dissected uplands. Geologically, the Darling Plateau consists mainly of ancient crystalline and metamorphic rocks (Macgregor et al 2010).

The Collie Coal Basin has two distinct sub-areas, the Cardiff and the Premier, separated by the Stockton Ridge formation (DOW 2009). The hydrogeology of the Collie Coal Basin is complex, with multiple aquifers separated by shale and coal seams with numerous faults throughout (DOW 2009)

The Upper Collie Catchment can be described by considering the description of the Lowden Valleys landform. The landform is made up of deeply incised valleys. The dominant geology is colluvium over metasediments and granite rocks. The soils are friable red/brown loam earths, brown loamy earths, loamy gravels, brown deep loamy duplexes, duplex sandy gravels and stony soils (DOW 2009).

6.3 Climate

The climate of the Collie region is Mediterranean with hot dry summers and cool wet winters (Seddon 1972 in Macgregor et al 2010). Mean annual rainfall is approximately 836.41mm (BOM 2018). The mean annual rainfall has fallen to 722.9mm for years between 2003 to 2017 (BOM 2018). Maximum rainfall generally occurs between May and September.
6.4 Climate change
Streams in south west Western Australia have been experiencing declining rainfall and increasing temperatures. Research from across Australia has found that typically a 1% change in mean annual rainfall would result in a 2-3% change in mean annual runoff (DOW 2010). Since the Upper Collie Water Allocation Plan 2009 was released, annual average rainfall has decreased by 4% compared to the 1975 to 2008 average and using the Department of Water Environment and Regulation (DWER) climate guidelines it is expected to decline a further 3% compared to the 2009 to 2016 average by 2030 (DWER 2017).

6.5 Aboriginal Heritage
The rivers and wetlands of the south west, their surrounding landscapes and story lines are significant to the cultural and spiritual beliefs of Aboriginal people. The Collie River is a registered Aboriginal Heritage site (DOW 2009). Aboriginal people believe that the Collie River, the surrounding creeks and waterholes were formed by the Ngarrunguudjit Walgu which now rests at Minninup (DOW 2008).

6.6 Vegetation
The Darling Plateau is vegetated by an array of vegetation complexes with Jarrah (*Eucalyptus marginata*) as the dominant species. Collectively known as the Northern Jarrah Forest, these complexes cover an area extending from Perth to Collie and bounded by the coastal plain to the west and by the wheatbelt to the east.

The lateritic soils of the Collie River catchment region of the Darling Range overlay granitic bed-rock and support a dry sclerophyll forest which is dominated by Jarrah (*Eucalyptus marginata*), with Marri (*Corymbia calophylla*) in some valleys (Shea et al. 1975). This over-storey can also be composed of eucalyptus species such as Blackbutt (*E. patens*), Bullich (*E. megacarpa*) and Flooded-Gum (*E. rudis*) (Bell and Heddle 1989). Some woodland areas are severely affected by Jarrah dieback (*Phytophthora sp.*). Blackbutt and flooded gum are common along less degraded watercourses (Macgregor et al 2010).

The Interim Biogeographic Regionalisation for Australia (Thackway & Cresswell 1995) categorised the Australian continent into 85 regions of similar geology, landforms, vegetation, fauna and climate. The study area occurs in the Jarrah Forest IBRA region. This bioregion is described as "duricrusted plateau of the Yilgarn Craton characterised by Jarrah-Marri forest on laterite gravels and, in the eastern part, Marri-Wandoo woodlands clayey soils. Eluvial and alluvial deposits support Agonis shrublands. In areas of Mesozoic sediments, Jarrah forests occur in a mosaic with a variety of species-rich shrublands.

Hedde et al. (1980) used landform - soil units mapped by Churchward and McArthur (1980) to define and map vegetation complexes for the Collie Basin at a scale of 1:250,000. Three vegetation complexes, Collie, Cardiff and Muja, were defined for the Collie Basin in which the study area is located (Hedde et al. 1980).

The vegetation of the Collie Basin reflects the underlying geology, landforms and soils. The Collie Complex consists of an open forest of Jarrah-Marri-Sheoak with a range of understorey species that reflect the relative proportion of sand and gravel in the soils. Those species commonly associated with gravely soils include Banksia grandis, Persoonia longifolia, Hibbertia hypericoides, Leucopogon capitellatus, Bossiaea ornata, Acacia browniana, Hakea lissocarpa and Astroloma pallidum. On sandier
soils common plant species include *Xylomelum occidentale*, *Daviesia incrassata*, *Bossiaea eriocarpa*, *Lyginia barbata*, *Dasypogon bromeliifolius* and species of *Calytrix*.

The understorey plants in the past have been described as being dominated by white-myrtle (*Hypocalymma angustifolium*), *Trymalium ledifolium* and *Astartea fascicularis*. However, very little of this understorey remains and the riparian understorey was characterised by dense sclerophyllous shrubs (e.g. *Agonis linearfolia*, *Hypocalymma angustifolium*, *Calytrix glutinosa* and *Hakea costata*) and sedges. Wetland and riparian vegetation on the Coastal Plain typically includes flooded-gum (*Eucalyptus rudis*), *Melaleuca preissiana* and *M. Rhaphiophylla* over heath (e.g. *Astartea fascicularis*, *Pericalymma ellipticum var. ellipticum*, *Regelia ciliata*, *Hypocalymma angustifolium*) and sedge lands (Macgregor et al 2010).

Vegetation growing in or in association with the river is referred to as riparian vegetation. Riparian vegetation is protected under the Environmental Protection Act 1986. Therefore, to clear vegetation in the study area a Clearing Permit under Part V of the Environmental Protection Act 1986 is required.

Flora and fauna surrounding the study has been largely disturbed by mining, farming and timbering activities over the past century. Extensive, natural vegetation is confined to State forests, specifically the Northern Jarrah Forest in the Collie region (Western Collieries 1991).

The Collie Basin has been an active coal-mining centre since 1898 and is still the only commercial coal-field in Western Australia. The area has been aggressively explored for the past 25 years (Western Collieries 1991).

The region supported a variety of land-uses, other than the dominant coal-mining component, including agriculture, hardwood milling, pine plantations, wildflower harvesting seed collection, water catchments, apiculture, recreation, conservation holdings, power production, tourism, quarrying, light industry and townships (Western Collieries 1991).

The vegetation in the study area is riparian vegetation. Vegetation growing in or in association with the river is referred to as riparian vegetation. Riparian vegetation is protected under the Environmental Protection Act 1986. Therefore, to clear vegetation in the study area a Clearing Permit under Part V of the Environmental Protection Act 1986 is required.
7 Existing Condition of the River

7.1 Dredging

Due to flooding in the 1960s, the river has been dredged through the town site, removing the historical series of pools and replacing them with a steep-sided channel between 15m and 40m wide with a relatively flat base. This section of the river has been significantly modified.

The Centre of Excellence in Natural Resources Management of the University of Western Australia carried out a survey for the Shire of the river water height and river bed spot heights from Venn Street river stops through to the Ewington Weir, a distance of about 4,200m (SOC 2010b).

The surveyed river bed level is stated below and presented in figure 3.

- **Venn St boards to East End Bridge (0-1090m)**
  The Venn St boards is at 173.8m AHD. The first section from 0 to about 450m upstream has a steep eastern bank and the river bed about 173.4 to 173.6m AHD which then slopes gently up to the western bank.

- **East End Bridge to Energy West (1090-1750m)**
  This area consists of a sandy river bed level of about 173.7m AHD.

- **Soldiers Park (Energy West to Coombe St Bridge) (1750-2140m)**
  The river bed levels in the channel were 173.5 to 173.7m AHD.

- **Commbes St Bridge to upstream of the Swinging Bridge (2140-2720m)**
  The river bed levels were at 172.9m AHD.

- **Upstream of Swinging Bridge to Robb St (2720-3380m)**
  This section is characterised by a sandy bottom and the river bed is about 2850m upstream to 3060m.

- **Robb St to Ewington Weir (3380-4300m)**
  This section of river predominantly has a rocky bottom, and river bed is generally 10-15m wide up to 25-30m wide in some small sections with 172.9m AHD.

![Collie River Profile](image)

*Figure 3: River Bed Profile from SOC 2010b*
7.2 Retention

Boards (or stops) have been constructed at Venn St Weir (figure 4) raising water levels about 2.2m above the river bed, creating a 4.3 km upstream backwater with water covering the channel to each steep sided bank. Venn St Weir was in a dilapidated condition and no longer has the structural integrity to be used at full capacity. Similarly, boards have been constructed at Roberts Rocks Weir raising water levels by about 0.8m and backing water up to the Venn St Weir. These boards seem to replicate a natural pool at Roberts Rocks (figure 5).

Figure 4: Venn Street Stop Boards

Figure 5: Roberts Rocks Stop Boards

It is likely that the boards have contributed to the maintenance of water level in especially Minninup Pool which has enhanced the amenity of the site and improved popularity of the site for recreation purposes. The boards seemed to have protected the upstream pools and habitats with increased retention of water. In times of high water velocity, the increased water depths of the upstream areas caused by the river boards have reduced velocities and which would have contributed to reduced erosion.
In addition to the boards, riffles have been placed in the river in accordance with the recommendations of the CRRP 2008 (figure 6). There is a constructed riffle around 200 meters downstream of the Lynn Street Bridge. The Shire constructed a second riffle in the river in 2013 between Solders Park and the Synergy Building in Lefroy Street. It is recommended that the performance of the riffles be monitored and assessed before considering additional riffles.

Figure 6: Riffle

7.3 Salinity

Salinity of the steam flow from the Collie Catchment began to increase before 1960 due to clearing of native forest for pasture development (Loh 1985 in Mauger et al 2001a). Deep-rooted native vegetation were replaced with shallow-rooted annual crops and pastures on deeply weathered soil profiles of Archaean origin, which contain high concentrations of salt and relatively low rainfall. This replacement vegetation has a lower capacity for transpiration, it therefore uses less groundwater. In addition, the shallow-rooted vegetation does not have roots deep enough to maintain a deep “dry” soil profile compared to the previous native vegetation. This results in the recharge from rain exceeding the rate of losses and the groundwater level rises. Which brings previously dissolved salts. This can cause salt scalds where the saline groundwater approaches the soil surface in severe cases. In other cases the saline drainage of the area and the salinity of the streams increases (DOW 2009).

The Government of Western Australia (WA government) legislated to control the release of Crown land, in 1961, and in 1976. The WA government legislated to control the clearing of native forest (Country Areas Water Supply Act, 1947, Part 11A). However, by this stage the clearing was already causing the stream salinity of the Collie River just upstream of the Wellington Reservoir to increase by 42 mg/L/yr (Scofield et al 1988 in Mauger et al 2001b). It was estimated that if no further action was taken, the stream salinity would raise to a flow-weighted mean value of 1500 mg/L, resulting in 1150 mg/L in the reservoir (Loh 1985 in Mauger et al 2001b).

With Wellington Reservoir becoming excessively saline the Harris Dam was built to replace it as the source for the Great Southern Town Water Supply scheme. An environmental commitment made as a condition of approval to build Harris Dam, was that the water supplied from Wellington Reservoir would be suitable for domestic purposes (EPA, 1987). Another condition made was for the release of sufficient water to meet environmental water provisions (EPA, 1987).
7.4 Nutrients

Nutrient levels have been measured below and above the town site by Dr Peter Cook, UWA (CENRM 2016). The measurements taken downstream below the town site had significantly higher levels of Nitrogen when compared with the measurements taken above the town site (tables 1&2) (CENRM 2016). This suggests that these pollutants entering the river originate in the town site.

Nutrient concentrations were assessed at the following locations:

- Johnson Street Drain - upstream (samples 1 and 2) and downstream (samples 3 and 4) from the township.
- The Energy West Drain (samples 5 and 6),
- A drain immediately below the Bowling Club (samples 7 and 8)

Table 1: Nutrient concentrations found at the various sample sites (from CENRM 2016).

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Mean Total Nitrogen Mg/L</th>
<th>Mean Nitrate levels Mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johnson Street Drain – upstream of township</td>
<td>1.80</td>
<td>0.12</td>
</tr>
<tr>
<td>Johnson Street Drain – downstream of township</td>
<td>0.87</td>
<td>0.23</td>
</tr>
<tr>
<td>Energy West Drain</td>
<td>1.18</td>
<td>0.79</td>
</tr>
<tr>
<td>Drain below Bowling Club</td>
<td>2.12</td>
<td>1.77</td>
</tr>
</tbody>
</table>

At all sites, total phosphate levels were low and relatively constant (mean 0.344 mg per litre). Free reactive phosphate levels were also low and, in some cases, were below detectable levels (mean 0.007 mg per litre).

For nitrogen however, there was some considerable variation in levels between sites.

Table 2: Nutrient concentrations found at the various sample sites (from CENRM 2016)

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>TP (mg/L)</th>
<th>TN (mg/L)</th>
<th>FRP (mg/L)</th>
<th>NOx-N (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.382</td>
<td>2.794</td>
<td>0.008</td>
<td>0.113</td>
</tr>
<tr>
<td>2</td>
<td>0.335</td>
<td>0.797</td>
<td>0.012</td>
<td>0.116</td>
</tr>
<tr>
<td>3</td>
<td>0.335</td>
<td>0.838</td>
<td>nd</td>
<td>0.223</td>
</tr>
<tr>
<td>4</td>
<td>0.331</td>
<td>0.898</td>
<td>0.005</td>
<td>0.246</td>
</tr>
<tr>
<td>5</td>
<td>0.342</td>
<td>1.219</td>
<td>nd</td>
<td>0.809</td>
</tr>
<tr>
<td>6</td>
<td>0.343</td>
<td>1.148</td>
<td>nd</td>
<td>0.777</td>
</tr>
<tr>
<td>7</td>
<td>0.346</td>
<td>2.373</td>
<td>0.006</td>
<td>1.978</td>
</tr>
<tr>
<td>8</td>
<td>0.335</td>
<td>1.874</td>
<td>nd</td>
<td>1.556</td>
</tr>
</tbody>
</table>

Nitrogen is a contributing factor to the dense aquatic weed growth found in the river (SOC 2010a). An evaluation has been made of these sites, with priorities being developed for the installation of nutrient stripping basins and sculptured drains to capture nutrients before it reaches the river ecosystem (CENRM 2016).

The Shire has built a number of biofiltration basins and is implementing other strategies to reduce/remove these nutrients. One of these biofiltration basin is located between Soldiers Park and the Synergy Building in Lefroy Street in 2017. Work is being continued to progress the biofiltration basin to full operational capacity. There is also a network of biofiltration basins built between 2012 and 2017 around Forrest
Street. The biofiltration network is regularly maintained. It is recommended that the Biofiltration basins be monitored to assess their performance.

Biofiltration systems have been found to outperform conventional piped stormwater systems with respect to water quality improvements (suspended solids, total nitrogen and phosphorus) due to flow reduction and filtration of the flow into the underlying soils (DOE 2006).

7.5 Weeds
The reshaped banks within the town site (formed at the same time as the dredging) have been colonised by weeds. There is also some native regrowth along these banks. Some of the weeds have been cleared in areas and replaced with native species.

Other weeds found in the study area included in Table 3.

The river channel has been colonised by Nardoo (*Marsilea mutica*), a native plant which acts as a weed in this location. Nardoo forms in shallow, warm, slow moving, nutrient rich environments and has been thriving in the Collie River. The Nardoo is gradually slowing the flow of the main channel and colonising it until the entire river is congested. This prevents recreation activities, is considered unattractive and is a symptom of the health of the river. Nardoo has been reduced through a successful Shire spraying program.

Previously the Shire has trialled various mechanical methods to reduce the nardoo in the river. These include, manual control methods such as grappling hooks, floating weed harvesters, adjusting water levels, covering the area with plastic, and removal by hand. The methods outlined above had limited success or were not practically viable considering the large cover of Nardoo in the river (Observations from the Shire of Collie Parks and Gardens Department).

The chemical spraying of the nardoo with Reglone Hydrogel has proven to be the most successful method of controlling Nardoo. The Shire was able to control large areas of weed infested areas in a relatively short period of time. As Nardoo is an aquatic weed the application of the Reglone, Hydrogel and aquatic dye to the full extent of the infestation was very difficult. A combination of boat mounted spray tanks, wading applicators and bank based spraying is used to apply the chemical (Observations from the Shire of Collie Parks and Gardens Department).

From visual observation of the Shire staff it is estimated that there has been a 70% reduction in areas of Nardoo infestation in the study area. Annual weed control spraying is carried out to ensure that outbreaks of nardoo do not establish to a level prior to the commencement of the chemical control program. The follow up applications are targeted at controlling small difficult to access locations with remaining Nardoo and regrowth (Observations from the Shire of Collie Parks and Gardens Department).

Other steps undertaken to limit the regrowth of Nardoo are:

- Building riffles to oxygenate the water
- Controlling nutrients placed on Shire land
- Educating the community to limit nutrients on private land
- Planting trees to shade the river (depriving the weeds of sunlight)
- Increasing the depth of water in the river using Venn Street Boards
- Constructing and planting nutrient stripping basins at inlet points
Table 3: Weeds commonly found in the study area, from SWCC 2017.

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia longifolia</td>
<td>Sydney golden wattle</td>
<td></td>
</tr>
<tr>
<td>Avena fatua</td>
<td>Wild oat</td>
<td></td>
</tr>
<tr>
<td>Cytisus proliferus</td>
<td>Tagasaste</td>
<td></td>
</tr>
<tr>
<td>Cynodon dactylon</td>
<td>Green couch</td>
<td></td>
</tr>
<tr>
<td>Eragrostis curvula</td>
<td>African love grass</td>
<td></td>
</tr>
<tr>
<td>Gomphocarpus fruticosus</td>
<td>Cottonbush</td>
<td></td>
</tr>
<tr>
<td>Hypochaeris radicata</td>
<td>Flatweed</td>
<td></td>
</tr>
<tr>
<td>Lathyrus tingitanus</td>
<td>Tandier pea</td>
<td></td>
</tr>
<tr>
<td>Paspalum sp.</td>
<td>Paspalum</td>
<td></td>
</tr>
<tr>
<td>Pennisetum clandestinum</td>
<td>Kikuyu</td>
<td></td>
</tr>
<tr>
<td>Rubus anglocandicans</td>
<td>Blackberry</td>
<td></td>
</tr>
<tr>
<td>Typha orientalis</td>
<td>Bulrush</td>
<td></td>
</tr>
<tr>
<td>Watsonia meriana</td>
<td>Watsonia</td>
<td></td>
</tr>
<tr>
<td>Cortaderia selloana</td>
<td>Pampas Grass</td>
<td></td>
</tr>
</tbody>
</table>

7.6 Fauna

7.6.1 Macroinvertebrates

Aquatic macroinvertebrates are small animals that live for all or part of their lives in water. There are many types of macroinvertebrates such as dragonfly larvae, mosquito larvae, and aquatic beetles. Some of these animals are sensitive to pollution, whereas others can live in very polluted waters. Due to the variability in sensitivity to pollution, macroinvertebrates make good biological indicators. Sampling macroinvertebrates communities for the types and numbers of animals present can indicate the health of a river.

Representative macroinvertebrates previously recorded in the study area is presented in table 4. Reach 1a, Harris River below the Harris Dam from (WRM 2009) was used as the fauna representative node for the study area.

Table 4 represents a typical distribution of macro invertebrate fauna that could be found in the study site. This list should be updated with site specific surveys conducted in the future.

Table 4: Representative macroinvertebrate taxa previously recorded from Reach 1a from (WRM 2009).

<table>
<thead>
<tr>
<th>Macroinvertebrate</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOLLUSCA</td>
<td></td>
</tr>
<tr>
<td>Gastropoda (Glacidorbis, Ferrisia, Glyptophysa)</td>
<td>1</td>
</tr>
<tr>
<td>Bivalvia (Westralunio)</td>
<td>1</td>
</tr>
<tr>
<td>CRUSTACEA</td>
<td></td>
</tr>
<tr>
<td>Ostracoda (brine-shrimps)</td>
<td>&gt;2</td>
</tr>
<tr>
<td>Copepoda (shield shrimp)</td>
<td>&gt;2</td>
</tr>
<tr>
<td>Isopoda (phreatoicids)</td>
<td>1</td>
</tr>
<tr>
<td>Amphipoda (Perthia, Austroclintonia)</td>
<td>2</td>
</tr>
<tr>
<td>Decapoda (Cherax, Palaemonetes)</td>
<td>1</td>
</tr>
<tr>
<td>INSECTA</td>
<td></td>
</tr>
<tr>
<td>Ephemeroptera (mayflies)</td>
<td></td>
</tr>
</tbody>
</table>
7.6.2 Fish and Crayfish

Fish and crayfish species are not only of recreational significance to the people of Collie they are also good indicators of river conditions. These species are often top predators and important species within the ecosystem. This means that these species are closely linked with the overall health of the river ecosystem. Monitoring the species dynamics, such as change in species composition, abundance, diversity, health and condition can provide valuable information on the health of the river.

Fish species identified at the study area from Department of Fisheries, Freshwater Fish website (DOF 2017).

- Common Carp (Cyprinus carpio) – introduced species
- Freshwater Cobbler (Tandanus bostocki)
- Freshwater Shrimp (Palaemonetes australis)
- Gilgie (Cherax quinquecarinatus)
- Koonac (Cherax plebejus)
- Mosquitofish (Gambusia holbrooki) – introduced species
- Nightfish (Bostockia porosa)
- Redfin Perch (Perca fluviatilis) – introduced species
- Smooth Marron (Cherax cainii)
- Western Minnow (Galaxias occidentalis)

---

<table>
<thead>
<tr>
<th>Family Name</th>
<th>Species Name</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leptophlebiidae</td>
<td>Nyungara, Bibulmena, Neboissophlebia</td>
<td>3</td>
</tr>
<tr>
<td>Baetidae</td>
<td>Baetis, Cloeon</td>
<td>2</td>
</tr>
<tr>
<td>Caenidae</td>
<td>Tasmanocoenis</td>
<td>1</td>
</tr>
<tr>
<td>Odonata (dragonflies &amp; damselflies)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zygoptera (Austroagnion, Austrolestes, Ischnura)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Anisoptera (Hesperocordulia, Lathrocordulia, Synthemis)</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Plectoptera (stoneflies)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Griptopterygidae (Leptoperla, Newmanoperla, Riekoperla)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Coleoptera (aquatic beetles)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dytiscidae (Sternopriscus)</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Hydrophilidae (Paracymus, Berosus, Enochrus)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Gyrinidae (Macrogyrus, Aulonogyrus)</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Diptera (two-winged flies)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chironomidae (non-biting midges)</td>
<td></td>
<td>32</td>
</tr>
<tr>
<td>Simulidae (black-flies)</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Tipulidae (crane flies)</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Empididae (dance flies)</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Trichoptera (caddis-flies)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ecnomidae (Ecnomina, Ecnomus)</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Leptoceridae (Triplectides, Notolina, Condocerus)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Hydrobiosidae (Taschorema, Apsilochorema)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Hydroptilidae (Acritoptila, Oxyethira)</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Hydrooropsychidae (Smicrophylax, Cheumatopsyche)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Pilopotamidae (Hydrobiosella)</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>
Western Pygmy Perch (*Nannoperca vittata*)
- Yabby (*Cherax destructor albidus*)

### 7.7 Ground Water

Historically, in the Collie Basin the river was a system of interconnected pools watered from upstream springs and aquifers. Groundwater discharges into the Collie River and its tributaries, maintaining numerous river pools and wetlands. Pools in the Collie River that previously contained water throughout the year, have at times become dry (Varma 2002).

Permian sediments control groundwater flow directions. The natural groundwater flow pattern in the Collie Basin has been altered because of mine dewatering and large-scale groundwater abstraction for power generation. As a result of mine dewatering the flow is directed mainly towards the areas of mining (Varma 2002).

Abstraction in excess of annual recharge has led to a basin-wide decline in groundwater levels across the Collie Coal Basin below pre-mining state. This has resulted in alterations to groundwater flow patterns, induced recharge to the confined aquifers and reduced discharge to the Collie River (DOW 2009).

With large scale dewatering groundwater levels will continue to decline (DOW 2009). As a result, some river pools that were maintained by natural groundwater discharge in the pre-mining period continue to be dry in summer (Varma 2007).

The upper Collie River catchment and Collie Basin groundwater resources are already subject to significant impacts from existing land uses in the area. Historic land clearing and a long history of coal mining (since 1898) have resulted in degraded surface water and groundwater quality, changes to surface water–groundwater connectivity, altered surface water hydrology, groundwater drawdown and impacts on associated water-dependent resources.

The impacts of mining include:

- Long-term groundwater drawdown affecting groundwater dependent ecosystems.
- The accumulation of saline, acidic, metalliferous groundwater in mine voids.
- Altered hydrology and water quality in the re-aligned Chicken Creek.
- The loss of some flood areas.
- Long-term impacts of mine water discharge to the hydrology, geomorphology, water quality, riparian vegetation communities and in-stream fauna of the river and associated permanent pools.
- Substantial contribution to cumulative groundwater and surface water impacts in the region (ICSC 2014).

Current mining and power generation activities in the Collie area include:

- Blue Water Power Station is a 416 Megawatts capacity power station located 8 km northeast of Collie.
Muja Power Station was a 1094 Megawatts capacity power station located 22km east of Collie. Muja A and B comprising of 220 Megawatts was shut down in September 2017. Muja C and D comprising of 854 Megawatts remains operational.

Collie Power Station is a 340 Megawatts capacity power station located 10km east of Collie.

Griffin Coal’s Muja Mine 18 kilometres south east of Collie which stopped mining in 2010.

Griffin Coal’s Ewington 1 and 2 coal mines 10 kilometres east of Collie.

Premier Coal mine is 15km east of Collie.

7.8 Pools

The potential negative effects on the pools were initially obscured by the coal companies disposing their mine water to the rivers along with saline water from the Muja Power Station (Beckwith Environmental 2007). Mine dewatering started impacting on the groundwater levels since the 1950s as a result of increased coal mining in 1952 from those seams of the Muja Coal Measures at Western 2 that lie beneath the river pools (Varma 2002).

A study by Morgan et al. (1995) in (Varma 2002) on freshwater fish fauna in pools of the Collie River South Branch found the drying of a number of pools to have “enormous ramifications” on the ecology of the system and many fish deaths. A macro invertebrates survey carried out by Halse et al. (1999) in (Varma 2002) showed that the population in most river pools in the basin has lessened, and that the low pH of pool water may be a cause of this reduction (Varma 2002).

7.9 River Flow

Factors which are anticipated to reduce the volume of water flowing in the river are climate change (see section 6.4) and changes in available water due to farming. Saline water runoff has increased with the historic deforestation of the upper reaches of the catchment.

The disposal of surplus mine dewater to the Collie River has increased the amount of water in the river system over a number of years (see figure 7). Dewater destined for pool supplementation and disposal is treated for pH and metals however, it is expected that the disposal volume will be redirected for power station use within six mounts. This will reduce flows in the river, particularly over the summer period where a large portion of current flow originates from disposal. It is anticipated based on modelled data that average annual flows through town will decrease by around 33% (see Figure 9).
The Collie Water proposal will also have an impact upon the quantity of water available in the river.

7.10 Collie Water Proposal

The Collie Water Proposal is a public-private partnership driven by Collie Water which proposes to take saline water from the Collie River, retain it in a mine void, treat it in a desalination plant and sell the potable water to Watercorp. This will improve the quality of water flowing down the river, as the more saline water will be removed and increase the supply of potable water. This is anticipated to have an impact on the volumes of water in the river.

A secondary proposal is to replace the upstream pasture areas with plantations and forest to further reduce the salinity of the water. New plantation forest areas would be created downstream below the Wellington Dam. Replacing the upstream pasture areas will reduce surface water runoff in the river, if done on a broad scale. It is proposed to thin existing upstream forests to counter this effect (see Appendix 3 for further information).

This proposal is currently awaiting support and funding from the State and Federal governments before progressing to the development stage.
8 Implementation of recommendations from Collie River Revitalisation Plan 2008

8.1 Establishment of environmental flows
The following options were recommended for the establishment of environmental flows and the management of Nardoo in the Collie River in the CRRP 2008:

1. restoration of environmental flow
2. mechanical or chemical removal
3. seasonal management of stop-boards
4. removal of river stop-boards
5. installation of riffles
6. restoration of riparian vegetation
7. monitoring

8.2 Sediment Control
There was a recommendation from the CRRP 2008 to use scouring of the sediment to control Nardoo growth. Three possible options were provided in CRRP 2008 for the scouring of the sediment, (1) mechanical removal, (2) seasonal management of river stop-boards (3) permanent removal of stop-boards and/or installation of riffles. The Nardoo has been successfully controlled with Reglone.

8.3 Mechanical or chemical removal of Nardoo
The Shire undertook a Nardoo Control Trial Program (SOC 2014); the trials tested the effectiveness of a range of strategies including the application of Herbicide, Plastic Solarisation, Mechanical Excavation, Mechanical Harvester and the use of a Grappling Hook. The test sites were monitored over an eighteen month period, with the final evaluation revealing that the use of herbicide would achieve the best outcomes.

Following the determination that the use of herbicide would be the most effective means of treatment of Nardoo, the Shire sought native vegetation clearing approval to undertake larger trials to test the effectiveness of using the prescribed herbicide Reglone to control Nardoo. In 2012-2013 the small area was treated with Reglone. From this trial the use of Reglone to control Nardoo was found to be very effective. The Shire has since been using Reglone to successfully control Nardoo through an annual Nardoo control program.

8.4 Seasonal management of river stop-boards
The CRRP 2008 recommended the seasonal removal of the stop-boards over winter as a trial to allow scouring of the sediments over the period when the rivers flow is greatest. Replacement of river stop-boards over summer would maintain pool level over this period. The “pulsed” flows required to remove Nardoo during summer/autumn could be delivered by stop-board management. If the seasonal removal was successful it was recommended to permanently remove the stop boards.

The stop-boards have been replaced however not to full capacity (figures 3 & 4).
The Shire carried out a study from the Venn St Boards through to the Ewington Weir (SOC 2010b). The study assessed feasibility of retaining water by management and/or removal of stop-boards. The study found that it was feasible to establish environmental flow by management of stop-boards. In the study it was also suggested that shallow water areas be planted with rushes, sedges and a low density of trees. The suggested species list is in Appendix 2.

8.5 Permanent removal of stop-boards and installation of riffles
The CRRP 2008 recommended the permanent removal of stop-boards to control Nardoo and for ecological reasons. The CRRP also recommended building riffles and prior to the construction of riffles, a site survey be undertaken to establish the profile, slope, geometry and alignment of the river channel.

As previously mentioned the use of the herbicide Reglone was found to be the most effective means of treatment of Nardoo at the study area. As it was found that establishing environmental flow through seasonal management of environmental flow was possible permanent removal of the stop boards was not considered.

8.6 Restoration of riparian vegetation
Since the release of the CRRP 2008 the Shire have carried out various restoration programs. These include:

- Revegetation of some areas along the river has taken place. This includes the planting of 20,000 reeds, sedges and rushes close to the riverbanks and at Minninup Pool where larger tree stocks were planted with the help of community groups.
- Weed management along the river bank has occurred at targeted areas. Large sections of Blackberry and Watsonia were controlled.
- The Preston Rd Revegetation Project involves rehabilitating three areas around the Preston Rd Bridge. Considerable weed management was undertaken over a period of time, prior to the area being revegetated with local species. This was a collaborative project between the South West Catchment Council and involved a range of community groups including; Collie Rotary, Collie Scout Group, Ngalang Boodja Aboriginal Corporation, Community Garden Group, Shire of Collie elected members and community members.
- The Jack Mears Spring Site Project is a collaborative project between the Shire and the Ngalang Boodja Aboriginal Corporation to restore a heavily weed impacted natural spring site within the study area, which has cultural significance to Indigenous people (SWCC 2017). An important aspect of the site was the discovery of a previously unidentified species of invertebrate which is found only at the site.
- Snap Shot Water Quality Testing undertaken. This has identified a large number of drains with significantly higher levels of Nitrogen (CENRM 2016). See section 7.4 for further detail.
8.7 Monitoring

The following monitoring regime was recommended in the CRRP 2008 (table 5).

Table 5: Monitoring regime recommended in CRRP 2008.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Methodology</th>
<th>Sites/Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrology</td>
<td>Gauging station</td>
<td>Daily flows</td>
</tr>
<tr>
<td>Physical</td>
<td>Water quality sampling Pool aggradation</td>
<td>Annually at the downstream “node”.</td>
</tr>
<tr>
<td></td>
<td>Channel morphology</td>
<td>Annually at areas within the “nodes” (both banks).</td>
</tr>
<tr>
<td>Biological</td>
<td>Nardoo areal coverage Aquatic macroinvertebrates Fish recruitment Riparian assessment</td>
<td>During summer/autumn(weekly) TWice yearly (wet and dry seasons at the three nodes). Annually at the three “nodes”(coincide with breeding). Annually (summer) at the three “nodes”</td>
</tr>
</tbody>
</table>

Snap shot monitoring has occurred, part of this is presented in section 8.6 and the full results are in SOC 2010b, however to date continuous monitoring has not occurred.
9 Current State and Management

9.1 River Flow

The DWER undertook modelling on the Collie river flow with data from 1980 to 2015 (DWER 2017). The aspects modelled by DWER included, the modelled sum of flow with mine dewatering input into the river with no diversion of the Collie River East Branch (Figure 8), the modelled sum of flow with no mine dewater with diversion of the Collie River East Branch (Figure 8), and the calculated flow with no mine dewater input and no diversion of the Collie River East Branch (Figure 8). The diversion of the Collie River East Branch refers to the proposed diversion by Collie Water (see section 7.9). It should be noted that the information provided in figure 8 is modelled on scenarios that may not eventuate. It does not illustrate all scenarios.

The (LUCICAT River Flow Forecasting) modelling data comparing the current and projected scenarios indicates that there is a 65% reduction in flows in a minimum flow year which was 2015 (the worst case scenario) and 14% reduction in a maximum flow year which were 1983 and 1987 (best case scenario).

![Modelled sum river flow (in ML) data with/without mine dewatering and with/without diversion of Collie River East Branch for the Collie Water project (from DWER 2017).](image-url)
Other scenarios modelled by DWER are shown in figure 9. These modelled scenarios include the following:

- The modelled average of Collie town site flow with no diversion of the Collie River East Branch and with input from mine dewatering.
- The modelled potential average of Collie townsite flow with diversion of Collie River East Branch and no mine dewatering input.

The modelled average mine dewatering is included in figure 9. The calculated average of Collie townsite flow with no diversion of the Collie River East Branch and no mine dewater input is also shown in figure 9. The averages were modelled for 2011 to 2015.

The results show that the reduction in summer flows from current with mine dewater input and no diversion of the Collie River East Branch to the projected scenario of no mine dewater input with diversion of the Collie River East Branch is around 71%. This suggests that the large portion of the flow is directly attributable to dewater disposal during summer. In contrast the reduction in winter is less significant with a 34% reduction. Mine dewatering has artificially increased the monthly average flow over this time. Once the mine dewatering ceases the river will revert to seasonal conditions that occurred prior to discharge of mine dewatering. The results do not consider aquifer recharge.

### 9.2 Water Quality

Decline in water quality in the Collie River study area has been an issue. There has been various monitoring carried out within the study area by various organisations. However, there is a lack of a...
continuous structured quality controlled (QA/QC) monitoring programs in the study area. Furthermore, the monitoring program is required to be consistent and carried out for a significant time period.

Quality Assurance consists of a system of documented procedures and plans established to ensure that the water monitoring program produces data of known precision and bias. This includes staff training programs, calibration process, written procedures and record keeping. In addition, this also includes a quality control program.

Quality Control in monitoring refers to operational activities that confirm the quality assurance methods are functional and that information collected is accurate, precise and properly recorded. Therefore, consistent QA/QC activities produce data of known quality.

It is recommend that the Shire develop and implement a monitoring program for salinity, water level, Phosphors, and Nitrogen (see section 10.1.7 recommendations).

9.3 Current Restoration of Riparian Vegetation

Nardoo Control

Since the release of CRRP 2008 the Shire has been successfully managing Nardoo within the study area. Reglone Hydrogel is used annually in autumn to control Nardoo along the entire stretch of river within the town. Spraying is conducted twice within two weeks to ensure maximum effectiveness.

Reglone has been found to be the most suitable herbicide to control Nardoo in the study area for the following reasons (SoC 2014):

- Reglone is authorised by the Australian Pesticides and Veterinary Medicines Authority for use on Nardoo in aquatic areas in all states.
- Reglone is considered to be non-residual with minimal biological consequence because it is inactivated by attachment to soil particles.
- Reglone is rapidly absorbed and deactivated by soil. Reglone is rapidly and completely deactivated by soil by a reaction between the double positively charged diquat ions and clay minerals present in soils to form complexes. Most soils have sufficient capacity in the top 2 - 5 cm to bind many hundred times the normal field rates of diquat.
- Reglone does not leach, so there is little chance of groundwater infiltration, and while there is a high likelihood of runoff in waterways due to attachment to clay particles, Reglone is inactive in this form and therefore has little biological consequence.
- Bioaccumulation of Reglone in an aquatic species is low.
- There is no effective mobility of Reglone in soil or water
- If spills occur, Reglone can be deactivated by absorption with earth, sand, clay or absorbent material such as vermiculite.
- In the event of a chemical spill, the spill site can be deactivated, and then decontaminated with detergent and small volumes of water.

Riparian Restoration

The Shire is implementing several environmental rehabilitation management plans including, Jack Mears Spring Rehabilitation Landscape Management Plan.

The Shire is also currently working on a priority section of the river in the main town of Collie targeting the removal of weeds and the replanting of the foreshore with native seedlings. The priority weeds
targeted are nardoo, Watsonia and Bulrush which out compete native vegetation and in turn impact the water quality, environmental diversity and native fauna.

The Shire has established a rehabilitation strategy for the CBD area (figure 10). Part one of the strategy is listed below.

Part one of the rehabilitation of this foreshore will occur in five stages over five years:

1. The first stage (4.4ha) covers the foreshore on both sides from the Swinging Bridge to the Coombes Street Bridge;
2. The second stage (2Ha) covers the area between the Coombes Street Bridge up to the riffle (Western Riders and Skate Park);
3. The third stage (0.7Ha) covers the area on the Southern bank from the biofiltration basin up to the railway bridge;
4. The fourth stage (0.8Ha) covers the area on the Northern bank from the Western Riders up to the railway bridge; and
5. The fifth stage (0.25Ha) covers the area from the skate park to the biofiltration basin on the Southern side of the river and will include infill planting of stages 1-4 to replace seedling mortality.

Figure 10: Shire proposed rehabilitation stages

Good quality remanent vegetation still exists in the study area (figures 11 &12). Revegetation of degraded areas will enhance the ecological value of the study area.
Figure 11: Coral Vine Kennedia coccinea (Curtis) Vent

Figure 12: Purple Enamel Orchid Caladenia brunonis and West Australian Kangaroo Paw Anigozanthos manglesii

9.4 Public access and erosion

There were two areas found within the study area that have been impacted by erosion caused by vehicular access (figures 13 to 14). A bank next to the Munglup Bridge has been eroded (figure 15 & 16). It is recommended that access be managed so as to reduce large exposed sandy areas and create narrower tracks for the Public to access the bank. Another river bank at the area known as ‘Sandy’ near Minningup Pool also had erosion impacts caused by vehicular access. The access to It is recommended
that area known as “Sandy” be managed to reduce the width of the access track to the water’s edge, to a narrower access track. It is recommended the Shire monitor the use of the access track and take further action if required.

Figure 13: Munglup Bridge exposed bank

Figure 14: Munglup Bridge exposed bank
Figure 15: 'Sandy' exposed bank

Figure 16: 'Sandy' exposed bank
9.5 Drainage management

Nutrient levels have been measured below and above the town site (CENRM 2016) (see section 7.5). The Shire has built a series of Biofiltration basins (figure 17). Biofiltration basins are a good solution for stripping pollutants from drains.

Figure 17: Biofiltration basin

9.6 Review

The Collie River Revitalisation Strategy 2018 to 2022 should be reviewed annually for progress to measure the recommendation and performance against the strategy. The strategy should be fully reviewed in 2022.
10 Recommendations

10.1 Water Level Management Options

There are three options for water level management to consider. These include construction of a river gate, construction of additional riffles, and using the ‘living’ river concept to transform the river back to a functional ecosystem.

10.1.1 River gates

To ensure existing pools are maintained, river gates such as Sluice gates are an option that could be installed at Venn Street. Under this option the Shire will have the ability to manage the water levels to desired outcome, depending on the seasonal flow in the river.

If river gates are to be installed they are to be suitably designed and constructed to ensure their structural integrity and safe operation. Functional and economically designed gates can be sourced and may use manual operation to avoid the higher cost of computer controlled systems. It is recommended that appropriate type and design of river gate is investigated. The cost of construction, operation, and maintenance of the chosen design must be factored into the project consideration. The existing board infrastructure may need structural assessment if a new system is to utilise the current infrastructure.

The gates can be opened during winter, depending on rainfall and the heavier flows between May and September. The risk with gates is that the can become stratified and the stillness of this water can lead to deterioration of water quality. The quality of this water in the retained area should be monitored and managed accordingly. The river gates are considered a solution for managing river levels until progressive restoration of the river occurs in the longer term which can be a 20 to 30 year process. The gate will also enable rehabilitation trials in the river to occur.

10.1.2 Riffle management

Installation of riffles is an alternative option for control of water flow. Riffles create pools, which can be habitat for fish and are typically a refuge for aquatic fauna during the dry season. Riffles can also aerate flows which assists in the rivers water quality (DOE 2004). There should be sufficient water flowing in the river for this to occur. It is recommended that the riffle be suitably designed incorporating future predicted river flow as well as providing a suitable grade for vegetation establishment, access for maintenance, and public safety (DOE 2004).

It is recommended that any design be integrated with the Shire of Collie rehabilitation strategy. The cost of construction and maintenance of the riffle must be factored into the project consideration.

10.1.3 Living River

Another option can be to transform the river back to a ‘living’ river. Living river or ‘living’ stream concept has been used in converting stormwater drains to functioning stream ecosystems. One of the oldest and most successful of these projects is the Living Stream project undertaken on Bannister Creek in Lynwood by the Bannister Creek Catchment Group and the City of Canning (DOE 2004). Lynwood is a suburb located in the south east of Perth. The top section of Bannister Creek was a straight, high walled channel. In 2000 major works was undertaken on the creek to provide a more natural shape with meanders, riffles, fringing sedges, gentle sloping banks and thick vegetation on the banks (SERCUL 2018).

Within a few years great results were achieved creating a more natural landscape with healthier ecosystem, more controlled water flow, and a system able to remove nutrients and other pollutants from the water before it enters downstream wetlands and the Canning River. The entire stretch of Bannister Creek restored to date is 4 km and has taken 20 years.
These ‘living’ stream restoration or retrofitting works have mainly been carried out on stormwater drains. Retrofitting is the process of installing or undertaking additional or alternative stormwater management devices or approaches in an existing developed area (DOE 2004).

These restoration works have been based on the Western Australian Stormwater Management Objectives and developed by the Department of Environment in 2004.

Western Australian Stormwater Management Objectives (from Dow 2004):

**Water Quality:** To maintain or improve the surface and groundwater quality within the development areas relative to predevelopment conditions.

**Water Quantity:** To maintain the total water cycle balance within development areas relative to the predevelopment conditions.

**Water Conservation:** To maximise the reuse of stormwater.

**Ecosystem Health:** To retain natural drainage systems and protect ecosystem health.

**Economic Viability:** To implement stormwater management systems that are economically viable in the long term.

**Public Health:** To minimise the public risk, including risk of injury or loss of life, to the community.

**Protection of Property:** To protect the built environment from flooding and water logging.

**Social Values:** To ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.

**Development:** To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

Western Australian Stormwater Management Principles (from DOE 2004)

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub-catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management.
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.
- Recognise stormwater as a valuable resource and ensure its protection, conservation and reuse.
- Recognise the need for site specific solutions and implement appropriate non-structural and structural solutions.

The shape and size of the channel and extent of vegetative growth in the channel of natural waterways are in balance with the discharge characteristics. In the ‘living streams’ approach, constructed channels
are designed to mimic natural streams, with high flows accommodated along the vegetated streamline and its floodway.

The aim of typical drain revegetation projects is to maximise channel roughness at low flows, while managing roughness at higher flows. Infiltration, detention and treatment of the stormwater through contact with vegetation are maximised at base flow and during low intensity rainfall events. During high rainfall events, flood protection is maintained by conveyance in the floodway. Flow velocities can be reduced and flood storage maximised for high flows by providing a broad vegetated floodway.

An example of restoring a low flow river system is on the Vasse river where the City of Busselton is currently scoping a project based on the West Australian Stormwater Management Objectives and principles in converting a section of the Vasse River. This section of the river has low flow due to 90% of flow from the Vasse River being diverted to the Vasse Diversion Drain (Hart 2014).

The retrofitting the study site with reshaped banks and revegetating riparian areas including floodplain is an option. The costs associated with a system such as the study site, particularly with the civil/earth works, can be large and required to be considered for this option. There are other costs associated with site investigations, design, approvals, construction (including civil/earth works, infrastructure and vegetation) and project management. Consideration is required to be given to the cost of maintenance and appropriate monitoring when evaluating the project. It is recommended that life cycle costs be included in project budgets and plans (DOE 2004). As an example, the Banister Creek project had an estimated cost of $1.3 million to carry out restoration works on 2 KM length of the creek in 2011 (SERCUL 2014).

10.1.4 Preferred Water Level Management Option
The river gates such as Sluice gates are the preferred option to be installed at Venn Street. This option will give the Shire the ability to manage the water levels to desired outcome. The river gates will become more significant for maintaining water levels with the ceasing of mine dewatering and the predicted reduction of rainfall. The river gates will also help maintain pool levels in the summer.

Further community consultation is required to occur with stakeholders, including the public prior to the Shire making a final decision on the solution for the management of water level.

10.2 Restoration of Riparian Vegetation
Continue Nardoo control with Reglone Hydrogel annually within the first two weeks of autumn or as weather and conditions allow. Renew clearing permit from the DWER for Nardoo control.

Develop and implement the Shire rehabilitation strategy for the study area. Integrate the strategy into the Shire five year works programme. Ensure that the section of the river where removal of weeds and the replanting of the foreshore with native seedlings is maintained regularly to improve the success of the restoration work. This will involve Shire ensuring rehab weed control is followed by planting and 2-3 year establishment program. It is recommended that establishment program include watering, maintenance, weed control. Capital and maintenance budgeting and planning to allow for this cycle.

10.3 Drainage management
Undertake installation of biofiltration basins in accordance with the recommendation from CENRM 2016. Once these have been constructed carry out another review of nutrient and pollutant levels from drains and prioritise actions accordingly.
10.4 Access and erosion management
It is recommended that the Shire investigate access and erosion issues in the study areas such as ‘Sandy’ and Munglup Bridge. Consideration is required by the Shire to prioritise and manage these issues accordingly.

10.5 Community engagement and support
It is recommended that the Shire continue to support community groups such as Friends of Collie River, Collie Rotary Club, Collie High School, and Scouts for involvement in restoration work. Friends of Collie River in conjunction with the Shire coordinating training of volunteers in restoration.

Regularly inform the community of the progress of the implementation of the CRRS. This can be achieved by using various communication mediums such as social media, print media, radio interviews, The Shire website and on-site signage.

It is recommended that the Shire engage with the indigenous community on the progress of this strategy.

10.6 Community Education
It is recommended for the shire to carry out a community education campaign to reduce nutrient input into the river.

10.7 Nutrient Management
Consideration is required by the Shire to review the fertiliser program used in parks and gardens and reduce nutrient load into the river. It is recommended that the Shire also work with the Collie Golf Course and other large businesses to reduce their nutrient load.

10.8 Monitoring
River Flow and River Water Level
The Shire monitor water level in mAHD at the following locations:

a. Just below Lynn Street bridge  
b. Venn St Boards  
c. Minninup Pool  
d. Roberts Rocks

The water level and flow monitoring will provide information that will inform the Shire on the status of river flow and level and enable the shire to carry out suitable management actions.

Water Quality
It is recommended that the water quality monitoring be completed as the monitoring information will guide the Shire in implementing the appropriate management action. The monitoring results can be used to pinpoint any changes or trends that appear in the river over a period of time. This can include short and long term issues.
Recommended monitoring for the study area include: nitrogen, phosphorus, salinity, and Reglone spray at Lynn Street Bridge and Roberts Rocks river boards.

The monitoring can be done by existing Shire staff after undergoing training or external resources. Develop a water quality monitoring program. This will be an operational program designed to provide direction to staff or contractors carrying out water sampling.

Portable in-situ salinity meter can be used to measure salinity. It is recommended that to test levels of nitrogen and phosphate, collected water samples be sent to a chemical analysis laboratory.

Consideration is required to monitor the potential impact of Reglone assessing any impact to:

- Invertebrates
- Fish
- Water fowl and birds
- Other non-targeted vegetation
- Water Quality, including oxygen levels, sedimentation and turbidity
- Aquatic mammals

Table 6: Recommended monitoring regime

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Methodology</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>River Flow and River Water Level</td>
<td>Gauging Station installed currently by DWER</td>
<td>Monthly</td>
</tr>
<tr>
<td>Water Quality</td>
<td>Grab sample</td>
<td>Quarter</td>
</tr>
<tr>
<td>Nitrogen, Phosphorus, and salinity</td>
<td>Send to chemical analysis laboratory (P&amp;N)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Portable in situ salinity meter</td>
<td></td>
</tr>
<tr>
<td>Potential impact of Reglone</td>
<td>Monitor detrimental impact on:</td>
<td>To be assessed</td>
</tr>
<tr>
<td></td>
<td>- Invertebrates</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Fish</td>
<td></td>
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<td></td>
<td>- Water fowl and birds</td>
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<tr>
<td></td>
<td>- Other vegetation</td>
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<td></td>
<td>- Water quality</td>
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<td></td>
<td>- Oxygen levels</td>
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<td></td>
<td>- Sediment and turbidity</td>
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<tr>
<td></td>
<td>before and after treatment with Reglone.</td>
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<tr>
<td></td>
<td>The Shire should continue to carry this out in partnership with SWCC, DWER, or academic institutions currently carrying out impacts of herbicide monitoring.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Before and after treatment</td>
<td></td>
</tr>
</tbody>
</table>

10.9 Advocate for the health of Collie River

Although the 12 km stretch of the river running through the town was investigated in this strategy, what occurs upstream of the river impacts the health of the study area. Similarly, activities that occur within the study area will impact down stream areas. Therefore, it is recommended that the Shire work with the managers of the upstream section of the study area (Shires of Williams and West Arthur), and
downstream section of the river (Shire of Dardanup) to improve the overall health of the study area. Consideration is required by the Shire also to maintain collaboration with the DWER, Leschenault Catchment, and South West Catchment Council on river management issues.

It is recommended that the Shire also advocate in relation to future projects:

- Sufficient public consultation occurs.
- The opportunity for Collie employment through future projects
- The impact of the future projects on the Collie River both environmentally and socially from a community perspective.

Consideration is required by the Shire to work with other Local Government Agencies, Industry, Government Agencies, and Community groups on river management issues.

It is recommended that the Shire also advocate ensuring that the values of the river are protected in any future developments.
11 Recreational and Tourism Opportunities

The Collie River, and more particularly the study area, has great potential for passive recreation for Collie residents and visitors to the town.

The Western Australian Strategic Trails Blueprint 2017–2021 (the Blueprint) is an overarching guide for consistent and coordinated planning, development and management of quality trails and trail experiences across Western Australia. It provides a vision, guiding principles, strategic directions and actions for consideration across the State for government, trail managers, landholders, trail support groups, tourism operators and the community.

Given the level of existing infrastructure within town, Collie has potential to develop other adventure tourism activities such as bush walking trails and formalisation and development of camping areas along the river. River pools created by the existing and future rivers weirs could be developed with access areas to cater for day use canoeing activity.

11.1 Paddle Trail
The Shire of Collie is currently planning a paddle trail that will pass through the Town and connect with the recreation sites detailed for development elsewhere within this report.

11.2 Cycle Trail
West Cycle is the Governing body responsible for the development of cycling and the distribution of Federal and State Government funding for the sports development. West Cycle recently released the Southwest West Mountain Bike Master Plan, which identifies Collie as one of three potential high priority regions to develop a national standard trail network that interconnects with local businesses such as breweries, restaurants and accommodation. It is recommended that opportunities are explored and developed further for funding opportunities.

The Shire of Collie is in the process of applying for a Building Better Regions Fund (BBRF) Grant from the Federal Government, for a dual use (walking and cycling), 2.5-metre-wide sealed pathway along the river. The Collie River Trail will start in the CBD area at Soldiers Park and take a route along the river to Minninup Pool. A return loop will also be created from Soldier’s Park along the Trail, to the East End Bridge and along the other side of the bank and back to Soldier’s Park, via the Coombes Street Bridge. The new pathway will link the Bibbulmun Track (bushwalking trail) at the Visitors Centre, through Collie CBD on Forrest Street to Soldier’s Park and then on the proposed River Trail along the river, to Minninup Pool. The connection to the existing Bibbulmun Track will be at Mungalup Bridge.

The Munda Biddi Track (mountain biking) will connect from the Visitors Centre, through Collie CBD, on Forrest Street to Soldier’s Park and then on the proposed River Trail along the river to Minninup Pool. From Minninup Pool a connection with the Munda Biddi Track will be made along Scenic Drive.

The development of the Collie River Trail will enhance tourism and encourage the economic development of the accommodation and hospitality industries, as well as the other attractions within the town. The Collie River trail will provide direct trail connections with the existing long-distance walking and mountain bike trails and will provide the community of Collie with a number of benefits. Users of the Bibbulmun Track
and Munda Biddi trail, will be more likely to divert to Collie, which will benefit local business. The Collie Community will be provided with a new recreation opportunity that displays the Collie river environment and strengthens the connection between the town Minninup pool area. The path will connect the proposed Minninup Camp Ground (see South West Development Commission) to Collie CBD.

The precedent for mountain bike tourism already exists in Margaret River and Pemberton. These towns have recently constructed much longer mountain trail networks that are now contributing to increased levels of tourism and overnight stays. In addition, the trails are of a standard that both towns attract regular large mountain bike competition and community events. Collie is well placed to take advantage of similar tourism benefits given its location to the population centres of Bunbury and Perth as recommended in the South West mountain bike Masterplan. The semi degraded or altered state of some bushland surrounding the river within the study area is ideal for further development for mountain bike trails.

11.3 Fishing

The Collie River is a valuable fresh water fishing location within the region. The implementation of the Collie River Revitalisation Strategy will improve the health of the river and can lead to an increase in fish stock. Fishing in the Collie River is mainly for Black Bream, the odd Mulloway and further upstream for Trout and Redfin Perch. The Collie River is also stocked with Trout and around 45,000 triploid rainbow trout that were released into the Collie River below Wellington Dam early 2014. Redfin Perch also dominate in the fresh water parts of both the Collie River and Brunswick River. They can fish all year around however, during the warmer months they tend to be more active, taking almost anything that lands in the water.
12 Conclusion

Channel morphology and flows have been altered significantly due to river training. A deep channel now flows which would have flooded the flats at one time (WRM 2009). Mine dewatering discharge into the river and groundwater abstraction has altered water levels and flows. Returning the river system to pre-European state or even to pre-dredging condition is an unrealistic aim given the competing needs of ecology, community, and industry.

However, with strategic focus, effort, resources, and time the river study area can be greatly enhanced by increasing public amenity, water quality, ecological diversity, and recreational opportunities.
References


DWER 2017. Email from Department of Water and Environmental Regulation (South West Office) to Shire of Collie. 28 August 2017.


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14 Appendices
Appendix 1 Community Consultation
## Appendix 2 Riparian Revegetation Suggestion

From SOC 2010b

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Wetland zone</th>
<th>Depth below summer water level (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sparse Twig Rush</td>
<td>Baumea arthropylla</td>
<td>Damp zone to 1m into emergent zone</td>
<td>1.0</td>
</tr>
<tr>
<td>Jointed Twig Rush</td>
<td>Baumea articulata</td>
<td>Damp zone to 1m into emergent zone - can tolerate low water levels.</td>
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</tr>
<tr>
<td>Native Bullrush</td>
<td>Typha domingensis</td>
<td>Damp zone to inundation of 1m</td>
<td>1.0</td>
</tr>
<tr>
<td>Sharp leaf Club Rush(1)</td>
<td>Schoenoplectus pungens</td>
<td>Damp zone to 40cm into emergent zone</td>
<td>0.4</td>
</tr>
<tr>
<td>Sheath Twig Rush</td>
<td>Baumea vaginalis</td>
<td>Damp zone to 40cm into emergent zone</td>
<td>0.4</td>
</tr>
<tr>
<td>Spike Rush</td>
<td>Eleocharis acuta</td>
<td>Damp zone to 30cm into emergent zone</td>
<td>0.3</td>
</tr>
<tr>
<td>Shore Rush</td>
<td>Juncus kraussii</td>
<td>Damp zone to 30cm into emergent zone</td>
<td>0.3</td>
</tr>
<tr>
<td>Broad Twig Rush</td>
<td>Baumea preissii</td>
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<td>0.3</td>
</tr>
<tr>
<td>Bare Twig Rush</td>
<td>Baumea juncea</td>
<td>Ephemeral zone to 30cm into emergent zone</td>
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</tr>
<tr>
<td>Tassell Sedge</td>
<td>Carex fasicularis</td>
<td>Ephemeral zone to 20cm into emergent zone</td>
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</tr>
<tr>
<td>River Twig Rush</td>
<td>Baumea rubiginosa</td>
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</tr>
<tr>
<td>Marsh Club Rush</td>
<td>Bolboschoenus caldwellii</td>
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</tr>
<tr>
<td>Pithy Sword Sedge</td>
<td>Lepidosperma longitundinale</td>
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</tr>
<tr>
<td>Tall Sedge</td>
<td>Carex appressa</td>
<td>Damp zone to 10cm into submergent zone</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Appendix 3 Further Information on Collie Water Project

Further information on the Collie Water Project can be found on [http://www.aquaferre.com/News/collie-water-solution-selected-for-wellington-dam-salinity-project](http://www.aquaferre.com/News/collie-water-solution-selected-for-wellington-dam-salinity-project) or contact Harvey Water on (08) 9729 0100 and admin@harveywater.com.au.