APPENDIX C

Lake Macdonald Water Lowering – Adaptive Management Plan

Table of Contents

Appendices

List of Tables

List of Figures

C.1 Introduction

C.1.1 Background

Six Mile Creek Dam, commonly referred to as Lake Macdonald, is located on the Sunshine Coast. It is one of two principal raw water sources that supply potable drinking water to the residents of Noosa Shire. The dam requires an upgrade to meet modern safety standards and the performance requirements of the Queensland dam safety regulations into the future (the Project).

The upgrade of Six Mile Creek Dam will allow the dam to better manage severe weather and earthquake events; it includes improving the spillway discharge capacity and earthquake stability while maintaining water supply security. The Project will not change the scale of the existing water impoundment, with the dam's Full Supply Level (FSL) and inundation area remaining the same post-upgrade and the proposed dam infrastructure largely occupying the existing footprint.

The Project comprises the removal of the existing spillway and embankments and the construction of a new spillway and embankments on weathered rock. This will require the lowering of water stored in Lake Macdonald to facilitate demolition and construction. The water level will initially be lowered to RL 89 m AHD for up to two months while a temporary coffer dam is constructed; it will then be maintained at RL 89.5 m AHD for the duration of construction, subject to inflows and weather which will be approximately 16-24 months. Lake Macdonald will not be relied upon for water supply during the construction period.

C.1.2 Site Description

Lake Macdonald is located on Six Mile Creek, approximately 10 km from the centre of Cooroy in the Noosa hinterland. The dam was constructed in the early 1960s and raised in 1979. When full it holds 8018 ML of water, with a surface area of 260 ha and a total catchment area of 49 km^2. Lake Macdonald and its location are shown in Figure C.1-1.

Although Lake Macdonald is primarily a water storage with no flood mitigation objectives, the dam provides some flood attenuation. The Mary Basin Resource Operations Plan (ROP) includes operating rules to minimise changes to the low flow regime of Six Mile Creek downstream of the dam, and to minimise changes to the hydraulic habitat requirements of aquatic fauna. The lake is also used as a recreation facility by the community, supporting rowing, paddling, fishing, and foreshore recreation, including the Noosa Botanical Gardens.

A number of protected species are known to occur or potentially occur in and around Six Mile Creek and Lake Macdonald. In particular, five species that are listed as Matters of National Environmental Significance (MNES) may occur in Lake Macdonald and Six Mile Creek: Mary River cod (*Maccullochella mariensis*), Australian lungfish (*Neoceratodus forsteri*), Mary River turtle (*Elusor macrurus*), white-throated snapping turtle (*Elseya albagula*), and giant barred frog (*Mixophyes iterates*). These species are also Matters of State Environmental Significance (MSES), with two additional MSES also known to occur in Six Mile Creek: platypus (*Ornithorhynchus anatinus*) and tusked frog (*Adelotus brevis)*.

C.1.3 Purpose and Objectives

Reducing the depth of water in a waterbody typically involves pumping the water out and transferring it to a nearby location, usually downstream. This can have an impact on the aquatic ecosystem of the waterbody and receiving environment through, for example, changes to water quality and/or hydrology, the loss of aquatic habitat, and the direct disturbance of aquatic fauna. The potential impacts associated with lowering water can be avoided or minimised through the implementation of appropriate and adaptive management measures before, during, and after the water is lowered.

This plan has been developed to manage potential impacts on aquatic ecosystems in Lake Macdonald and Six Mile Creek as a result of lowering the water level in Lake Macdonald for the duration of the Project. Incidental impacts, such as impacts to recreational activities, are addressed in the Project's Impact Assessment Report (IAR). The primary objective of the plan is to prevent serious environmental harm due to the lowering. The plan is intended to be adaptive and will evolve over the course of the Project in response to changing conditions and expert advice. It describes:

- The process for lowering Lake Macdonald before construction
- The process to maintain the water level during construction
- Potential impacts associated with lowering Lake Macdonald

- Management measures that will be implemented to reduce potential impacts
- Incident and contingency planning associated with managing the impacts of lowering Lake Macdonald.

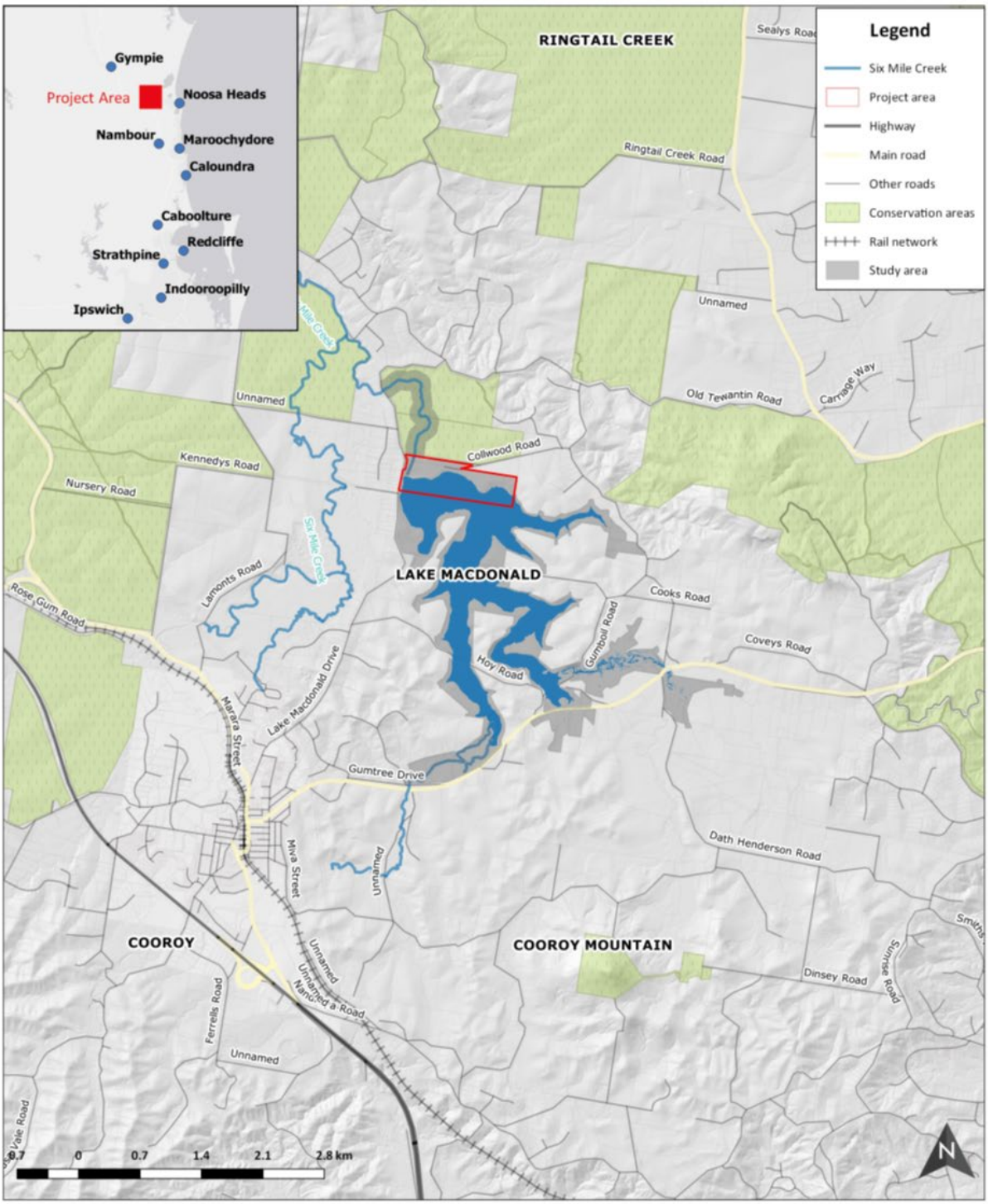

Figure C.1-1: Lake Macdonald location and Project area

C.2 Lowering Lake Macdonald

C.2.1 Water Quantity

Full Supply Level (FSL) in Lake Macdonald is at an elevation of RL 95.3 m AHD. Water in Lake Macdonald will be lowered to RL 89 m AHD for up to two months during construction of a temporary coffer dam and demolition of the existing spillway. The coffer dam will then maintain the maximum water level at RL 89.5 m AHD for 16-24 months during construction of the new spillway and embankments. This equates to retaining up to 226 ML (2.8% of capacity) of water in Lake Macdonald for 1-2 months, followed by up to 412 ML (5.0% of capacity) of water for the remaining construction period. The water level during construction will be subject to inflows and weather, and so natural fluctuation in water level during construction is expected.

Assuming Lake Macdonald is full at the time water lowering begins, a minimum of 7,792 ML of water, will need to be removed from the lake before the temporary coffer dam can be installed.

C.2.2 Drawdown Method

The lowering of Lake Macdonald will be undertaken over approximately three months for the purpose of environmental management. The water level will be lowered in increments, as shown in Table C.2-1 and Figure C.2-1, to facilitate management of potential impacts to aquatic fauna and limit the rate of exposure of previously inundated lake bed.

The drawdown of the lake could theoretically occur in a period as short as 8-10 days, assuming a maximum lowering capacity of 10 m^3/s (864 ML/day) and no inflows, however the impacts on environmental conditions in the lake may be unacceptable. The key issues with rapid drawdown are the concentration of aquatic fauna into reduced habitat with potentially reduced water quality, stranding of fauna in isolated pools, and the rate of exposure of the lake bed (erosion/water quality). For this reason, the guiding principle of this lowering plan is to limit the rate of lowering relative to lake level at each week.

Mechanical equipment, such as submersible pumps or siphons, will be installed at Lake Macdonald specifically for the drawdown and some equipment will remain throughout the Project to maintain lake levels. For the drawdown phase, the equipment drawdown capacity will be up to 10 m^3/s, though release rates will be managed per the limits indicated in Table C.2-1. This maximum drawdown capacity was selected based on the bankfull capacity of Six Mile Creek, such that releases will not exceed the banks of the creek.

The intake pipework for dewatering equipment will likely be located on the spillway and/or the right (eastern) embankment. The duration and rate of the lake lowering will be balanced by using variable release rates through the drawdown period (as shown in Table C.2-1 and Figure C.2-1).

The Project will require an adaptive approach to drawdown methodology, because inflows are unpredictable. The limitations put on lake level changes may need to be reviewed following inflows that exceed release capacity, so as to continue the lowering plan outcomes, though this would depend on circumstances at the time of the event.

The construction phase arrangement for the lowered lake is described in Section C.2.4.

Table C.2-1: Proposed Lake Macdonald dewatering plan.

WEEK	LAKE LEVEL (M AHD)		TARGET DECREASE IN LAKE LEVEL	REMAINING LAKE CAPACITY (% FSV)	DECREASE IN STORED VOLUME (ML)	MINIMUM DRAWDOWN EQUIPMENT CAPACITY (ML/D) TO ACHIEVE LOWERING TARGET FOR DIFFERENT INFLOW RATES[1]			
	Start of Week	**End of Week**	**Change Over the Week**			**No Inflow**	**10 ML/d Inflow**	**20 ML/d Inflow**	**50 ML/d Inflow**
1	95.3	94.7	0.60	81.9	1454	207.7	217.7	227.7	257.7
2	94.7	94.0	0.70	63.2	1500	214.3	224.3	234.3	264.3
3	94.0	93.3	0.70	48.5	1174	167.7	177.7	187.7	217.7
4	93.3	92.6	0.60	35.9	1009	144.1	154.1	164.1	194.1
5	92.6	92.2	0.40	29.6	506	72.3	82.3	92.3	122.3
6	92.2	91.8	0.40	24.2	436	62.3	72.3	82.3	112.3
7	91.8	91.45	0.35	20.2	319	45.6	55.6	65.6	95.6
8	91.45	90.9	0.55	14.3	426	60.9	70.9	80.9	110.9
9	90.9	90.4	0.50	10.5	306	43.7	53.7	63.7	93.7
10	90.4	89.9	0.50	6.7	283	40.4	50.4	60.4	90.4
11	89.9	89.2	0.70	3.7	260	37.1	47.1	57.1	87.1
12	89.2	89.0	0.20	2.8	74	10.6	20.6	30.6	60.6

[1] A 7-day week was assumed for calculations

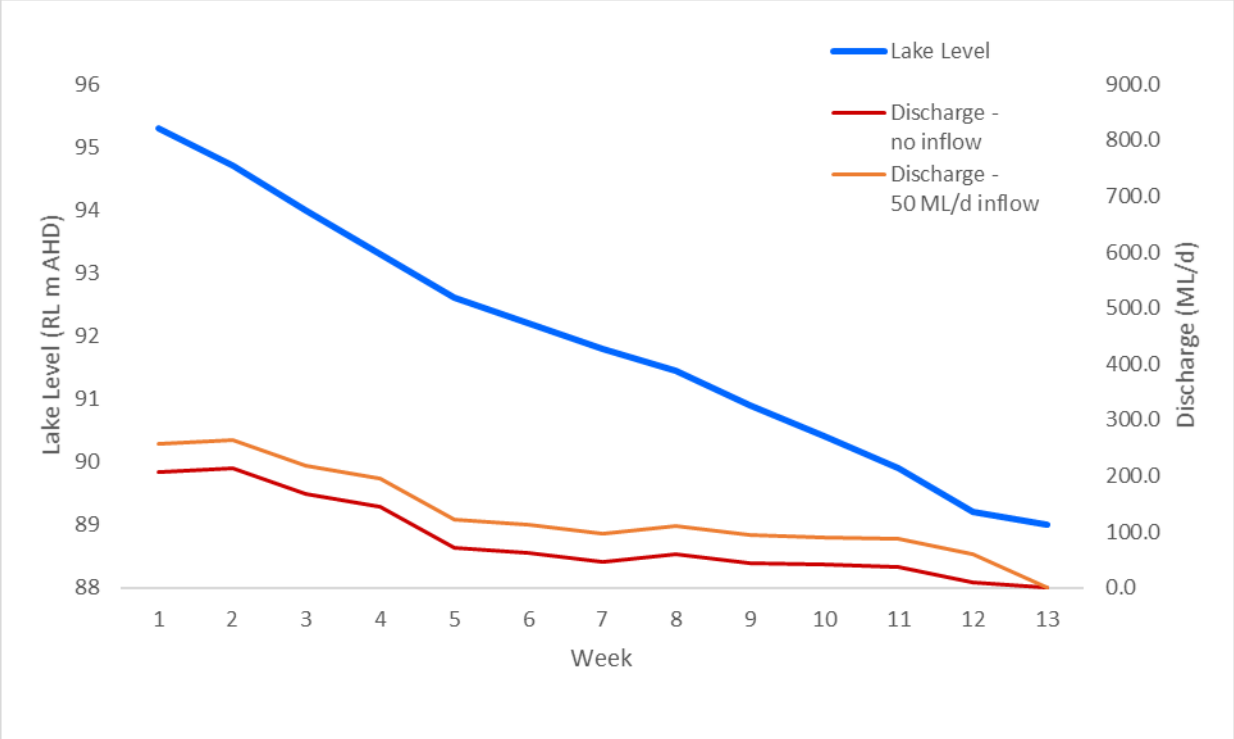

Figure C.2-1: Proposed timeline for Lake Macdonald lowering.

C.2.3 Discharge Location

Water releases from Lake Macdonald will be undertaken using mechanical equipment such as pumps and/or siphons. The release points for drawdown flows will be installed at an appropriate discharge location with appropriate energy dissipation to minimise bed and bank erosion. For example, this may be achieved by discharging onto the concrete apron of the existing spillway. The water quality of the source water shall also require consideration, for both what remains in the upstream environment and what is released. For example, aeration of the discharged water will be important. Discharged water will then flow downstream through Six Mile Creek.

The maximum discharge capacity of 10 m^3/s (864 ML/ day) is not likely to be utilised, but if inflows do occur during the drawdown and require increased flow rate, the maximum discharge capacity will not exceed the current bank full capacity of Six Mile Creek flow channel downstream of the existing dam.

C.2.4 Maintenance of Water Level Following Drawdown

Water will pass through the construction site via a low flow section in the coffer dam (the location of which will vary during construction). The low flow section will effectively be the coffer dam crest level that forms the maximum water level at RL 90.5 m AHD. However, high flow and flood events are likely to occur during the construction period.

In the event that high inflows cause the lake water level to exceed the RL 90.5 m AHD, flows will travel over the temporary coffer dam crest and flow downstream in a similar fashion to the existing dam.

Following high flow events, as well as for small inflow events or ongoing catchment inflows, it is expected that the lake water level may continue to spill for long periods of time. Allowing long-term low/trickle flows over the coffer dam crest and through the spillway construction area is not ideal from the perspective of construction efficiency, safety, and preventing contamination of water flowing downstream. As such, the construction contractor will have the ability to use mechanical drawdown infrastructure, as described in Section C.2.2, to manage lake water level and bypass low flows around the spillway construction part of the work site. The following constraints will be implemented for contractor lake water management:

- The Contractor shall have the option of managing lake water level through bypass releases within a defined water level relative to the coffer dam low flow crest
  - When the Contractor uses a bypass arrangement to manage the reservoir water level, such as to match inflows or for day to day management, the lake water level is to be maintained within 0.2 m of the coffer dam low flow crest level
  - In other circumstances, such as preparation for wet weather, the Contractor may drawdown the lake water level no greater than 0.5 m below the coffer dam low-flow crest level.

There may also be cause for drawdown events during construction, other than described above, for the purposes of further aquatic fauna salvage or other management measures. This could be triggered, for example by a high flow event that increases fauna population in the lowered lake. This possibility will be addressed on a case by case basis.

In addition to the discussion above, the lake water level during construction may be subject dry weather that naturally reduces water level.

C.3 Water Quality

C.3.1 Water Quality in Lake Macdonald

Six Mile Creek, including Lake Macdonald, has defined waterway Environmental Values (EVs) and Water Quality Objectives (WQOs) under the *Environmental Protection (Water) Policy 2009* (EPP(Water)) (DERM 2010). The WQOs for parameters listed in the EPP (Water) for the protection of the aquatic ecosystem EV in Six Mile Creek are provided in Appendix A. Also provided in Appendix A are median water quality results for Lake Macdonald (at the dam wall, mid-lake and in the tailwater) and Six Mile Creek downstream of the dam.

A review of the water quality results shows that WQOs are typically achieved in Lake Macdonald and Six Mile Creek downstream, but not in the dam tailwater. WQOs for total and oxidised nitrogen are generally not met in the lake or tailwater; the WQO for chlorophyll-a is also not achieved in the lake (no downstream data available). The tailwater typically fails to achieve WQOs for pH, dissolved oxygen, total suspended solids, and ammonia.

Long-term water quality monitoring data supplied by Seqwater also indicates that:

- Dissolved aluminium in Lake Macdonald was often higher than the National Water Quality Guideline (ANZECC & ARMCANZ 2000) for the 95% protection level of aquatic ecosystems
- Total aluminium, zinc and cobalt in Lake Macdonald were sometimes higher than the National Water Quality Guideline
- Total aluminium, chromium, copper, mercury and zinc, and dissolved aluminium in the Lake Macdonald tailwater were higher than the National Water Quality Guideline.

The *Water Monitoring Data Collection Standards* (DNR 2007) defines a reservoir as stratified if the temperature difference between surface and basement layers exceeds 5ºC. A review of monthly depth profile measurements in Lake Macdonald (mid-lake) from November 2011 to November 2017 indicated that Lake Macdonald rarely stratifies, and when it does it is only weakly stratified. Further information on stratification is provided in Appendix C.A.

C.3.2 Potential Impacts of Lowering Lake Macdonald

Drawdown of waterbodies can have adverse impacts on water quality both at, and downstream of, the discharge site(s) and in the source waterbody, including:

- Increasing turbidity and total suspended solids via disturbance of bed sediments and / or the erosion of bed and banks
- Reducing pH by exposing or disturbing acid sulphate soils[1] and / or decomposing organic material (e.g. aquatic plants)
- Reducing dissolved oxygen, through eutrophication or if the source waterbody is stratified
- Increasing nutrient concentrations in receiving waters if the source water has high nutrient concentrations (or is allowed to eutrophy)
- Contaminating water if there are spills of fuels, oils or other chemicals from pumping equipment or other machinery / vehicles.

Increased turbidity (and total suspended solids) may negatively impact aquatic fauna as highly turbid water reduces respiratory and feeding efficiency. Increased turbidity may also adversely affect submerged aquatic plants as light penetration (required for photosynthesis) is reduced. Reduced light penetration can also lead to a reduction in temperature throughout the water column. Small and brief increases in turbidity, consistent with increases in turbidity that occur during natural flow events, would be unlikely to have a significant impact on aquatic fauna (Dunlop et al., 2005). However, significant increases in turbidity, especially turbidity caused by fine silt and clay particles, could adversely impact the health, feeding and breeding ecology of aquatic fauna species (Dunlop et al., 2005).

Reduced pH can negatively impact fish health by causing diseases (e.g. lesions and ulcers) and impacting metabolism and reproduction in fish, with very low pH potentially causing fish kills. Changes in pH also influence the solubility of metals in water, such as aluminium, and can have detrimental impacts on fauna including fish kills. While some

[1] Testing indicates that although there is some acidity in the soils at lake Macdonald, this is non-sulfuric (i.e. acid sulfate soils are unlikely to be present).

variation in pH is tolerated by aquatic fauna of Six Mile Creek, significant reductions in pH may have adverse effects on aquatic ecosystem health.

Dissolved oxygen is essential for respiration and metabolism by aquatic fauna. Reduced dissolved oxygen can cause stress to fish, and very low dissolved oxygen can cause mass mortality ('fish kills'). Some waterways of the region can have naturally low dissolved oxygen, especially during low flow periods, and thus much of the aquatic fauna of the region can tolerate periods of low dissolved oxygen (i.e. approximately 50% saturation or 4 mg/l at 27°C water temperature), but sustained periods of low dissolved oxygen will cause mortality in aquatic fauna.

High nutrient concentrations can increase the growth of phytoplankton, which in turn can deplete dissolved oxygen concentrations. Benthic algae, including filamentous algae, and aquatic plant growth may increase under high nutrient conditions, especially under high sunlight conditions. Excessive algae and aquatic plant growth can reduce in-stream habitat quality for some aquatic fauna.

Fuels, oils and other chemicals (e.g. lubricants and solvents) that may be required for the operation of pumps and other machinery for lake drawdown are toxic to aquatic flora and fauna at relatively low concentrations. Spilt fuel is most likely to enter watercourses via an accidental spill when activities are adjacent to waterbodies. A significant fuel spill to waterways (in the order of tens or hundreds of litres) is likely to have a locally significant impact on both flora and fauna, with the size of spill and the volume of water in the creeks being the most significant factors influencing the length of stream impacted.

C.3.3 Management Measures

Potential impacts to water quality can be mitigated by implementing the measures outlined in Table C.3-1. Where appropriate, the proposed management measures will be adapted over the course of the Project in response to changing conditions and expert advice.

Table C.3-1: Management of water quality during the lowering of Lake Macdonald

ENVIRONMENTAL OBJECTIVE: Minimise impact of lowering on water quality in Lake Macdonald and Six Mile Creek.	
Performance criteria	• Maintain water quality within the current range of variability in Lake Macdonald and Six Mile Creek, with suggested trigger values[2]: Lake Macdonald • turbidity (field): low <11.1 NTU, high <114 NTU • dissolved oxygen (field): low >4.1 mg/L, high >2.2 mg/L • pH (field): low 6.5 – 7.3; high 5.1 – 9.3 • suspended solids (lab): low <8.0 mg/L, high <65.0 mg/L • total nitrogen (lab): low <0.88 mg/L; high <4.5 mg/L • nitrate (lab): low <0.005mg/L; high 0.196 mg/L • NOx (lab): low <0.06 mg/L; high <0.986 mg/L • ammonia (lab): low <0.05 mg/L; high <0.487 mg/L • total phosphorus (lab): low <0.05 mg/L; high <0.89 mg/L Six Mile Creek • turbidity (field): low <11.0 NTU; high < 16 NTU • dissolved oxygen (field): low >3.0 mg/L; high >2.0 mg/L • pH (field): low 6.2 – 7.2; high 5.6 – 7.4
Mitigation measures	• Aeration of water in Lake Macdonald for entire Project period (e.g. using existing bubble plume destratification unit).

[2] 'low trigger' based on either > 20th or < 80th percentile (depending on the parameter) of monitoring data in Lake Macdonald, or in Six Mile Creek downstream of Lake Macdonald. The 'high trigger' is based on either the maximum or minimum recorded values (depending on the parameter).

ENVIRONMENTAL OBJECTIVE: Minimise impact of lowering on water quality in Lake Macdonald and Six Mile Creek.	
	• Arrange intakes of mechanical dewatering equipment such that suction does not disturb sediments on the bed of Lake Macdonald. • Arrange intakes of mechanical dewatering equipment to take from several lake water levels to discharge a blended water quality. • Aeration of water as it is discharged downstream (may be natural aeration in the energy dissipation). • Preferably use food grade oils/lubricants where pumps are used. • Real-time monitoring of key water quality parameters. • Ensuring that: fuels, oils and other chemicals are stored in bunded areas in accordance with Australian Standard 1940 (2004) – *The storage and handling of flammable and combustible liquids.* • Appropriate controls for refuelling or chemical use away from waterways or drainage lines. • Where possible, restrict stock access to the lake, for example by installing fencing.
Monitoring	• Daily monitoring of temperature, pH, dissolved oxygen and turbidity and visual observations for oil slicks, at four sites in the lake (50 m, 150 m, 250 m and 500 m from the coffer dam) and two sites downstream of the discharge location (50 m and 500 m). Water quality monitoring to be undertaken with a calibrated hand-held water quality meter, or an appropriately installed and calibrated water quality monitoring station. • Fortnightly monitoring of suspended solids, nitrate, ammonia and total phosphorus (laboratory analysed) at four sites in the lake (50 m, 150 m, 250 m and 500 m from the coffer dam) and two sites downstream of the discharge location (50 m and 500 m). • Monitoring to be in implemented by suitably qualified persons in accordance with the Monitoring and Sampling Manual (DES 2018).
Reporting	• Weekly reporting to Seqwater Project Manager where no exceedances are recorded. • Daily reporting if exceedances are recorded.
Responsibility	Contractor, ensure monitoring is implemented by suitably qualified persons.
Corrective actions	• Low trigger exceeded: – Notify Seqwater Project Manager • High trigger exceeded: – Notify Seqwater Project Manager – Review implications for aquatic fauna and implement incidental fauna salvage as required – Review mitigations, including reducing rate of release, increasing aeration

C.4 Erosion and Sediment Control

C.4.1 Sediment in Lake Macdonald

Surface geology mapping indicates that Lake Macdonald is within a drainage channel composed of Quaternary Alluvium overlying Upper Triassic-Jurassic aged Myrtle Creek Sandstone. Triassic Kin Kin Beds outcrop to the east of Lake Macdonald and host a Tertiary aged rhyolite intrusion, and the Jurassic aged Tiaro Coal Measures outcrop further east.

Borelogs show that Lake Macdonald is positioned on top of clay that reaches a depth between 3 m and 21 m below ground level. The alluvium is thought to be largely comprised of fine grained overbank sediments, rather than coarser channel deposited materials. Field surveys conducted by frc environmental noted that the substrate in Lake Macdonald was dominated by silt with some sand near the banks. Silt and sand are highly mobile sediments.

Sediment quality has not been assessed in detail for the Project, as geology and soils are not expected to be affected. However, the potential for acid sulphate soils was assessed and determined to be unlikely (refer to section 15 of the IAR).

C.4.2 Potential Impacts of Lowering Lake Macdonald

The drawdown process for Lake Macdonald could potentially lead to erosion and sedimentation in the lake area and downstream of the dam, particularly in areas with mobile sediments such as silt and sand. Erosion and sedimentation may also occur after the drawdown, during the 18-24-month period that the lake is lowered.

Erosion of the bed and banks of Lake Macdonald and Six Mile Creek downstream of the dam may be caused by:

- The water being drawn out of the lake, particularly if a fast drawdown rate is used (such as may be required in the final two weeks before construction begins)
- The release of water downstream of the dam, if it is not discharged with suitable scour protection or is high velocity
- Wind and / or rainfall events, and associated surface runoff, while the lake is lowered.

Erosion within the dam inundation area is more likely to be a concern in the upper reaches, where the channel is narrower and flow is constricted, than at the centre of the lake or near the dam wall, where the gradient of the bed and banks is lower.

Where erosion occurs, the mobilised sediment could potentially be carried downstream and deposited over the substrate and aquatic plants in Six Mile Creek. This has potential implications for water quality and habitat condition, and could subsequently affect aquatic fauna.

Lake Macdonald contains extensive beds of Cabomba (*Cabomba carolina*), along with other aquatic plants. The presence of these aquatic plants will minimise the potential for erosion in the areas where they occur as their roots help bind the sediment and, when the water level is lower, the dying plants will cover sediment that would otherwise be exposed.

C.4.3 Management Measures

Potential impacts associated with erosion can be mitigated by implementing the measures outlined in Table C.4-1. Where appropriate, the proposed management measures will be adapted over the course of the Project in response to changing conditions and expert advice.

Table C.4-1: Management of erosion and sediment during the lowering of Lake Macdonald

ENVIRONMENTAL OBJECTIVE: Minimise environmental impact by preventing soil loss and erosion.	
Performance criteria	• The risk of soil erosion impacts from drawdown discharge into Six Mile Creek is managed and mitigated. • The risk of sediment erosion within Lake Macdonald after drawdown is managed and mitigated.
Mitigation measures	• Placement of intake pipes for drawdown equipment above the bed of Lake Macdonald, to minimise disturbance of bed sediments and organic matter. • Drawdown releases discharged in a manner that prevents erosion at discharge sites. Example controls: discharge onto the concrete apron on the downstream side of the Lake Macdonald spillway, use diffusers or spray nozzles at the downstream end of drawdown pipes, and / or energy dissipation methods such as riprap to slow water flow. • Where possible, allow Cabomba and other exposed aquatic plants to decompose in situ. • Seed areas likely to be susceptible to erosion as they are exposed (i.e. during the drawdown process) to minimise the duration of exposure of bare bed/banks. Seeding should take into account the season and conditions. A sterile, fast growing groundcover is recommended as an initial groundcover to allow germination of the natural seedbank. • Consider use of physical barriers (e.g. staggered baffles) at key upstream locations to slow flow and reduce erosion in the upper reaches of the lake. This measure will be assessed during and following drawdown in conjunction with the potential for these works causing erosion through disturbance of exposed lake bed and banks. • Where appropriate, use of erosion control sprays to stabilise exposed sediment. Any erosion control sprays must be suitable for use in aquatic ecosystems, as well drinking water sources (noting that Lake Macdonald will not be used to supply water during construction, but any risks relating to return to service must be assessed). • During the drawdown period, compliance with the construction erosion and sediment control plan.
Monitoring	• Weekly inspection of sediment and erosion control structures and measures. In wet weather more frequent monitoring may be necessary. • Monitoring of turbidity in Lake Macdonald (refer to water quality monitoring – section C.3).
Reporting	• Weekly report to Seqwater Project Manager that includes details of monitoring, audits, non-compliances, complaints, and incidents. • Report any erosion issues to the Supervisor immediately. • Report incidents, complaints, and any significant environmental harm to regulatory body(ies) where required.
Responsibility	Seqwater and contractors – in relation to the Lake Macdonald water lowering
Corrective actions	• Appropriate/additional control measures implemented where unacceptable sediment or erosion is occurring or at risk of occurring. • Amend erosion and sediment control management measures as required to account for changes in site conditions or treatment methods in the case of failure. • Necessary corrective action implemented following incident or complaint.

C.5 Aquatic Flora and Fauna

C.5.1 Flora and Fauna in Lake Macdonald and Six Mile Creek

The aquatic flora and fauna in Lake Macdonald and Six Mile Creek are described in detail in Appendix C.B. Detailed descriptions of aquatic species listed as MNES and MSES, and their ecology, are also provided in Appendix C.B. A brief summary of aquatic flora and fauna in Lake Macdonald is provided below.

As accurate population estimates of aquatic fauna are only achievable via a long-term survey operations of three to four years, current population sizes in Lake Macdonald have been estimated from fish stocking numbers and advice from industry professionals. It has been assumed that some species of fauna are present in high numbers. Consequently, management measures for aquatic fauna have been developed based on this assumption.

Aquatic Plants

Lake Macdonald contains a dense cover of Cabomba, which is a restricted invasive plant, scattered native water snowflake (*Nymphoides indica*), and isolated occurrences of other native aquatic plants. *Hygrophila* (*Hygrophila cosata*), which is also a restricted invasive plant, occurs along the margins of the lake. There are few aquatic plants in Six Mile Creek downstream of Lake Macdonald, due to extensive shading by riparian vegetation, though there are isolated occurrences of Cabomba and water snowflake. No threatened aquatic plant species is known to occur in Lake Macdonald.

Fish

The native fish community in Lake Macdonald and Six Mile Creek comprises 26 species that are known or likely to occur. Of the native species known to occur in the area, several of them do not occur upstream of the Lake Macdonald dam wall (e.g. Pacific blue eyes) and do not occur naturally in Six Mile Creek, having been stocked in Lake Macdonald (e.g. saratoga, yellow belly).

Surveys have recorded Mary River cod and Australian lungfish only from Six Mile Creek downstream of Lake Macdonald, although records indicate that at least 112,730 Mary River cod fingerlings were released to Lake Macdonald between 1983 and 2015, with 6,430 released to Six Mile Creek (MRCCA 2016). There are no records of Australian lungfish being stocked in Lake Macdonald or Six Mile Creek. Six Mile Creek is considered to harbour an important relict population of Mary River cod (Simpson & Jackson 2000), and the high stocking rate suggest that this species has the potential to occur in relatively high numbers, especially in Lake Macdonald. Large numbers of yellow belly and Australian bass have also been stocked to Lake Macdonald, suggesting that the abundance of large bodied fish in Lake Macdonald could be very high.

Five pest fish are known from the area: eastern Gambusia (*Gambusia holbrooki*), platy (*Xiphophorus maculatus*), swordtail (*Xiphophorus hellerii*), guppy (*Poecilia reticulata*) and tilapia (*Oreochromis mossambicus*). Tilapia was only recorded in Six Mile Creek downstream of the Lake Macdonald dam wall for the first time in January 2018. Eastern gambusia and tilapia are restricted biosecurity matter under the *Biosecurity Act 2014*.

Turtles

Four species of turtle have been caught in Six Mile Creek and Lake Macdonald, with diversity and abundance higher upstream of the dam wall than in Six Mile Creek downstream. These are: Krefft's river turtle (*Emydura macquarii*), saw-shelled turtle (*Wollumbinia latisternum*), eastern long-necked turtle (*Chelodina longicolis*) and broad-shelled river turtle (*Chelodina expansa*). It is likely that the population size of Krefft's river turtle and saw-shelled turtle is high in Lake Macdonald. White-throated snapping turtle and Mary River turtle, which are MNES, have not been caught in Six Mile Creek or Lake Macdonald. It is possible that these species occur in low abundance in the lower reaches of Six Mile Creek, and it is expected that few, if any, of these species would be present in Lake Macdonald.

Other Fauna

Platypus are known from Six Mile Creek, including in the upper reaches of Lake Macdonald and in Six Mile Creek upstream of the lake. This species is listed as Special Least Concern in Queensland's *Nature Conservation (Wildlife) Regulation 2006*, but is not a threatened species.

Amphibians

Six amphibian species are known to occur within the Study Area of Lake Macdonald, including two threatened species and four least concern species. Giant barred frogs were heard calling downstream of Six Mile Creek, however field survey results suggest that only a low density population is present in this area.

The tusked frog was recorded along Collwood Road within roadside drainage, and also in the upper reaches of Lake Macdonald close to the water's edge.

Other least concern species observed include sedgefrog (*Litoria fallax*), graceful treefrog (*Litoria gracilenta*) and striped marshfrog (*Limnodynastes peronii*). Cane toads (*Rhinella marina*), which are a restricted biosecurity matter, occur in the Project area.

C.5.2 Matters of National and State Environmental Significance

MNES are protected under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC). MSES are protected under the *Nature Conservation Act 1992* (NCA). NCA and EPBC species that have the potential to occur within Lake Macdonald and Six Mile Creek are listed in Table C.5-1.

Table C.5-1 Species listed under the NCA and EPBC

SPECIES	KEY HABITAT	KNOWN LOCATIONS (AS OF SEPTEMBER 2018)	LIKELIHOOD OF OCCURRENCE IN LAKE MACDONALD AND SIX MILE CREEK
Australian lungfish (*Neoceratodus forsteri*)	• Wide, slow flowing or still permanent reaches with deep pools (1 m – 3 m). • Low flow conditions above 10 cm. • Prefer areas with submerged logs, high aquatic plant cover and underwater crevices.	The closest record is in Six Mile Creek near the tailwater pool.	Moderate. Minimal suitable habitat present within the study area. One individual recorded in Six Mile Creek near the tailwater pool, but an important population of this species does not occur in Six Mile Creek.
Giant barred frog (*Mixophyes iterates*)	• Rainforest and wet sclerophyll forest, occasionally adjacent farmland • Moist riparian habitats with deep leaf litter	The closest record is 185 m downstream of Six Mile Creek	High. Suitable habitat present within the downstream tributaries of Six Mile Creek. Individuals were recorded during the site survey.
Mary River cod (*Maccullochella mariensis*)	• Shaded pools within complex in-stream structures (i.e. woody debris, crevices). • Water depths of 1 m – 3 m. • Slow flowing water	The closest record is within 20 m of the Dam wall in Lake Macdonald and also in Six Mile Creek near the tailwater pool.	High. Suitable habitat present within the study area. Three individuals recorded from recorded in Six Mile Creek near the tailwater pool, spawning Mary cod recorded in the creek downstream of the dam (Dunlop 2016), and large numbers stocked to Lake Macdonald.
Mary River turtle (*Elusor macrurus*)	• Permanent streams and large pool habitats. • Sparsely vegetated, north-facing sloping sandy river banks.	The closest record is along Middle Creek Road across from Middle Creek.	Low. Minimal sparsely vegetated sloping sandy river banks present within the study area. No individuals were recorded during the site survey and no records within 1 km available on the Atlas of Living Australia.

SPECIES	KEY HABITAT	KNOWN LOCATIONS (AS OF SEPTEMBER 2018)	LIKELIHOOD OF OCCURRENCE IN LAKE MACDONALD AND SIX MILE CREEK
Platypus (*Ornithorhynchus anatinus*)	• Permanent water surrounding stable earthen banks, held by native overhanging vegetation. • Woody debris and cobbled habitats.	The closest record is 130 m downstream in Six Mile Creek.	High. Suitable habitat present within the downstream and upstream tributaries of Six Mile Creek. Individuals have been observed by the Seqwater ranger within Lake Macdonald, and there is one database record of platypus upstream of Lake Macdonald.
Tusked frog (*Adelotus brevis*)	• Wet eucalypt forest, rainforest and occasionally dry eucalypt forest. • Occur near slow moving sections of streams, stagnant ponds and dams.	The closest record is along Collwood road, in roadside drainage near Tewantin National Park.	High. Wet eucalypt forest has been identified within the study area. Two individuals were recorded during the site survey.
White-throated snapping turtle (*Elseya albagula*)	• Permanent, clear, well oxygenated flowing water. • Complex habitat structures (i.e. woody debris and undercut banks). • Sandy- gravel substrates	The closest individual was identified within Yabba Creek, near Yabba Creek Road, Imbil.	Low. Minimal suitable habitat present within the study area. No individuals were recorded within the study area during the site survey or on Atlas of living Australia.

C.5.3 Potential Impacts of Lowering Lake Macdonald

Water drawdown in Lake Macdonald, and release of water downstream in Six Mile Creek, may impact aquatic flora and fauna via:

- Indirect impacts to water quality (see section C.3.0)
- Direct impacts of injury or mortality of fauna from pumping equipment
- Indirect impacts due to stranding of fauna in shallow isolated pools or burrows as water levels decline, or stranding in areas that rapidly become totally dry
- Indirect impacts associated with changes in the downstream flow conditions during drawdown, which could lead to impacts on breeding success, reduced water quality, and loss of habitat
- Indirect impacts associated with the spread of aquatic biosecurity matters (see section 7.0).

Aquatic fauna may be injured by pumping equipment, which could result in individuals becoming susceptible to pathogens and disease. Alternatively, aquatic fauna may become fatally injured by pumping equipment, or become trapped within pumping equipment and consequently drown.

Aquatic fauna could be stranded in small isolated pools once water in Lake Macdonald is lowered, which may increase predation (e.g. predation of smaller fish my larger fish and / or birds), and / or competition leading to crowding. Crowding may result in reduced dissolved oxygen concentrations in water, reduced food supply, and increased stress on fauna. As small isolated pools evaporate, or in areas that are dewatered rapidly, there is a risk that aquatic fauna could become stranded on dry areas.

The release of water into Six Mile Creek during the drawdown of Lake Macdonald may impact aquatic fauna through the creation of a high flow event that could carry fauna downstream or trigger behaviour that would usually occur at another time (e.g. breeding migration).

C.5.4 Management Measures

Potential impacts to aquatic flora and fauna can be mitigated by implementing the measures identified in Table C.5-2. Where appropriate, the proposed management measures will be adapted over the course of the Project in response to changing conditions and expert advice.

Table C.5-2: Management of aquatic flora and fauna during the lowering of Lake Macdonald

ENVIRONMENTAL OBJECTIVE: Minimise impact of lake drawdown on aquatic flora and fauna.	
Performance criteria	• Prevent direct impacts and minimise indirect impacts of drawdown on aquatic flora and fauna
Mitigation measures	• Gradual lowering of the lake over a 3-month period to allow fauna to move away from potential isolated pools to minimise the need for intervention • Avoid releases during natural low flow periods and changes to hydrology during the breeding seasons for MNES species known to be in Six Mile Creek downstream of the dam • Avoid undertaking fauna recoveries in hot conditions (e.g. summer months). • Use a discharge rate that will not exceed the bank full width of Six Mile Creek downstream of the dam. • Manage water quality, as described in section 3.0. • Use intake exclusion screens of suitable design (low intake velocity) to prevent aquatic fauna from being entrained into mechanical drawdown equipment. Screen design should ensure water velocity at the intake screen is < 0.1 m/s. • Monitor screened intakes to ensure screens are functioning correctly, water velocity is sufficiently low, and no aquatic fauna are trapped against the screens. • Following drawdown, manage water flows downstream of Six Mile Creek to meet existing environmental flow requirements. This may include supplementing flows via the existing Mary River supply to the water treatment plant. • Implement an aquatic fauna salvage plan to prevent crowding and stranding (see section 6.0) – platypus will not be relocated unless absolutely necessary. • Manage biosecurity matters (see section C.7.0). • Maintain habitat/waterholes for platypus within home range in the Lake Macdonald footprint, with consideration of natural behaviours (this may require deepening of channels). • Where possible, and if none present, create suitable habitat within the lowered lake during construction, for example by placing large woody debris or root balls in the retained water. • Implement triggers and planning for incidental fauna salvage during the construction phase. • Ensure the existing bubble plume destratification unit is maintained and fully operational during the initial stages of fish recovery and kept in operation (standby) to respond to water quality triggers or signs of fish distress. • Develop (and have ready for implementation) a feeding plan if scarce food resources are determined to be a limiting factor (based on assessment of abundance of zooplankton and small fish). Noting that this is not considered likely with the proposed fauna salvage strategy.
Monitoring	• Daily inspection of intake screens during dewatering periods, where possible, to ensure screens are functioning correctly, water velocity is sufficiently low, and that no aquatic fauna are trapped against the screens

ENVIRONMENTAL OBJECTIVE: Minimise impact of lake drawdown on aquatic flora and fauna.	
	• Targeted dawn visual surveys for platypus to assess presence and condition on a monthly basis, and following a significant rainfall event • During drawdown – aerial (drone) surveys of recently exposed areas of the Lake Macdonald full supply area at least twice a week to identify isolated pools and potentially stranded fauna • During construction – targeted visual surveys of fish, and opportunistic salvage of Mary River cod and Australian lungfish if observed, through the Lake Macdonald full supply area at least once a week, and following significant rainfall • Use real time water quality monitoring in Lake Macdonald in conjunction with trigger levels to assess risks of fauna kills (e.g. low dissolved oxygen and high water temperature triggers).
Reporting	• Weekly to Seqwater Project Manager if there are no trapped fauna • Daily to Seqwater Project Manager if fauna are trapped
Responsibility	Contractor, using suitably qualified persons
Corrective actions	• Implement adaptive measures incorporated in the salvage plan • Review management measures and adjust if required • Slow the rate of pumping • Undertake incidental fauna salvage of isolated pools or lake as necessary • Implement a feeding plan developed in accordance with specialist knowledge if the remaining fauna exhaust food supplies, coupled with further salvage of large bodied fish.

C.6 Aquatic Fauna Salvage and Relocation

C.6.1 Purpose

The purpose of the planned aquatic fauna salvage and relocation is to minimise stranding and crowding of aquatic fauna (in particular large bodied fish and turtles) in Lake Macdonald during the Project (i.e. during the lake drawdown and the subsequent construction period).

Fish and turtle salvage will be in accordance with the EPBC Translocation of listed Species Policy (DSEWPaC) and DAF's Fish Salvage Guidelines (DPI 2004), and implemented by suitably qualified fish biologists. These guidelines collectively presents principles that are relevant to the planned aquatic fauna salvage operation:

1. Reduce impacts on translocated animals:
   (a) Removal of fish and turtles prior to drawdown
   (b) Removal of fish and turtles during drawdown – lower water by 25% and remove as many fish as possible, then lower water by another 25% and remove as many fish as possible; continue dewatering and fish salvage operations but do not completely dewater until it is established that fish numbers are very low; do not lower water level such that fish are over-crowded.
   (c) Handling of:
      (i) fish – use nets with soft mesh; handle fish with wet hands or wet towels; handle fish carefully, ensuring that the spinal cord of large fish is fully supported and they are held in a horizontal position; place fish in suitably sized receptacles with good quality water as soon as possible.
      (ii) turtles – use nets with soft mesh, handle turtles carefully by the carapace (i.e. not by limbs or tail) so they are fully supported in a horizontal position; suitably sized receptacles without over-crowding in the shade and with good airflow.
   (d) Storing and transporting of:
      (i) fish – relocation of fish must be implemented as quickly as possible; receptacles must allow fish to swim comfortably in upright position; approximately 0.2 kg of fish per litre of water is acceptable; fish and water conditions should be regularly monitored; use good quality water from the site and replace water in receptacles regularly; use aerating device to maintain dissolved oxygen levels; a sluice can be used to transport fish if practical.
      (ii) turtles – relocation of turtles must be as quickly as possible.
   (e) Releasing:
      (i) fish– release carefully by placing receptacle in water at release location and allowing fish to swim away (do not drop from fish height); exchange water at release location and in receptacle if water temperature is notably different at release location.
      (ii) turtles – release carefully by placing receptacle in water at release location and allowing turtles to swim away (do not drop from fish height).
   (f) Action in the event of a fish or turtle kill – DAF must be notified if there is a fish kill; DES must be notified if there is a turtle death.
2. Reduce impacts at the translocation site, including prevention of:
   (a) Competition with other animals
   (b) Predation of other animals
   (c) Establishment of pest species and pathogens
   (d) Admixture between genetically differentiated populations of closely related species.
3. Evaluation of short- and long- term success of translocation via appropriately designed monitoring programs.

As identified in section C.11, all salvage will be performed by suitably qualified personnel in accordance with permits.

Note that relocation of platypus, giant barred frog and tusked frog is not currently planned. It is proposed to maintain refugial platypus habitat in Six Mile Creek for the duration of the Project, where possible. However, contingencies for platypus relocation are provided in section C.8. Giant barred frog and tusked frog are expected to relocate in response to changing water levels and return once the Project is complete and the lake refills.

C.6.2 Baseline Surveys

Prior to the lake drawdown commencing, targeted field surveys will be undertaken:

- In Lake Macdonald, with a focus on the upper reaches, to assess the presence of key species
- At proposed relocation sites to assess their suitability (with respect to logistical concerns and aquatic fauna) and carrying capacity.

The surveys will be used to familiarise teams with Lake Macdonald and the proposed salvage methods, and will focus on:

- Large-bodied fish – specifically MNES species in Lake Macdonald (including salvage of these species), and all large species in the proposed relocation sites. Catch per Unit Effort (CPUE) for each species to be calculated.
- Small bodied fish in Lake Macdonald – recording species and their abundance, but releasing them back to the lake. CPUE to be calculated for each species.
- Platypus – dawn visual surveys that comprise timed transects from a canoe and the bank (depending on accessibility) along with searches of burrows (distinguishing active from non-active burrows)
- Turtles – MNES listed and common species, using methods including trapping (fyke nets and baited cathedral traps), snorkelling, spotlighting and night-time dip netting from boat, as outlined in DSEWPC (2011), in Lake Macdonald and the proposed release locations
- Fish communities – assessment of species diversity and abundance at relocation sites only, using methods including electrofishing and a suite of nets
- Aquatic habitat – assessment of habitat type, condition, suitability for key fauna, and potential risks/impacts (relocation sites only).

Care should be taken during all surveys to reduce potential impacts to other fauna (i.e. during fish and turtle surveys, nets should be checked regularly and set to minimise potential impacts to platypus).

C.6.3 Salvage and Relocation Targets

Salvage targets will be based on a reduction in CPUE of large bodied fish and turtles for each of three separate salvage phases during lake lowering:

- **Salvage Phase 1, lake capacity 30%**: CPUE will be calculated for the first day of salvage, with salvage at 30% capacity continuing until CPUE has reduced to 20% or less than recorded on the first day of salvage at 30% capacity
- **Salvage Phase 2, lake capacity 10%**: CPUE will be calculated for the first day of salvage, with salvage at 10% capacity continuing until CPUE has reduced to 20% or less than recorded on the first day of salvage at 10% capacity
- **Salvage Phase 3, lake capacity 2-5%**: CPUE will be calculated for the first day of salvage, with salvage continuing until CPUE has reduced to 20% or less than recorded on the first day of salvage at 2-5% capacity.

The proposed drawdown and fauna salvage program differs from the DAF guidelines due to the size and bathymetry of Lake Macdonald and the likelihood that salvage methods would be less effective at the recommended percentages because of the area to be covered. Furthermore, preliminary modelling of the lowering of Lake Macdonald suggests there is likely to be connectivity in the lake until it reaches 30% capacity. As such, prior to Salvage Phase 1, fauna salvage will be undertaken on an incidental basis in response to aerial monitoring of stranding events.

The quantitative approach to salvage is intended to give confidence to all stakeholders that salvage will be effective in mitigating potential impacts of low water levels on aquatic fauna (i.e. demonstrating that salvage has been successful), and have clear points where salvage is no longer needed (i.e. has achieved the mitigation), until incidental salvage is needed following other triggers such as water quality deterioration, receding water level in dry weather, or a large flow event. It is anticipated that the water retained in Lake Macdonald during the construction period (i.e. 412 ML) will be sufficient for the remaining aquatic fauna to survive during the construction period, noting that monthly monitoring will be implemented and incidental salvage undertaken when required.

C.6.4 Relocation Sites

Relocation sites will be selected to prevent admixture between genetically differentiation populations of:

- all turtle species (including common species) among catchments (i.e. turtles will not be relocated outside of the Mary River Basin)

- Mary River cod, Australian lungfish, white-throated snapping and Mary River turtles between the main Mary River and Tinana Creek, with the precautionary principle applied (i.e. fauna will not be relocated to the Tinana Creek sub-catchment)
- White-throated snapping turtle and Australian lungfish between lower and upper Mary River.

The process for the selection of relocation sites will comprise:

- Desktop assessment of potential sites based on key criteria (i.e. distance from Lake Macdonald, accessibility, catchment, known sensitivity of the ecosystem, biosecurity)
- Field surveys and evaluation of logistics (e.g. accessibility for vehicles and equipment, land ownership) at sites shortlisted in desktop assessment
- Selection and prioritisation of preferred sites (may vary based on species) based on their suitability for relocated fauna (e.g. habitat condition, carrying capacity) and operational considerations (e.g. access)
- Additional desktop and field assessment if required (e.g. if the capacity of preferred sites is limited).

An initial desktop assessment of potential relocation sites, based on local and expert knowledge of the region and species to be relocated, has identified the following preliminary options:

- Cooloolabin Dam – Cooloolabin Dam is approximately 18 km south of Lake Macdonald in the South Maroochy River Basin. It contains habitat similar to that of Lake Macdonald, is in a forested catchment, has complex aquatic habitat structure, and Cabomba is present. This site could be suitable for bass and yellow belly and will be a non-return release site.
- Local farm dams – farm dams of a sufficient size and quality may provide suitable relocation options for cod, lungfish, and turtles. The suitability will of farm dams for relocation will depend on the size and condition of the dam as well as landholder permission, and fencing may be required to protect relocated turtles. The aim of these temporary relocation options is to allow recovery of these species for restocking back into Lake Macdonald shortly after the Project ends, when water levels and quality stabilise.
- Six Mile Creek downstream of Lake Macdonald – may be suitable for small number of Mary River cod and Australian lungfish and white-throated snapping turtle, potentially once carrying capacity of hatchery is exceeded. The carrying capacity of Six Mile Creek would need to be determined, and supplemental flows may need to be provided if significant numbers of fish are released to Six Mile Creek.
- Carter's Ridge – there is a former turtle breeding facility at Carter's Ridge, 18 km west of Lake Macdonald, that was previously used for Mary River turtles and is currently unused. This may be an option for the relocation of turtles and/or platypus.
- Ewan Maddock Dam in the Mooloolah River Basin – this dam may be suitable for large bodied, non-MNES species (i.e. bass and yellow belly) and Cabomba is present throughout the area.
- Local wildlife parks or carers – may be an option for limited numbers of fauna and key species. To be further investigated through engagement with local parks and carers.

The above options are expected to be subject to change based on further evaluation of logistical and environmental considerations following the surveys described in section C.6.2. It is expected that multiple relocation sites will be used during the salvage and relocation operation.

The purpose of the surveys described in section C.6.2 will be to assess the carrying capacity and suitability of sites (e.g. availability of appropriate habitat and food sources) to host species salvaged from Lake Macdonald. The survey methods used will be appropriate for the types of species being relocated, with platypus being assessed at potential relocation sites for the purpose of contingency planning only.

Note that no aquatic fauna will be relocated to Tinana Creek due to the sensitivity of the aquatic ecosystem. Bass and yellow belly will not be relocated to the main stem of the Mary River as they may compete with recovering Mary River cod populations.

C.6.5 Schedule and Resourcing

C.6.5.1 Initial Lowering

In accordance with the fauna salvage guidelines, there will be a baseline survey / initial fish and turtle salvage operation before drawdown commences (weeks -1 and -2). This will provide an indication of the catch rates of the species to be salvaged, and enable salvage logistics to be fine-tuned prior to water levels dropping in the lake.

After dewatering has commenced, there will be three phases of fish and turtle salvage. The first will be when lake capacity is reduced to approximately 30%. Salvage will continue until the salvage targets above have been achieved, with a notional two-week salvage period presented in the scheduled (Table C.6-1). The second salvage phase will commence when lake capacity is reduced to approximately 10% and will continue until the salvage targets described above have been achieved. Again a notional two-week salvage period has been scheduled, although salvage will continue beyond week 10 if necessary to achieve the salvage target (Table C.6-1).

Table C.6-1: Initial dewatering aquatic fauna salvage schedule

WEEK	LAKE CAPACITY (%)	INDICATIVE SALVAGE EFFORT
-2	100	• 4 boat electrofishing teams (7.5 / 5.0 GPP units) • 1 cathedral trap team (20 x cathedral traps) • 1 fyke net team (20 x large mesh fyke nets) • 4 land-based transport teams
-1	100	• 4 boat electrofishing teams (7.5 / 5.0 GPP units) • 1 cathedral trap team (20 x cathedral traps) • 1 fyke net team (20 x large mesh fyke nets) • 4 land-based transport teams
0-5	100-30	• Incidental salvage in response to monitoring of stranding using appropriate methods as described in C.6.5.2.
5	~30	• 4 boat electrofishing teams (7.5 / 5.0 GPP units) • 1 cathedral trap team (20 x cathedral traps) • 1 fyke net team (20 x large mesh fyke nets) • 4 land-based transport teams
6	~24	• 4 boat electrofishing teams (7.5 / 5.0 GPP units) • 1 cathedral trap team (20 x cathedral traps) • 1 fyke net team (20 x large mesh fyke nets) • 4 land-based transport teams
9	~10	• 4 boat electrofishing teams (2 x 7.5 GPP units; 2 x 2.5 GP units) • 4 boat electrofishing teams (7.5 / 5.0 GPP units;) • 1 cathedral trap team (20 x cathedral traps) • 1 fyke net team (20 x large mesh fyke nets) • 4 land-based transport teams
10-12	~6	• 4 boat electrofishing teams (7.5 / 5.0 GPP units) • 1 cathedral trap team (20 x cathedral traps) • 1 fyke net team (20 x large mesh fyke nets) • 4 land-based transport teams
+1 [a]	2.8	• 4 boat electrofishing teams (7.5 / 5.0 GPP units) • 1 cathedral trap team (20 x cathedral traps) • 1 fyke net team (20 x large mesh fyke nets) • 4 land-based transport teams

[a] one or more week of fish salvage may be needed after dewatering is complete to achieve the fish salvage targets.

C.6.5.2 Incidental Fauna Salvage

After the two-month coffer dam construction period, water levels will be allowed to refill to approximately 5% of full capacity (RL 89.5 m), subject to rainfall/inflows, and this maximum level will be retained for the remainder of the construction period. Small inflows will not significantly increase water levels as small flows will pass through the low flow crest of the temporary coffer dam. However, there will be a threshold at which significant flows, caused by heavy rainfall in the Lake Macdonald catchment area, will cause hydrological connectivity over the coffer dam with Six Mile Creek, meaning that fish could potentially move upstream into Lake Macdonald. Therefore, incidental or follow-up fish salvage is likely to be needed following high flows. The threshold of flows giving rise to hydrological connectivity will be determined prior to construction and incorporated into this plan.

Additionally, where exceedance of the high trigger for dissolved oxygen in Lake Macdonald occurs incidental salvage has been identified as a potential mitigation. Incidental salvage may also be triggered by site observations and aerial (drone) surveys, such as if large fish or turtles appear crowded or stressed or stranded fauna are observed in isolated pools.

It is anticipated that incidental fauna salvage in response to a flow event will utilise two boat (7.5 / 5.0 GPP) electrofishing teams and one cathedral trap team, supported by two land-based transport teams. It is proposed that salvage will occur for a minimum of three days after each large flow / adverse water quality event, with CPUE of each large bodied fish species and turtle species calculated on the first day of salvage. Where an 80% reduction in CPUE has not been achieved by the third day, then additional days of salvage will be implemented until this salvage target has been achieved.

Incidental fauna salvage in response to observations and aerial surveys are likely to utilise a range of methods based on the area to be targeted, including backpack or boat electrofishing, dip netting, fyke netting and cathedral traps. The number of personnel required will depend on the size of the target area(s), but it is anticipated that a minimum of one electrofishing tem and one netting team will be required.

C.6.6 Capture Methods

Active salvage will be implemented, with regular monitoring of traps and nets (e.g. twice daily).

The following capture methods will be used:

- Boat electrofishing: 4 x large units (i.e. 7.5 / 5.0 GPP), each operated by a team of three suitably qualified persons
- 20 x baited cathedral traps, for turtles, set by a team of two suitably qualified persons from a boat
- 20 x fyke nets (mesh size 10 mm), set in upper reaches of Lake Macdonald for fish and turtles by a team of two suitably qualified persons from a boat
- Seine net, on an as-needed basis, such as to catch stranded fish from shallow isolated pools.

All species, the number of each species, and the apparent health of individuals that are relocated will be recorded. The total length of all Mary River cod and Australian lungfish, and carapace length and sex of all Mary River and white-throated snapping turtles, that are relocated will be recorded. It will not be practical, nor in the interests of fish welfare, to record measurements for any other species.

No unmanned evening or overnight trapping will be undertaken.

C.6.7 Holding and Transport Methods

At the time of capture, all fish will be carefully placed in sufficiently large receptacles (i.e. large plastic tubs, located on the deck of the boats) containing Lake Macdonald water, with dissolved oxygen concentrations of the water maintained using battery-operated aerator units. All turtles will be placed in sufficiently large receptacles (i.e. large tubs), separate from fish, with adequate shade and airflow.

Once the capacity of the receptacle is reached or two hours since the first individual was caught has passed (whichever comes first), fish and turtles will be transferred to the larger receptacles on the land-based transports (suitable vehicles with trailer-based holding tanks), and from there they will be taken to the pre-determined release locations, and released according to the Fish Salvage Guidelines. It is expected that the average time from capture to release will be less than 3 hours for Mary River cod, Australian lungfish, Mary River turtle and white-throated snapping turtle, and 4 hours for other species.

Any pest fish caught will be euthanised using ethics committee-approved methods and disposed of appropriately (e.g. in plastic bags at an appropriate refuse facility or buried on site a minimum of 20 m from the water's edge).

C.6.8 Monitoring

Visual monitoring of fish in the Lake Macdonald full supply area at least twice a week as described above in Table C.5-2.

Visual monitoring of the relocation sites will occur on a weekly basis from week 6 to week +4 of the lake lowering schedule. Observation will be made of fish and turtle crowding and / or stress. Where observations indicate early signs of crowding or stress, then the site will not be used for further fauna relocation and de-stocking will be implemented to reduce the number of animals in the relocation site.

Visual monitoring of the relocation sites will occur on a monthly basis for 12 months after week +4 of the lake lowering schedule, to assess long-term success of the salvage and relocation operation.

Where salvaged fauna are returned to Lake Macdonald after works are completed, visual monitoring will occur on a monthly basis for 12 months to assess long-term success of the salvage and relocation operation.

C.7 Biosecurity

C.7.1 Biosecurity Matter in Lake Macdonald

The *Biosecurity Act 2014* identifies two types of biosecurity matters: prohibited matters, which are not yet present in Queensland, and restricted matters, which are currently present within Queensland.

Eight restricted biosecurity matters are present in Six Mile Creek:

- Pest fish, including eastern gambusia (*Gambusia holbrooki*), carp (*Cyprinus carpio*) and tilapia (*Oreochromis mossambicus*)
- Aquatic plants, including salvinia (*Salvinia molesta*), water hyacinth (*Eichhornia crassipes*), Hygrophila (*Hygrophila costata*), and Cabomba (*Cabomba caroliniana*)
- Amphibians, including the cane toad (*Rhinella marina*)

There are extensive beds of Cabomba within Lake Macdonald and the upstream tributaries of Six Mile Creek. Small populations of Cabomba and water snowflake have also been identified downstream in Six Mile Creek. Restricted matters from the lake (e.g. gambusia and Cabomba) are likely transported downstream when the dam overtops, which occurs frequently.

Surveys in August 2015 identified eastern gambusia populations in Lake Macdonald, with 62 individuals captured. To date, tilapia have only been recorded downstream of Lake Macdonald in Six Mile Creek. It is not known if the species is present in Lake Macdonald, though it is considered unlikely.

Cane toads were identified around lake Macdonald during amphibian surveys conducted in February 2018, including the upstream and downstream tributaries of Six Mile Creek.

C.7.2 Potential Impacts of Lowering Lake Macdonald

Potential impacts associated with biosecurity matters that could occur by lowering Lake Macdonald are:

- Spread of aquatic weeds
- Spread of aquatic pest species
- Introduction of new biosecurity matter to Lake Macdonald.

There may be a slight increase in the transport of restricted matter downstream from the lake to Six Mile Creek during the lowering process. Water pumped from Lake Macdonald to Six Mile Creek may contain a greater concentration of restricted matter than is present during overtopping events, and this could place pressure on the downstream aquatic communities if the restricted matter becomes established.

Additional aquatic weeds and invasive fauna may enter the dam as the lake is lowered and water is initially drawn in from upstream tributaries. Cabomba from upstream, as well as existing Cabomba, may establish in the new shallow environment of the lake during the construction period.

The conditions in the Lake Macdonald while it is lowered may favour some invasive pest fauna species, such as cane toad tadpoles. Shallow, low oxygen waterbodies suit cane toads and could potentially lead to increased breeding and competition with native frog species.

The coffer dam height during the construction period (which is lower than the existing dam wall) may increase the potential for drown-out or overtopping events. These events may encourage upstream movement by fish in Six Mile Creek past the dam, including tilapia, resulting in a possible increase in the distribution of this species.

C.7.3 Management Measures

Potential impacts of fauna biosecurity matters can be mitigated by implementing the management measures in Table C.7-1 and Table C.7-2. Where appropriate, the proposed management measures will be adapted over the course of the Project in response to changing conditions and expert advice.

Seqwater also plans to implement an opportunistic program to eradicate Hygrophila in Lake Macdonald. This program is independent of the Six Mile Creek Dam Upgrade Project, but is facilitated by the drawdown for the Project.

Table C.7-1: Management of pest animal biosecurity matters during the lowering of Lake Macdonald

ENVIRONMENTAL OBJECTIVE – PEST MANAGEMENT: Distribution of pests does not increase due to the Project and existing populations of pest fauna do not increase.	
Performance criteria	• Obligations under the Queensland *Biosecurity Act 2014* are met. • No new pest infestations, or increase in distribution of pests, as a consequence of the lake lowering activities.
Mitigation measures	• Where possible, the water level in the lake will be managed to reduce the potential for drown-out / overtopping (i.e. via active releases) • The hydrological conditions that give rise to drown-out of the temporary coffer dam, and potential for upstream movement of fish, will be determined and set as a threshold for follow up actions. • If drown-out or extensive overtopping occurs, the water will be lowered and a fish salvage event targeting tilapia will be undertaken. • Salvaged fish will be sorted before relocation, wherever possible, and pest fish euthanised humanely. • Cane toad traps, as manufactured by the Mary River Catchment Coordinating Committee, will be installed around the lowered lake to control cane toad populations. • For the construction period, all relevant personnel will be required to complete pest identification training.
Monitoring	• During construction, presence of pest species in lake monitored as part of weekly site inspections.
Reporting	• Fortnightly report submitted to the Seqwater Project Manager with details of monitoring results and incidents. • Immediately report any tilapia in the lake to the Seqwater Project Manager.
Responsibility	Contractors and Seqwater
Corrective action	• Implement appropriate control measures where infestations are occurring. • Review existing control measures to identify potential improvements.

Table C.7-2: Management of pest plant biosecurity matters during the lowering of Lake Macdonald

ENVIRONMENTAL OBJECTIVE – WEED MANAGEMENT: Restricted invasive plants not present in Lake Macdonald are not introduced. Restricted invasive plants already present in Lake Macdonald are not spread to new areas.	
Performance criteria	• Obligations under the Queensland *Biosecurity Act 2014* are met. • All vehicles and plant working in the lake have weed hygiene certificates. • No additional weed infestations or increase in distribution in the lake due to construction activities. • All employees working on site attend induction training sessions to identify weeds.
Mitigation measures	• Relocation of fauna to sites where restricted invasive aquatic plants that occur in Lake Macdonald are also present. • All vehicles (including boats) and plant to have weed hygiene certification before entering Lake Macdonald. • All vehicles used in the transport of relocated fauna to be inspected and washed before leaving site if they have entered Lake Macdonald or marginal areas where aquatic plants are exposed. • Undertake weed control in the lake area as required, based on monitoring stipulated below. This may include, for example, where Hygrophila is likely to establish on exposed banks that have previously been controlled or eradicated.
Monitoring	• Weekly audits of weed hygiene certifications and inspection and wash down records. • Monitor lake for outbreaks of not previously established restricted aquatic or semi-aquatic plants (noting that new growth of Cabomba will not be prevented in the lake to provide food for aquatic species).
Reporting	• Personnel to notify the Seqwater Project Manager of weed outbreaks or potential contamination immediately. • Fortnightly report to Seqwater that includes details of monitoring and audits.
Responsibility	Contractors and Seqwater
Corrective action	• Increased monitoring of weed hygiene measures, if appropriate. • Implement appropriate control measures if required.

C.8 Incident and Contingency Planning

This section describes proposed measures to manage unforeseen events and incidents that may occur during the drawdown process and construction period. The described management measures are indicative only, and will be adapted in response to an event and in response to changing conditions and expert advice.

C.8.1 Lowering of Lake Macdonald

Mechanical equipment will be used during the drawdown of Lake Macdonald and a similar arrangement will also be retained for the duration of the Project to manage flows if required in day to day operation. Where possible, during drawdown and throughout construction, the bypass will be used to release water from Lake Macdonald at a rate that matches inflow. This will be done to:

- Reduce the potential for overtopping, drown out, and water flow through the construction site
- Maintain a steady water level in the lake, as much as practical, and reduce the requirement for rapid drawdown following high flow events.

During the initial drawdown phase, releases will aim to lower the water level for aquatic fauna salvage, but there are likely to be rainfall events in this phase that disrupt the drawdown. Where the bypass release capacity is exceeded by catchment inflows (i.e. a high flow event), the bypass releases will also be used for drawdown of the lake following high flow events to reinstate the aquatic fauna salvage schedule. Due to Project scheduling demands, drawdown after high flow events may need to be rapid (i.e. two weeks or less). The implementation of fauna salvage and erosion and sediment controls over the initial three-month drawdown period is expected to minimise the potential impacts of a subsequent rapid drawdown (if required). However, the frequency of monitoring for aquatic fauna, water quality, and erosion will increase during the rapid drawdown period, with:

- Aquatic fauna and water quality monitored twice per day
- Erosion monitored daily.

If issues are detected during monitoring, the release rate will be slowed to enable appropriate mitigation measures, including fauna salvage if needed, to be implemented. The mitigation measures will be similar to those described in this plan, but adapted as needed in response to the conditions at the time.

C.8.2 Aquatic Fauna Relocation

C.8.2.1 High Fauna Abundance

Up to four reserve fauna salvage teams, appropriately equipped, will be on standby during each of the salvage events (30%, 10% and 5% lake capacity). Should the abundance of fauna be such that the active salvage teams are unable to safely capture and relocate aquatic fauna, these reserve teams will be mobilised to assist in the salvage and relocation effort.

A suite of relocation sites will be identified before the drawdown of Lake Macdonald begins. This will include contingency relocation sites that will not be utilised for relocation unless the abundance of fauna caught for relocation exceeds the capacity of the primary relocation sites.

C.8.2.2 Fauna Injury or Death

All salvage will be implemented in accordance with DAF's Fish Salvage Guidelines to protect the welfare of fish and turtles during capture, transport and release. Seqwater will liaise with wildlife carers and veterinarians in the region before the lake drawdown begins in order to develop:

- Awareness of the Project and the potential need for care and treatment of injured fauna
- A network that can provide support if required.

In the event that an aquatic animal is injured during the salvage operation:

- if the species is a Mary River cod or Australian lungfish, then it will be transported as quickly as possible to an appropriately sized receptacle with aerated water to for assessment by a veterinarian or qualified wildlife carer; or
- If it is any other native fish species (e.g. yellowbelly or Australian bass), then it will be:
  - placed in holding tank of suitable size with aerated water to allow recovery and then subsequent relocation

  - if at the end of the day recovery has not been achieved, then the fish will be humanely euthanised using methods approved under an ethics permit. Where more than 50 fish are injured and are required to be euthanised, it will be reported to DAF.
- If the species is a turtle it will be transported as quickly as possible to a wildlife carer or veterinarian
- If the species is a platypus it will be transported as quickly as possible to a wildlife carer or veterinarian

C.8.2.3 Platypus

It is not planned to relocate platypus during the Project. However, if maintaining suitable habitat conditions becomes difficult/impractical or a platypus is in distress, relocation may be necessary. If circumstances require the care and/or relocation of platypus, the following steps are proposed:

- A veterinarian or wildlife carer will be contacted to assess the platypus condition and take it into care, if required
- If the platypus is considered to be in healthy condition, and suitable habitat is present in the vicinity of where it was found, it will be returned to the habitat in this location by a suitably qualified person (i.e. carer), and monitored at a frequency determined by the carer (e.g. hourly in the first instance, then every three hours and daily until recovery is confirmed)
- If the platypus is considered to be in healthy condition, and no suitable habitat is present in Lake Macdonald or Six Mile Creek, the platypus will be relocated to an appropriate location that was identified before the drawdown began. It will be relocated by a suitably qualified person (i.e. carer) with the support of Seqwater, and monitored at a frequency determined by the carer (e.g. hourly in the first instance, then every three hours and daily until recovery is confirmed).

If a platypus is relocated to a holding facility (as opposed to a creek site) due to the above circumstances, it will be returned to Lake Macdonald once conditions in the lake are suitable and monitored regularly for up to one year evaluate the success of relocation.

The proposed management of platypus during the drawdown will be refined through consultation with appropriate experts and the Department of Environment and Science.

C.8.3 During the Construction Period

C.8.3.1 Aquatic Fauna Illness or Death in Lake Macdonald

As described in previous sections, while Lake Macdonald is lowered there is potential for the remaining aquatic habitat to become unsuitable for fauna. If regular monitoring indicates aquatic fauna are in distress or dying, the following actions will be taken:

- Incidental salvage, as described in section C.6.5.2.
- Develop and implement a feeding program for turtles in the unlikely event that food resources are considered to be depleted, which would be indicated by low abundance of small fish and zooplankton (i.e. via survey of small fish and comparison to baseline CPUE, and zooplankton survey). Where zooplankton and small fish surveys show normal abundance of both small fish and zooplankton, then food resources will not be considered to be limiting.
- Water quality monitoring and implementation of mitigations described above in Table C.3-1. Where the high trigger for dissolved oxygen is exceeded, then incidental salvage as described above will be considered by the Seqwater Project Manager.
- A veterinarian and/or wildlife carer will be consulted as appropriate.

Regular monitoring will be undertaken by the contractor's environmental representative as well as the local Seqwater rangers.

C.8.3.2 Decline in Water Quality

If monitoring indicates that water quality in the lake is not meeting the objectives identified in section C.3.3, the following actions will be taken:

- Low dissolved oxygen – increase aeration, with increased settings or additional units
- High temperatures – where there is a difference in surface and at depth, homogenise water through mixing
- Low pH – dose with appropriate agent, with consideration to potential impacts to fauna
- High turbidity – investigate and manage potential erosion sources, institute additional or alternative erosion controls.

C.8.3.3 Increased Erosion

Where inspections and/or reports identify areas of erosion, the following actions will be taken:

- Implementation of additional or alternative controls, including seeding of eroding areas, where appropriate.

C.9 Community Involvement

Although not a core component of the Project or Lake Lowering Plan, where possible, Seqwater will encourage support and assistance from the local community. This may include, but not be limited to:

- A tool for members of the public to report potential issues observed in the lake (e.g. interactive website)
- Input into the identification of contingency relocation sites
- Assistance with fauna salvage through an organisation such as the Mary River Catchment Coordinating Committee (MRCCC)
- Assistance with expert advice and care where relevant, such as for Mary River cod through the MRCCC

The extent and nature of community involvement will be determined by Seqwater in consultation with relevant community organisations.

C.10 Rehabilitation of Lake Macdonald

Based on Seqwater water balance modelling for Six Mile Creek Dam (GoldSim simulation over a period of 1890-2011), mean annual inflow and direct rainfall for Lake Macdonald is 33,732 ML/y. The full supply volume of Lake Macdonald on completion of the Project will remain unchanged compared with the existing dam, at 8,018 ML. In an average year, Lake Macdonald is expected to return to its full supply level within approximately one year of the completion of the Project.

C.10.1 Aquatic Habitat

The lowering of Lake Macdonald may provide an opportunity to improve aquatic habitat. Seqwater will investigate these opportunities in the lead up to and during construction. Opportunities include the potential to improve aquatic habitat through the installation of fish habitat structures and the management of biosecurity matters, such as Hygrophila. Fish habitat structures could be created through the strategic placement of:

- Broken concrete slabs from existing dam spillway structure
- Leftover concrete from pours during construction, which may be redirected into moulds designed to produce fish habitat structures
- Root balls from vegetation cleared for the Project.

In addition, the opportunity to facilitate the growth of native aquatic plant species and increase competitive pressure on Cabomba through the seeding and planting of native plants will also be investigated and considered.

C.10.2 Aquatic Fauna

A post construction survey may be undertaken when the lake fills to 50% of capacity to identify aquatic species that have been retained within Lake Macdonald during the Project and identify which species may need to be restocked. Implementation of this survey may depend on the outcomes of the fauna salvage operation during drawdown and construction.

The survey will involve:

- Electrofishing at 10 locations throughout the lake
- Setting fyke nets at 10 locations in the upper reaches of the lake
- Setting cathedral traps at 10 locations in the lake.

All species caught and their abundance will be recorded, along with length / carapace measurements for any Mary cod, Australian lungfish, Mary River turtle or white-throated snapping turtle. Any species that were recorded in the baseline survey and are not recorded in the post-Project survey will be stocked / re-introduced from source populations in the Mary River to Lake Macdonald.

Where appropriate, restocking may be undertaken through the fish stocking associations. Following restocking, additional surveys will be undertaken for up to three years to assess the recovery of aquatic fauna communities.

C.10.3 Water Quality

During the refilling and initial dam establishment/operation, depth profiles of dissolved oxygen will be recorded weekly and surface water samples collected monthly for nutrient analysis at five locations in Lake Macdonald to ensure that water quality will support aquatic fauna, and that the lake has not become eutrophic. Mitigation measures such as water aeration units will continue to be applied until the lake has filled to full capacity and water quality monitoring has consistently indicated that water quality conditions are comparable with pre-Project water quality (i.e. compliant with the 'low trigger').

C.10.4 Removal of Project Infrastructure

At the completion of the Project equipment and facilities associated with construction will be demobilised and removed from the Project site, this includes water pumps and erosion and sediment controls. Areas of ground disturbance will be seeded with suitable grasses or re-vegetated with locally sourced plants.

C.11 Permits and Qualifications

C.11.1 Permits and Approvals

The necessary permits and approvals required for the lake lowering and fauna relocation include:

- Rehabilitation Permit (Spotter Catcher) in conjunction with a Species Management Program (SMP).
- An SMP is required to tamper with the breeding place of a protected animal under *the Nature Conservation Act 1992*.
- General fisheries permit
- Animal ethics permit

C.11.2 Qualifications

The qualifications required of individuals managing the fauna salvage and relocation may include:

- A degree in natural science, ecology, or similar with experience surveying and/or handling aquatic fauna
- A rehabilitation permit issued under the *Nature Conservation Act 1992*.

C.12 References

ANZECC & ARMCANZ, 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, National Water Quality Management Strategy, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

DERM 2010. Environmental Protection (Water) Policy 2009, Mary River Environmental Values and Water Quality Objectives Basin No. 138, including all tributaries of the Mary River. Queensland Department of Environment and Resource Management, Brisbane.

DERM 2010. Environmental Protection (Water) Policy 2009, Mary River Environmental Values and Water Quality Objectives Basin No. 138, including all tributaries of the Mary River. Queensland Department of Environment and Resource Management, Brisbane.

DES 2018. Monitoring and Sampling Manual, Environmental Protection (Water) Policy 2009. Queensland Department of Environment and Science, Brisbane

DNR 2007. Water Monitoring Data Collection Standards, Version 2.1. Queensland Department of Natural Resources, Brisbane.

DPI (2004) Fish Salvage Guidelines. Queensland Department of Primary Industries and Fisheries, Brisbane.

DSEWPC 2011. Survey Guidelines for Australia's Threatened Reptiles: guidelines for detecting reptiles listed as threatened under the EPBC Act 1999. Department of Sustainability, Environment, Water, Populations and Communities, Canberra.

Dunlop, J., McGregor, G. and Horrigan, N. 2005. Potential Impacts of Salinity and Turbidity in Riverine Ecosystems: characterisation of impacts and a discussion of regional target setting for riverine ecosystems in Queensland. Queensland Department of Natural Resources and Mines, Brisbane.

Dunlop, A. 2016. Ecology of Larval Freshwater Fish in the Mary River System, South-eastern Queensland, with a focus on the nationally threatened Mary River cod (*Maccullochella mariensis*). Honours Thesis, Griffith University.

MRCCA 2016. Gerry Cook Fish Hatchery 5 Year Strategy (2016 – 2021). Mary River Catchment Coordination Association, Gympie.

Simpson R. & Jackson P. (2000) The Mary River Cod Research and Recovery Plan. Environment Australia: Canberra.

Appendix C.A Background Information – Water Quality

Environmental Values and Water Quality Objectives

Six Mile Creek, including Lake Macdonald, has defined waterway Environmental Values (EVs) and Water Quality Objectives (WQOs) under the Environmental Protection (Water) Policy 2009 ((EPP(Water)) (DERM 2010). EVs are the various environmental and human uses that have been formally identified for a waterbody for which water quality should be protected or improved. WQOs are the numerical concentration levels or narrative statements of indicators established for waters to support and protect the identified EVs for those waters. The EVs that apply to Six Mile Creek are:

- Aquatic ecosystems
- Irrigation
- Stock water
- Aquaculture
- Human consumers of fish
- Primary, secondary and visual recreation
- Drinking water, and
- Cultural and spiritual values.

The WQOs for water quality parameters listed in DERM (2010) for protection of the aquatic ecosystem EV are presented in Table C.12.1.

Water Quality in Lake Macdonald

Table 3.1 provides the median water quality results recorded in:

- Lake Macdonald at the dam wall
- Lake Macdonald – mid-lake
- Lake Macdonald tailwater, and
- Six Mile Creek downstream of Lake Macdonald.

The water quality results show that many WQOs are typically achieved within Lake Macdonald and Six Mile Creek downstream, but many are not for the tailwater from the dam. WQOs for total and oxidised nitrogen are typically not achieved within the lake or tailwater; and the WQO for chlorophyll-a is also not achieved within the lake (there is no data for downstream waters). The tailwater typically fails to achieve WQOs for: pH, dissolved oxygen, total suspended solids and ammonia.

Long-term monitoring water quality data supplied by Seqwater also indicated that:

- dissolved aluminium was commonly higher than the National Water Quality Guideline (ANZECC & ARMCANZ 2000) for the 95% protection level of aquatic ecosystems in Lake Macdonald
- total aluminium, zinc and cobalt were sometimes higher than the National Water Quality Guideline in Lake Macdonald, and
- total aluminium, chromium, copper, mercury and zinc, and dissolved aluminium, were higher than the National Water Quality Guideline in the Lake Macdonald tailwater.

The *Water Monitoring Data Collection Standards* (DNR 2007) defines a reservoir as stratified if the temperature difference between surface and basement layers exceeds 5ºC. Depth profile measurements of water temperature through the depth profile in Lake Macdonald (mid-lake) were summarised on a monthly basis between November 2011 and November 2017 (i.e. 70 months), with measurements for 69 of these months indicating no stratification. Stratification was detected in only one month (January 2015). Overall, these results indicate that Lake Macdonald rarely stratifies, and when it does it is only weakly stratified.

Table C.12-1:Water Quality Objectives for Protection of Aquatic Ecosystems in lowland waters of the Mary River Basin.

WATER QUALITY PARAMETER	UNIT	WATER QUALITY OBJECTIVE FOR AQUATIC ECOSYSTEM EV		MEDIAN WATER QUALITY RESULT		
			Lake Macdonald – dam wall [b]	**Lake Macdonald – mid-dam [b]**	**Lake Macdonald tailwater [b]**	**Six Mile Creek – downstream Lake Macdonald [c]**
pH	unit	6.5 – 8.0	6.8	7.0	6.4	6.78
Electrical conductivity	µs/cm	<626 [a]	117	116.5	90	161
Dissolved oxygen	% saturation	85 – 110	85.3	93.3	11.78	49.1
Turbidity	NTU	<50	3.6	3.05	17.9	7.9
Suspended solids	mg/L	<6	4.0	3.0	7.0	–
Total nitrogen	µg/L	<500	520	600	550	–
Oxidised nitrogen	µg/L	<60	27	21	10	–
Organic nitrogen	µg/L	<420	570	600	705	–
Ammonia	µg/L	<20	20	12.5	35	–
Total phosphorus	µg/L	<50	20	20	40.5	–
Filterable reactive phosphorus	µg/L	<20	4.0	5.0	2.0	–
Chlorophyll a	µg/L	<5	10	9.0	–	–

[a] based on the 75th percentile of the Sandy Coastal salinity zone in Appendix G of the Queensland Water Quality Guidelines
[b] median calculated from long-term monitoring data supplied by Seqwater
[c] median calculated from data collected by frc environmental during the AHMP program and baseline surveys for the current project
– no data available
Grey shading indicates median results that did not achieve the WQO

Appendix C.B Background Information – Aquatic Flora and Fauna

Aquatic Plants

The aquatic plant community of Lake Macdonald is characterised by a dense cover of the 'restricted biosecurity matter' Cabomba (*Cabomba carolina*), scattered occurrence of the native water snowflake (*Nymphoides indica*), and isolated occurrences of other native aquatic plants, such as Javan pondweed (*Potamogeton javanicus*), water primrose (*Ludwigia peploides*), spike rush (*Eleocharis* sp.), and bull rush (*Typha* sp.). There are few aquatic plants in Six Mile Creek downstream of Lake Macdonald, although there are isolated occurrences of Cabomba and water snowflake. A range of native aquatic plants grow on the banks of Lake Macdonald and Six Mile Creek, including sedges (*Carex* spp. and *Cyperus* spp.), knot weeds (*Persicaria* spp.) and mat rushes (*Lomandra* sp.). The 'restricted biosecurity matter' *Hygrophila* (*Hygrophila cosata*) occurs in high cover along the margins of the lake.

Relatively high concentrations of chlorophyll a, and blue-green algae cell counts, for water samples taken from Lake Macdonald indicate an abundant phytoplankton community.

No threatened species of aquatic plant is known from the Project area. Several aquatic plants known from the Project area are biosecurity matters, including notable infestations of *Cabomba* and *Hygrophila.*

Aquatic Macroinvertebrates

A range of aquatic macroinvertebrates are known from Lake Macdonald and Six Mile Creek, including crustaceans (e.g. river prawns, glass shrimp and crayfish), insects (e.g. aquatic beetles, various aquatic bugs, mayflies, caddisflies and true flies), molluscs (e.g. snails and mussels) and worms.

While the *abundance* of macroinvertebrates is variable but relatively high overall, the overall *diversity* of macroinvertebrates is lower than the biological WQO for macroinvertebrates presented in the EPP(Water) (DERM 2010). The diversity of sensitive taxa, and the abundance of sensitive taxa, also tended to be lower than the biological WQO presented in the EPP(Water) (DERM 2010).

No threatened species of aquatic macroinvertebrate is known from the Project area, and none of the macroinvertebrate species known from the Project area are biosecurity matters.

Fish

The native fish community of the Project area comprised 26 species that are known or likely to occur in Six Mile Creek. The community was numerically dominated by small bodied species, such as Agassiz's glassfish (*Ambassis agassizii*), unspecked hardyhead (*Craterocephalus fulvus*), common gudgeons (*Hypseleotris* spp.), purple spotted gudgeon (*Mogurnda adspersa*), flat head gudgeones (*Philypnodon* spp.), crimson-spotted rainbowfish (*Melanotaenia duboulayi*), Pacific blue-eye (*Pseudomugil signifier*), and Australian smelt (*Retropinna semoni*). Medium-sized native fish included bony bream (*Nematolosa erebi*), spangled perch (*Leiopotherapon unicolor*), eel-tailed catfish (*Tandanus tandanus*) and mouth almighty (*Glossamia gillii*); and large bodied species included eels (*Anguilla* spp.), saratoga (*Scleropages leichardti*), Australian lungfish (*Neoceratodus forsteri*), Australian bass (*Percalates novemaculeata*), yellow belly (*Macquaria ambigua*) and Mary River cod (*Maccullochella mariensis*). Mary River cod is endemic to the Mary River Basin.

A number of diadromous species expected to occur in Six Mile Creek have not been recorded (e.g. striped gudgeon (*Gobiomorphius australi*) and Empire gudgeon (*Hypseleotris compressa*), potentially reflecting cumulative impacts from barriers to fish passage in the lower Mary River between the estuary and Six Mile Creek.

Of the native species occurring in the Project area, several of them:

- occur in Six Mile Creek downstream of Lake Macdonald but do not occur upstream of the Lake Macdonald dam wall (e.g. Pacific blue eyes)
- have been stocked and although native to Australia, do not occur naturally in Six Mile Creek (e.g. saratoga, yellow belly), and
- are threatened species under the *Environmental Protection and Biodiversity Conservation Act 1999* (i.e. are Matters of National Environmental Significance):
  - Mary River cod, listed as endangered, and
  - Australian lungfish, listed as vulnerable.

Surveys have recorded Mary River cod and Australian lungfish only from Six Mile Creek downstream of Lake Macdonald, although records indicate that at least 112,730 Mary River cod fingerlings were released to Lake Macdonald between 1983 and 2015, with 6430 released to Six Mile Creek (MRCCA 2016). There are no records that Australian lungfish have been stocked in Lake Macdonald or Six Mile Creek, and while this species is known from the Project area, Six Mile Creek is not likely preferred habitat for the Australian lungfish and it is consequently considered that this species would be in relatively low abundance in the Project area. In contrast, Six Mile Creek is considered to harbour an important relict population of Mary River cod (Simpson & Jackson 2000), and the high stocking rate suggest that this species has the potential to occur in relatively high numbers, especially in Lake Macdonald. Large numbers of yellow belly and Australian bass have also been stocked to Lake Macdonald, suggesting that the abundance of large bodied fish in Lake Macdonald could be relatively high.

Five pest fish are known from the Project area: eastern Gambusia (*Gambusia holbrooki*), platy (*Xiphophorus maculatus*), swordtail (*Xiphophorus hellerii*), guppy (*Poecilia reticulata*) and tilapia (*Oreochromis mossambicus*), with this latter species only recently recorded for the first time in Six Mile Creek downstream of the Lake Macdonald dam wall. It is currently unknown if tilapia occur in Lake Macdonald, or if the dam wall has prevented this species extending further upstream. Eastern gambusia and tilapia are restricted biosecurity matters.

Two threatened species of fish (Mary River cod and Australian lungfish) occur in the Project area. Two species of fish (Eastern gambusia and tilapia) that are biosecurity matters occur in the Project area.

Turtles

Recent surveys found that four species of turtle (i.e. Krefft's river turtle (*Emydura macquarii*); saw-shelled turtle (*Wollumbinia latisternum*); eastern long-necked turtle (*Chelodina longicolis*); and broad-shelled river turtle (*Chelodina expansa*) occur in the Project area, with the diversity and abundance of turtles higher upstream of the Lake Macdonald dam wall than in Six Mile Creek downstream of Lake Macdonald. It is possible that white-throated snapping turtle (*Elseya albagula*) and Mary River turtle (*Elusor macrurus*), both of which are endemic to the Mary River Basin, also occur in the lower reaches of Six Mile Creek, with white-throated snapping turtle likely occurring further upstream than Mary River turtle. These two species of turtle are threatened species under the EPBC Act 1999, with:

- White-throated snapping turtle listed as critically endangered, and
- Mary River turtle listed as endangered.

Platypus

Platypus (*Ornithorhynchus anatinus*) is known from Six Mile Creek, Lake Macdonald, and the tributaries upstream of Lake Macdonald. This species is listed as Special Least Concern in Queensland's *Nature Conservation (Wildlife) Regulation 2006*, but is not a threatened species.

Aquatic Matters of National Environmental Significance

Matters of National Environmental Significance (MNES) are matters that are protected under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC). This section considers in greater detail, aquatic species that are MNES: Mary River cod, Australian lungfish Mary River turtle and white-throated snapping turtle.

Mary River cod

Status

The Mary River cod (*Maccullochella mariensis*) is listed as endangered under the EPBC Act, and is a 'no take' species under the Queensland *Fisheries Act 1994* except from specific impoundments nominated by DAF to which the species has been stocked.

Distribution

The Mary River cod is endemic to the Mary River system. Through the 1950's to the 1970s, the Mary River cod became very rare in the main channel of the Mary River, Yabba Creek, Munna Creek and Booloumba Creek. Currently, only three tributaries of the Mary River (i.e. Tinana-Coondoo creek, Six Mile creek and Obi Obi Creek) contain relatively abundant numbers of Mary River cod. The approximate area of occupancy across these three creeks is between 5 – 7.5 km^2, with the population size estimated to be fewer than 600 individuals (Simpson & Jackson 1996). In Six Mile Creek, Mary River cod have been caught at the confluence with the Mary River (SKM 2007) and occur in the creek for approximately 40 km upstream to Lake Macdonald. Historically, the Six Mile Creek population has been considered to

be in a stable condition (Simpson & Jackson 1996). In Tinana-Coondoo Creek, Mary River cod occur up to seventy kilometres upstream of the confluence with the Mary river, of which only 25-30% is considered suitable habitat. In Obi Obi creek, the species range extends approximately 10 km upstream from the confluence with the Mary River (Simpson & Jackson 1996). A number of impoundments have been stocked with Mary River cod for recreational fishing (DoE SPRAT Profile).

Preferred Habitats

The pool habitats within Obi Obi, Six Mile and Tinana-Coondoo creeks are known strong-holds for Mary River cod. These pools are not particularly deep (up to 3 m) and usually occur along pool and shallow riffle or run sequences (Simpson & Jackson 1996). The in–stream habitat features preferred by Mary River cod include submerged large woody debris, undercut banks, rock ledges and boulders (SKM 2007; DoE SPRAT profile). Reaches of creek with intact riparian vegetation are also favoured by the species as it provides shade and a supply of woody debris (GHD 2012). Woody debris and other complex submerged habitat features (e.g. boulders, undercut banks) are utilised by the species for foraging, shelter and nesting (SKM 2007; DoE SPRAT profile). Of the three creeks inhabited by Mary River cod, preferred habitat for the species is most common in Tinana–Coondoo Creek. This creek flows through areas of low human population density (Simpson & Jackson 1996). Larval and juvenile fish habitat preferences are relatively unknown.

Water Quality

The reported water quality tolerances of Mary River cod are:

- pH = 6.0 – 7.3
- conductivity (µS/cm) = 100 – 800
- temperature (^{o}C) = 15.7 – 29.0, and
- dissolved Oxygen (mg/L) = 3.9 – 9.7 (Hydrobiology 2008a).

Of the listed water quality parameters, temperature and dissolved oxygen are the most important, as high temperatures and low dissolved oxygen levels can be lethal to the species (DNRM, pers. Com.)

Flow Requirements

Adults of the species typically prefer low flowing water of suitable depth (i.e. 1 – 3 m), and generally avoid shallow (<1 m) areas. During periods of high flow, they shelter amongst woody debris and undercut banks which act to baffle and reduce flow velocities (GHD 2012). Mary River cod have been observed dispersing from 10 km to 70 km over several months following high flows (Simpson & Jackson 1996). Juvenile Mary River cod utilise shallow water habitats, including runs and pools margins, where sufficient cover in the form of trailing root masses or rocky substrates occurs. Spawning is triggered by light episodic rainfall (up to 20 mm) and associated flows, when it coincides with a water temperature of at least 19 ºC and the full moon phase (R Manning 2014, pers. comm.).

Foraging and Movement

Mary River cod typically have relatively narrow home ranges, and have been reported to occupy a particular pool for extended periods (Simpson & Jackson 1996). Within their ranges, movement tends to be upstream during the summer months when rainfall and flows are higher, connecting pools, and downstream or into larger tributaries during the winter months (DoE SPRAT profile). Murray River cod disperse widely as larvae drifting at night for approximately one to two weeks (DoE SPRAT profile), suggesting larval drift could be important for dispersal of Mary River cod.

Mary River cod are predatory and generally feed on smaller fish and crustaceans, most commonly during dawn and dusk; but the species is also known to consume waterbirds and other fauna (DoE SPRAT Profile ; MRCCC ; Aurecon 2013). The species often forages on prey immediately downstream of riffles, presumably due to a constriction of the watercourse and the concentration of prey items (SKM 2007). This suggests that shallow riffle habitat is important for Mary River cod, although this habitat may not be commonly occupied by the species.

Breeding

Mary River cod mature at approximately 38 cm and are considered to be a large, slow growing, long-lived fish with relatively low fecundity (DoE SPRAT Profile; Aurecon 2013). The cod is presumed to spawn more than once a year, initiated by a rise in water temperature to 20 °C during spring and into early summer (Simpson & Jackson 1996). Eggs are typically deposited inside a nest formed by a hollow log or similar habitat features (e.g. submerged open pipe) (Simpson & Jackson 1996). The male will subsequently guard the eggs until they begin to hatch towards the end of the

fourth day at 20°C (Aurecon 2013). The male will continue to guard the brood until they are ready to search for food between seven and nine days after hatching (Aurecon 2013; Simpson & Jackson 1996). In the event that conditions do not coincide i.e. water temperature of at least 19ºC, moon phase at full and light episodic rainfall up to 20 mm, female Mary River cod will reabsorb their eggs and will not spawn (DoE SPRAT Profile).

Threats

There are a number of threats facing the Mary River cod, including:

- Overfishing - overfishing during the late 1800's and early 1900's saw the removal of large numbers of fish (Simpson & Jackson 1996). Currently, fishing for Mary River cod is prohibited in the Mary River, however there is evidence that illegal capture of the Mary River cod still occurs (Simpson & Jackson 1996).
- habitat degradation – specifically clearing of riparian zones, which exposes bank soil to erosion and leaded to sedimentation of pool habitats (Simpson and Jackson 1996). Loss of riparian vegetation also reduced input of branches and other habitat elements that are preferred by Mary River cod
- dams and weirs – impose barriers to movement; while long-range dispersal by cod is not frequent as they generally have relatively small home ranges, periodic movement over longer distances is likely important for the long-term survival of the species (Simpson & Jackson 1996). Cold-water releases from dams and altered flows downstream of dams may also impact breeding and / or survival of larvae (DoE SPRAT Profile)
- pollution – various sources of pollution may impact the suitability of water quality for Mary River cod, with increased nutrients and reduced dissolved oxygen known water quality issued for Mary River cod (Simpson & Jackson 1996), and
- introduced species – may increase competition for food or habitat resources, or may prey on larval and juvenile cod (Simpson & Jackson 1996).

Australian lungfish

Status

Australian lungfish (*Neoceratodus forsteri*) is listed as vulnerable under the EPBC Act, and as a 'no take' species under the Queensland *Fisheries Act 1994*.

Distribution

Australian lungfish is known to occur in the Mary River and several of its tributaries between Conondale (220 km from the mouth of the river) and the Mary River Tidal Barrage (59.3 km from the mouth of the river) (DoE SPRAT profile). It has previously been caught at Coles Crossing and near the confluence of the Mary River and Six Mile Creek (LinkWater Projects 2008). The natural distribution of Australian lungfish also includes the Burnett River system. It has been stocked into several other rivers (e.g. Brisbane River). It is estimated that the Australian lungfish population consists of less than 10,000 individuals (DoE SPRAT Profile).

Preferred Habitats

Generally, Australian lungfish require riparian vegetation comprising eucalypt woodland, native grasslands or minimally modified pastures in moderate to good condition, although the species has been reported from reaches with moderately cleared riparian zones (Smith et al. 2012).

Australian lungfish are generally found in wide, slow-flowing or still permanent reaches with deep pools (i.e. 1 – 3 m) and shallower sections (i.e. 1 – 2 m deep) with abundant aquatic plant cover. Riffles or runs may also be present along a reach (DEWHA 2009). Open water with an absence of complex in-stream structures is not preferred habitat of the species (DoE SPRAT profile).

Australian lungfish tend to inhabit reaches with structurally complex submerged habitat, including submerged logs, high aquatic plant cover and underwater crevices formed by rock scouring and / or undercut banks (SKM 2007; Hydrobiology 2008a; Arthington 2009). Aquatic plant species associated with Australian lungfish habitat include *Vallisneria* sp.*, Hydrilla vertillata, Egeria densa, Ludwigia peploides* and *Nymphoides* sp. (DoE SRPAT profile).

Water Quality

The water quality tolerances of Australian lungfish are:

- pH = 7.0 – 9.1
- conductivity (µS/cm) = 421 – 1165

- temperature (°C) = 10 – 30, and
- dissolved Oxygen (mg/L) = 6.9 – 15.6 (Hydrobiology 2008a).

Flow Requirements

The specific flow requirements for lungfish are only partly understood. Adults of the species are found mostly in permanent still or slow flowing deep pools, or in shallow pools with high cover of submerged aquatic plants. Breeding and recruitment occurs under low flow conditions (i.e. water levels between 10 and 30 cm above cease to flow levels) (Hydrobiology 2008b).

Foraging and Movement

Lungfish are largely sedentary, having home ranges of less than 2 km, although long-term recoding of movement patterns shows that some individuals may move up to 5 km over a number of years (Kind 2002). Most movement is reported to occur during the summer months (Kind 2002).

Lungfish feed on benthic invertebrates, amphibian larvae and aquatic plants (e.g. *Vallisneria* spp. and *Hydrilla* spp.) (Aurecon 2013; DoE SPRAT [rofile). Lungfish tend to forage at night with adults utilising shallow macrophyte beds and juveniles employing ambush tactics (Aurecon 2013; DoE SPRAT Profile).

Breeding

Male Australian lungfish begin breeding at approximately 15 years of age while females first breed at approximately 20 years of age (Aurecon 2013, DoE SPRAT profile). Australian lungfish spawn over a variety of habitats (e.g. woody debris, rocks, boulders and aquatic plants), however, under slow-flow conditions they tend to spawn more commonly among aquatic plants e.g. ribbon weed (*Vallisneria* sp.) (Department of the Environment 2013). Spawning tends to occur at night from August to December and is triggered by increasing day length (Bunn 2008; Espinoza et al. 2012; DoE SPRAT profile). If spawning habitat is disturbed, Australian lungfish will either delay breeding or skip breeding entirely (DoE SPRAT profile). After spawning the Australian lungfish thrash their tail to disperse eggs that then adhere to submerged surfaces (DoE 2014). A single clutch consists of 50 to 100 eggs (DoE SPRAT profile). Hatching of eggs occurs approximately one month after fertilisation (McGrouther 2013). Juvenile lungfish are almost exclusively found in dense submerged aquatic plant beds (DoE SPRAT profile). Recently hatched lungfish are poor swimmers, and tend to rest on their sides on the stream bed while they digest their yolk and avoid daylight (DoE SPRAT profile).

Threats

The main threats to Australian lungfish are:

- Dams - impoundments act as a physical barrier to breeding sites; lungfish will migrate to find suitable areas for breeding. However, if they are unable to reach appropriate breeding habitat due to obstructions, spawning will not occur that year (Arthington 2009; DoE SPRAT profile). Repeated failure to breed may cause lungfish populations to decline substantially in a small number of generations (Aurecon 2013; DoE SPRAT profile). Furthermore, fluctuations of water levels in impoundments can result in stranding of lungfish and mortality of lungfish eggs (Arthington 2009; DoE SPRAT profile); and some reservoirs are known to undergo periods where lungfish density is very high (i.e. crowding of lungfish), which reduces the health and condition of lungfish at these times (DoE SPRAT profile).
- Fishing - recreational fishers are known to unintentionally catch the Australian lungfish. While some are returned to the water and survive others are unaccounted for (DoE SPRAT profile).
- Exotic fish species - predation on lungfish eggs and juveniles by exotic and native translocated fish species has also put pressure on the lungfish population, and alien fish also compete with adults for breeding habitat (Arthington 2009; DoE SPRAT profile), and
- Habitat degradation – specifically clearing of riparian zones, which exposes bank soil to erosion and leads to sedimentation of pool habitats.

Mary River turtle

Status

The Mary River turtle (*Elusor macrurus*) is listed as endangered under the EPBC Act, and endangered under the NC Act.

Distribution

The Mary River turtle has been recorded in the Mary River and several of its tributaries (e.g. Yabba Creek and Tiana Creek) between Kenilworth (260 km from the river mouth) and the Mary River tidal barrage at Tiaro (Limpus 2007; SKM 2007 and references cited therein; Red Leaf Projects 2013; DoE 2014a). Individuals of the species have well defined home ranges and show strong site fidelity (Cann & Legler 1994; DEWHA 2008; Kuchling 2008; Limpus 2008; Micheli-Campbell et al. 2013).

Preferred Habitats

Much of the Mary River turtle habitat is surrounded by cleared grazing and agricultural land, although in such reaches, the species has been caught in areas where the river is wide and there is trailing vegetation and in-stream habitat (Cann & Legler 1994). Some areas of Mary River turtle habitat retain some riparian and catchment vegetation, especially in upper catchment areas and along several tributaries.

The species is regularly associated with areas of submerged habitat, including sparse to dense aquatic plant coverage, woody debris and rock crevices (SKM 2007 and references cited therein). Similar to other reptiles, the Mary River turtle often basks on emerging rocks and logs within the waterbody or along its banks (Cann & Legler 1994).

Water Quality

There are no specific water quality tolerances that have been published for Mary River turtle, however, they are known to prefer flowing water with high concentrations of dissolved oxygen (Thomson et al. 2006). It would be reasonable to assume that their preferences for other water quality parameters (e.g. temperature, electrical conductivity, turbidity and pH) would be similar to that of the Mary River cod, given that both species are endemic to the Mary River. Declines in water quality may reduce the efficiency of cloacal respiration by Mary River turtle, which can reduce foraging efficiency and more frequently expose juveniles to predators at the water surface.

Flow Requirements

The Mary River turtle prefers habitats characterised by shallow, fast-flowing streams with riffle zones and well-oxygenated water, and reaches with deep connected pools (depth ranging from approximately 1 m – 5 m) (DEWHA 2008; Flakus & Connell 2008). During flooding, the Mary River turtle takes refuge in backwaters until flow decreases to pre-flood levels (Sadlier et al. 2004). They are also known to swim upstream during moderate to high flow events, returning to the same pool once water levels recede (Flakus & Connell 2008).

Foraging and Movement

The Mary River turtle is omnivorous and feeds on aquatic plants (including algae) and invertebrates (including bivalves) (Cann & Legler 1994). Juvenile Mary River turtles eat aquatic insect larvae, supplemented by freshwater sponges, aquatic plants including green algae, and fruits of some terrestrial trees (Flakus 2002; Micheli-Campbell et al. 2013). During the winter months movement is generally limited to within a particular reach; however, movement up to 2 km in search of breeding sand banks have been recorded during the early summer months (Sadlier et al. 2004).

Breeding

Mary River turtles live for between 30 and 80 years of age and do not breed until between 15 and 25 years of age (Limpus 2008). Sparsely vegetated sandy river banks in close proximity to riffles and pools are preferred nesting habitats, with these sites revisited across decades by the same individual (Flakus 2002; Limpus 2008). Breeding occurs only once every year with a clutch size of approximately 13 eggs (Flakus et al 2008). Successful hatching is dependent on 50 consecutive days of non-inundation after nesting. For this reason, nests are typically located 5 m above the water level and up to 30 m inland from the watercourse. Nesting occurs in late October to December after the first significant summer rain (Cann & Legler 1994; Flakus & Connell 2008; Limpus 2008). Depending on sand temperature, eggs have an incubation period of 50 – 56 days (Cann & Legler 1994).

Threats

Major threats to the Mary River turtle include:

- Nest predation and reduced success of recruitment - for twelve years during the 1960's and 1970's large numbers of Mary River turtle eggs were collected for commercial purposes (DoE SPRAT Profile; Bunn 2008; Limpus 2008). As a result, little to no recruitment occurred during this time and this has resulted in poor breeding success of Mary River turtle for four decades (DoE SPRAT profile). Furthermore, pressure from

predation in nesting areas by foxes, goannas and wild dogs has meant the hatching success of the Mary River turtle continues to be very low (DoE SPRAT Profile; Flakus et al 2008; Limpus 2008).

- Dams - impoundments do not provide suitable habitat for the Mary River turtle, having typically still water with low levels of dissolved oxygen that reduces the efficiency of cloacal respiration (DoE SPRAT profile). There is also a decline in types and quality of food available for Mary River turtles in impoundments due to fluctuating water levels; aquatic plants and terrestrial fruiting trees do not tolerate inundation and will consequently die back. Dams also lack the insect larvae of flowing water habitats comprise part of the diet of the Mary River turtle (DoE SPRAT profile). Lastly, dams reduce the availability of suitable nesting habitat, as they do not support suitable sandy banks, and dams act as a physical barrier preventing females from reaching nesting sites (DoE SPRAT profile).
- Habitat degradation - including clearing of the riparian zone, which exposes bank soil to erosion and leaded to sedimentation of pool habitats, and sand and gravel mining which results in the destruction of sand banks that are used as nesting sites. The Mary River turtle may increase territorial behaviour with reduced habitat and breeding area, leading to a decrease in population size (DoE SPRAT profile).

White-throated snapping turtle

Status

White-throated snapping turtle (*Elseya albagula*) is listed as critically endangered under the EPBC and endangered under the NC Act.

Distribution

The white-throated snapping turtle is restricted to the Fitzroy, Mary and Burnett river catchments in Queensland (Threatened Species Scientific Committee 2014). The species has also been recorded in:

- adjacent small coastal river basins, including the Kolan and Gregory-Burrum systems (Hamann et al. 2007)
- impoundments upstream of weirs such as Eden Bann Weir and Glebe Weir (Limpus et al. 2007), and
- the spring-fed pools of the Dawson River (Hamann et al. 2007; frc environmental 2008).

White-throated snapping turtle is widely distributed in the Mary River and its major tributaries, including Tinana, Wide Bay, Obi Obi and Yabba creeks (Limpus et al. 2008).

Preferred Habitats

White-throated snapping turtles are habitat specialists that prefer permanent, clear, well oxygenated water that is flowing and contains shelter (e.g. large woody debris and undercut banks) (Limpus et al. 2008; Todd et al. 2013). The species has also been recorded in non-flowing waters, such as impoundments (e.g. Borumba Dam, Imbil Weir, Mary River Barage) but only in low numbers (Limpus et al. 2008; Threatened Species Scientific Committee 2014). Within the greater Fitzroy, Burnett and Mary river catchments, this species has been recorded almost exclusively in close association with permanent flowing stream reaches that are typically characterised by a sand-gravel substrate with submerged rock crevices, undercut banks and / or submerged logs and fallen trees, and are rarely found in reaches without such refuge (Hamann et al. 2007; Limpus et al. 2007). Across its distribution, individuals have been recorded from both shallow and deep, slow flowing pools (Hamann et al. 2007).

White-throated snapping turtles are rarely present in water bodies that are isolated from flowing streams, such as farm dams or sewage treatment ponds, suggesting that the species does not move extended distances over dry land (Hamann et al. 2007; Limpus et al. 2008). However, white-throated snapping turtles have been observed walking short distances from drying waterholes to nearby water bodies (Limpus et al. 2007).

Water Quality

There are no published water quality tolerances for white-throated snapping turtle, although they are known from flowing streams with generally clear, well-oxygenated water.

Flow Requirements

Flowing streams with clear water, in both shallow or deep pools. Uncommon in non-flowing waters and isolated waterbodies that are not connected to flowing water habitats. As the species is a cloacal ventilating species, it is thought that it would not function well in deeper habitats of larger pools where dissolved oxygen concentrations are low, such as dry season conditions in standing water bodies (Limpus et al., 2008), although could be in shallow upper reaches of impoundments where there are inflows.

Foraging and Movement

White-throated snapping turtles feed primarily on aquatic plants along with fruits and leaves from overhanging riparian vegetation (Limpus et al. 2007). They may also eat periphyton, freshwater bivalves and insects, particularly when plant food resources are limited (Limpus et al. 2007). The diet of juveniles is dominated by invertebrates, whereas the diet or larger individuals (i.e. standard carapace length < 6 cm) is dominated by plant material (Limpus et al. 2008).

Little is known of the movement patterns of these turtles in the greater Fitzroy River catchment. However, in the Burnett River they generally have small home ranges of less than 500 m and have limited spatial and temporal movements (Hamann et al. 2007).

Breeding

The life history of white-throated snapping turtles is characterised by a long life span and slow growth to maturity (Threatened Species Scientific Committee 2014). The age at first breeding is approximately 15 to 20 years (Limpus et al. 2011). Breeding occurs once per year, mostly during autumn and winter, with adult females breeding in each successive year unless the turtle has been injured or debilitated, or riverine habitat has been altered (e.g. water extraction, drought or weeds) (Threatened Species Scientific Committee 2014). Females generally nest on sandy banks, although nests have been observed on loose gravels and soils. Females lay a single clutch of eggs during the breeding season, with an average of 14 eggs per clutch (Hamann et al. 2007; Limpus et al. 2011). Nests are generally laid in areas of low canopy cover and in areas of dense grass cover; however, dense weeds at the water's edge may limit suitability of potential nesting banks (Hamann et al. 2007; Limpus et al. 2011). Nests are an average of 16.6 m from the water's edge, with eggs laid in deep chambers (greater than 20 cm in depth) and on banks with a slope of up to 26.5º (Hamann et al. 2007; Limpus et al. 2011). However, nests have been recorded up to 60 m from the water (Hamann et al. 2007). White-throated snapping turtles will repeatedly use specific areas of banks over multiple years (Limpus et al. 2007).

There is no parental care, and egg and small juvenile survival is typically low (Heppell et al. 1996; Hamann et al. 2007). There is abundant evidence of nesting in all three river basins (i.e. Fitzroy, Burnett and Mary River Basins), but most eggs are lost to predation or trampling by stock (Hamann et al. 2007; Limpus et al. 2011). The population growth or decline rate is highly responsive to changes in adult survivorship, rather than changes in egg or juvenile survivorship (Heppell et al. 1996). Nonetheless, where egg predation rates are high, population growth rate will be constrained.

Threats

The principal threat to white-throated snapping turtles in all three catchments is the excessive loss of eggs and hatchlings due to predation (Threatened Species Scientific Committee 2014). Primary predators include feral (e.g. foxes, dogs, pigs and cats) and native (e.g. water rats and lizards) animals. Trampling of nests by cattle is also a major threat.

An additional threat to this species includes limited suitable habitat, which is highly fragmented across its distribution range due to dams and weirs. Waterway impoundments, such as dams, barrages and weirs, also form significant barriers to the passage of freshwater turtles. The number of dead and injured turtles can be much greater in pools immediately downstream of weirs than in pools distant from weirs, presumably a result of turtles being swept downstream and over impoundments during major and sudden water releases (Hamann et al. 2007).

Other threats to this species are:

- stocking of fish into dam impoundments for recreational fishing
- recreational fishing resulting in hook injuries
- boat strike
- loss of nesting habitat to weed infestation in the riparian zone
- dense aquatic weeds in the waterways, and
- water extraction for agriculture and irrigation (Limpus et al. 2011).

References

Arthington, A.H., 2009, 'Australian lungfish, Neoceratodus forsteri, threatened by a new dam', Environmental Biology of Fishes 84: 211-221.

Aurecon, 2013, River cod (Maccullochella mariensis) and Australia Lungfish (Neoceratodus forsteri), report prepared for Department of Transport and Main Roads.

Bunn, S.E., 2008, Review of EIS and supplementary materials on proposed Traveston Crossing Dam, Mary River, SE QLD: II: Final report, , report prepared for Department of the Environment, Water, Heritage and the Arts.

Cann, J. & Legler, J.M., 1994, 'The Mary River Tortoise: A New Genus and Species of Short-Necked Chelid from Queensland, Australia (Testudines: Pleurodira)', Chelonian Conservation and Biology 1: 81-95.

DEWHA, 2008. Approved Conservation Advice for Elusor macrurus (Mary River Turtle).

Espinoza, T., Marshall, S.M. & McGougall, A.J., 2012, 'Spawning of the endangered Australian lungfish (neoceratodus fosteri) in a heavily regulated river: A pulse for life.', River research applications QLD dept. of natural resources and mines QLD Aus.

Flakus, S., 2002, The ecology of the Mary River turtle, Elusor macrurus. M.Sc. thesis, Department of Zoology and Entomology, The University of Queensland, Brisbane.

Flakus, S. & Connell, M., 2008, 'The Mary River Turtle: Yesterday Today and Tomorrow, Landcare Tiaro & District.

frc environmental, 2008, Blackwater Creek Diversion, Aquatic Ecology; Impact Assessment and Baseline Monitoring, report prepared for Parsons Brinckerhoff Australia Pty Ltd.

GHD, 2012, Bruce Highway (Cooroy to Curra) Upgrade - Construction Environment Management Plan - Giant Barred Frog and Mary River Cod, report prepared for Department of Transport and Main Roads.

Hamann, M., Schauble, C.S., Limpus, D.J., Emerick, S.P. & Limpus, C.J., 2007. Management Plan for the conservation of Elseya sp. [Burnett River] in the Burnett River Catchment. Queensland Environmental Protection Agency: Brisbane.

Heppell, S.S., Crowder, L.B. & Crouse, D.T. 1996, 'Models to evaluate headstarting as a management tool for long-lived turtles', Ecological Applications 6: 556-565.

Hydrobiology, 2008a, Northern Pipeline Infrastructure Stage 2 EIS Six Mile Creek Study. Prepared for LinkWater.

Hydrobiology, 2008b, NPI Stage 2 EIS: Potential Effects of Water Abstraction on Aquatic MNES Species in the Mary River and Six Mile Creek. Prepared for LinkWater.

Kind, P.K., 2002. Movement patterns and habitat use in the Queensland lungfish, Neoceratodus forsteri (Krefft, 1870), PhD. University of Queensland, Brisbane.

Kuchling, G., 2008, Independent Expert Review of the Information Provided in the Traveston Crossing Dam EIS that Relates to the Mary River Turtle, Chelonia Enterprises, Subiaco.

Limpus, C.J., 2008, Freshwater Turtles in the Mary River: Review of biological data for turtles in the Mary River, with emphasis on Elusor macrurus and Elseya albagula, Queensland Government, Brisbane.

Limpus, C.J., D.J., L., Parmenter, C.J., Hodge, J., Forrest, M.J. & McLachlan, J.M., 2007, Proposal for raising Eden Bann Weir and construction of Rookwood Weir – An assessment of the potential implications and mitigation measures for Fitzroy Turtles (Elseya albagula and Rheodytes leukops), report prepared for Environmental Protection Agency, Queensland Government.

Limpus, C.J., Limpus, D.J., Parmenter, C.J., Hodge, J., Forest, M. & McLachlan, J., 2011, The Biology and Management Strategies for Freshwater Turtles in the Fitzroy Catchment, with particular emphasis on Elseya albagula and Rheodytes leukops: A study initiated in response to the proposed construction of Rookwood Weir and the raising of Eden Bann Weir, report prepared for Department of Environment and Resource Management

LinkWater Projects, 2008, Northern Pipeline Connector – Stage 2 Environmental Impact Statement, LinkWater Projects.

McGrouther, M., 2013, Australian Lungfish, Neoceratodus forsteri (Krefft, 1870), http://australianmuseum.net.au/Australian-Lungfish-Neoceratodus-forsteri-Krefft-1870/, accessed July 2018.

Micheli-Campbell, M.A., Campbell, H.A., Connell, M., Dwyer, R. & Franklin, C.E., 2013, 'Integrating telemetry with a predictive model to assess habitat preferences and juvenile survival in an endangered freshwater turtle', Freshwater Biology 58: 2253-2263.

Sadlier, R., Shea, G. & Muir, G., 2004, Survey guidelines for Australia's threatened reptiles, Department of Sustainability, Environment, Water, Population and Communities.

Simpson, R. & Jackson, P., 1996, The Mary River Cod Research and Recovery Plan, Queensland Department of Primary Industries - Fisheries Group.

SKM, 2007, Traveston Crossing Dam Environmental Impact Statement, report prepared for Queensland Water Infrastructure Pty Ltd.

Threatened Species Scientific Committee, 2014, Conservation Advice for Elseya albagula White-throated snapping turtle, http://www.environment.gov.au/biodiversity/threatened/species/pubs/81648-conservation-advice.pdf, accessed July 2018.

Thomson, S., Georges, A. & Limpus, C.J., 2006, ' A new species of freshwater turtle in the genus Elseya (Testudines - Chelidae) from central coastal Queensland, Australia', Chelonian Conservation and Biology 5: 74-86.

Todd, E.V., Blair, D., Farley, S., Farrington, L., Fitzsimmons, N.N., Georges, A., Limpus, C.J. & Jerry, D.R., 2013, 'Contemporary genetic structure reflects historical drainage isolation in an Australian snapping turtle, Elseya albagula', Biological Journal of the Linnaean Society 169: 200-214.