7. Aquatic ecology

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7.1 Introduction

7.1.1 Overview

This chapter provides an assessment of aquatic ecology values and potential impacts as they relate to the Lower Fitzroy River Infrastructure Project (Project). The assessment addresses Part B, nature conservation, specifically aquatic ecology, sections 5.61 – 5.69, 5.76 – 5.87. 5.88 – 5.91 of the terms of reference (ToR) for the environmental impact statement (EIS). A table cross-referencing the ToR requirements is provided in Appendix B. Appendix J and Appendix K provide supporting baseline information in relation to aquatic fauna values of the Project (Eden Bann Weir and proposed Rookwood Weir, respectively) as well as detailed methodologies used for seasonal field surveys. Appendix L provides detail with regard to the Fitzroy River turtle (*Rheodytes leukops*). Cumulative impacts on aquatic ecology values are addressed in Chapter 21 Cumulative impacts. Where appropriate, management measures relating to aquatic fauna values are used to inform the environmental management plan (EMP) (Chapter 23). A separate species management program (SMP) for the Fitzroy River turtle is provided at Appendix M. Volume 2 of the EIS specifically addresses listed threatened species and ecological communities listed as matters of National Environmental Significance (MNES) under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act).

7.1.2 Approach and methodology

7.1.2.1 Desktop assessment

Prior to the commencement of field surveys (undertaken in 2009), and then again more recently (2013), a desktop assessment was conducted. The following databases, mapping layers and literature were reviewed:

- EPBC Act Environmental Reporting Tool (2009) and Protected Matters Search Tool (2013)

  The search area was defined by a 2 km buffer following watercourses upstream and downstream from Eden Bann Weir and the proposed Rookwood Weir site. The search area included Alligator Creek and the Fitzroy River and estuary downstream from Eden Bann Weir; the Fitzroy River between Eden Bann Weir and the Rookwood Weir site; and stretches of the Dawson and Mackenzie rivers upstream from the Rookwood Weir site.

- Queensland Government Wildlife Online database

  Searches were undertaken in 2008 and updated in 2013 to identify fauna species that have been historically recorded in or surrounding the Project areas including threatened species listed under the *Nature Conservation Act 1992* (Qld) (NC Act). The search area was defined by search rectangles encompassing a 2 km buffer following watercourses upstream of Eden Bann Weir and the proposed Rookwood Weir to the Stage 3 and Stage 2 inundation extents, respectively and downstream to the Fitzroy Barrage.

- The Queensland Department of Natural Resources and Mines (DNRM) Essential Habitat (Version 3.1, 2011) mapping database

- Queensland Museum's Specimen Database

  Search rectangles encompassing the area around Eden Bann Weir, the proposed Rookwood Weir site and the respective Stage 3 and Stage 2 upstream inundation extents, and downstream to the Fitzroy Barrage were assessed.

- Back on Track Actions for Biodiversity document for the Fitzroy Natural Resource Management region (DERM 2008)
- Fitzroy Basin Draft Water Resource Plan Environmental Assessment – Stage 1 Background Report (DERM 2009)

  A report that summarises the basic water resource management profile, environmental provisions, the previous planning strategies and the water monitoring programs for the Fitzroy Basin.
- Fitzroy Basin Draft Water Resource Plan Environmental Assessment – Stage 2 Assessment Report (DERM 2010)

  A report detailing the outcomes of technical ecological assessments (including ecological risk assessments and climate change analyses) and reviews of the Water Resource (Fitzroy Basin) Plan 1999 and the Fitzroy Basin Resource Operations Plan 2004 (amended in 2009).
- Previous studies and reports conducted for the Project and other scientific literature and other relevant material covering a wide range of studies focussing on various aspects of the aquatic ecology of the study area, and of the ecology of species known to occur in the study area. Details of these reports are provided in Appendix J and Appendix K.

7.1.2.2 Aquatic habitat calculation

The area of aquatic habitat to be impacted by the impoundments was calculated based on the digitisation of the river (water within river channel excluding rock and sand banks) using satellite imagery (Digital Globe World View 2, 2010) between the upper limit of the existing and proposed Eden Bann Weir impoundment and within the proposed Rookwood Weir impoundment. This was then cross-checked against river bed level cross-section data at 81 locations. While water levels in the system fluctuate seasonally, July was considered appropriate to represent early dry season water levels that are not influenced by wet season flows. Further detail on the method used to calculate aquatic habitat area is provided in Appendix J and Appendix K.

7.1.2.3 Field surveys

Field surveys were undertaken to ground-truth and supplement existing information on the aquatic ecological values of the Project footprints and verify species expected to occur, including the likely occurrence of EPBC Act and NC Act listed aquatic fauna species. Project footprints comprise the Eden Bann Weir site (and immediate downstream reaches) and associated impoundment; reaches between Eden Bann Weir and the proposed Rookwood Weir site; the Rookwood Weir site itself and associated impoundment along with river crossing locations.

Verification was based on direct and indirect (suitable habitat) observations. Survey timing and design considered:

- Seasonal variation to document seasonal changes in aquatic fauna assemblages, habitat condition and abundance within habitats
- The ecology of targeted threatened species
- Access and workplace health and safety requirements.

Specifically field surveys comprised:

- Assessment of aquatic habitat characteristics and values

- Assessment and mapping of potential freshwater turtle nesting banks, in particular the Fitzroy River turtle
- Fish trapping to sample species diversity
- Macroinvertebrate sampling
- Opportunistic recordings of conservation significant fauna.

Habitat assessment

Habitat assessments were conducted at sites representing aquatic habitats throughout the Project footprints and in downstream reaches to the Fitzroy barrage (as applicable). These included:

- Impounded (weir) pools: weir pool upstream of the existing Eden Bann Weir. The impounded pool comprises generally non-flowing, typically deep water impounded within the bed and banks of a river upstream of the weir wall
- Pools: pools that occur naturally within the riverine environment (as distinct from impounded pools) comprise relatively deep, still or very slow flowing water over variable substrates (AusRivAS 2001)
- Riffles: riffle zones comprise shallow (<0.3 m), fast flowing (>2 m/s) water over a stony bed (AusRivAS 2001)
- Runs: river runs comprise relatively deep, fast flowing unbroken water over a sandy, stony or rocky bed (AusRivAS 2001)
- Off-stream water bodies: these include palustrine wetlands (swamps and billabongs) and lacustrine habitat (ox-bow lakes and farm dams) in the floodplain within 1 km of the main channel; and flood-runners or secondary channels within the bed and banks. For the purpose of this assessment, off-stream water bodies within 1 km of the main channel and the lower reaches of adjoining creeks were considered
- Creeks: for the purposes of the assessment creeks comprised the lower reaches of tributaries adjoining the main river channel that persist for varying distances across the adjacent floodplain and beyond.

Habitat boundaries (that is the difference between a riffle and a run and the extent of the weir pool) vary between seasons. The percentages of each habitat type within the Project footprint provide an example of aquatic habitat extent at the time of assessment only. These values are likely to fluctuate substantially in response to seasonal variability in water flows and management of the storage.

Parameters recorded included:

- Stream channel and bank morphology (channel width, depth and bank height)
- Bank profile
- Substrate description (bedrock, gravel, sand or silt)
- Presence of plant material (aquatic plants (macrophytes), algae and submerged logs)
- Riparian vegetation description (width and length of stream side vegetation, overhanging and native vegetation)
- Adjacent land use

- Water velocity (deep and shallow areas)
- Position in relation to existing or proposed impoundment.

Habitat characteristics were defined (excellent, good, fair or poor) in accordance with a sub-sample of habitat variables from the Queensland Australian River Assessment System (AusRivAS 2001) Bioassessment Program criteria as relevant to the Project areas.

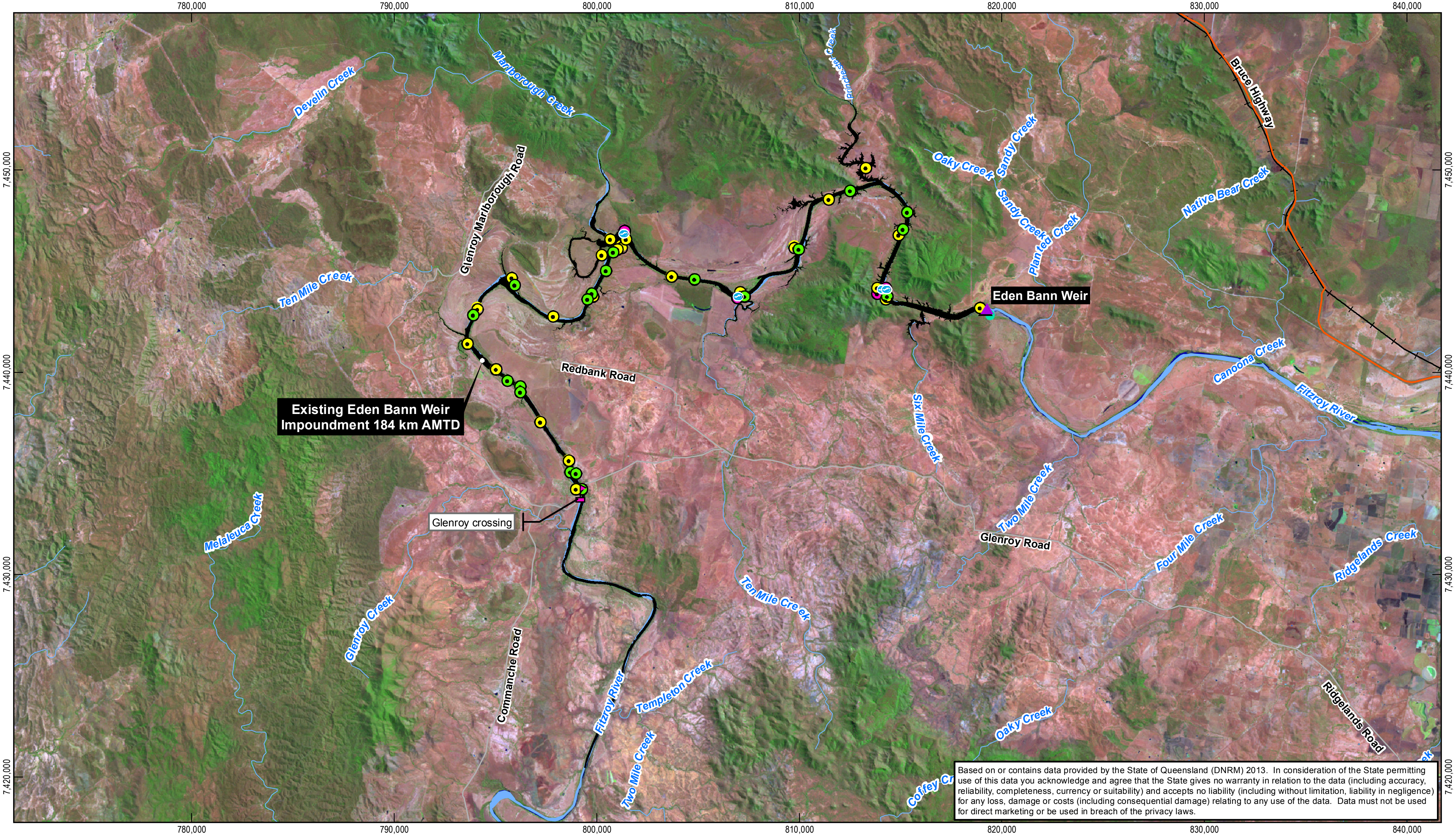
In the absence of being able to access all habitats, a habitat segment analysis was utilised to assess the extent of aquatic habitats, within, upstream and downstream of the Project footprint. The distribution and linear extent of aquatic habitat types were quantified and mapped from aerial photographs, and where possible, verified in the field (within the Project footprints during field studies and during the reconnaissance aerial overflight). Habitat boundaries were estimated based on the visual characteristics observed. For downstream reaches not accessed, habitat quality was inferred to be similar to that of the aquatic habitats assessed within the Project footprints, given the similarity of surrounding land uses up and downstream.

Where creek and off-stream water body habitats could not be accessed, the spatial distribution or extent of the habitat was assessed using the Queensland Government's Wetland Info Mapping Service in conjunction with satellite imagery. Habitat boundaries were estimated based on the visual characteristics observed. The extent of each habitat type in the main river channel within and downstream of the Project footprint was calculated based on the percentage of river length covered by each habitat type (off-stream water bodies and adjoining creeks were not included). Habitat boundaries (that is the difference between a riffle and a run and the extent of the weir pool) vary between seasons. The percentages of each habitat type within the Project footprint provide an example of aquatic habitat extent at the time of assessment only. These values are likely to fluctuate substantially in response to seasonal variability in water flows and management of the storage.

Table 7-1 summarises survey effort in relation to habitat assessments. Habitat assessment locations are provided in Figure 7-1 and Figure 7-2 for Eden Bann Weir and Rookwood Weir Project footprints, respectively.

Table 7-1 Summary of survey effort

Task description	Eden Bann Weir		Rookwood Weir	
	Wet season - January/February 2009	Dry season - July 2009	Wet season - April/May 2009	Dry season - July 2009
Aquatic habitat assessment (number of sites)	23	4	3	14
Turtle nesting bank surveys (number of sites)	19	0	11	7
Fish trapping				
• Number of Fyke trap nights	10	10	7	15
• Number of baited trap nights	14	0	15	30
Number of artificial substrate sites	2	4	1	0



1:250,000 (at A4)

0 2.5 5 7.5 10

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Weir Location
- River Crossing
- Highway
- Minor Road
- Railway
- Impoundment Area
- Waterway
- Aquatic Fauna Trapping Site (GHD)
- Turtle Nesting Bank Survey Site (GHD)
- Habitat Assessment Site (GHD)
- Macroinvertebrate articial substrate sites (GHD)
- Principal study sites (Limpus et al 2011)

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Lower Fitzroy River Infrastructure Project

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Revision	C
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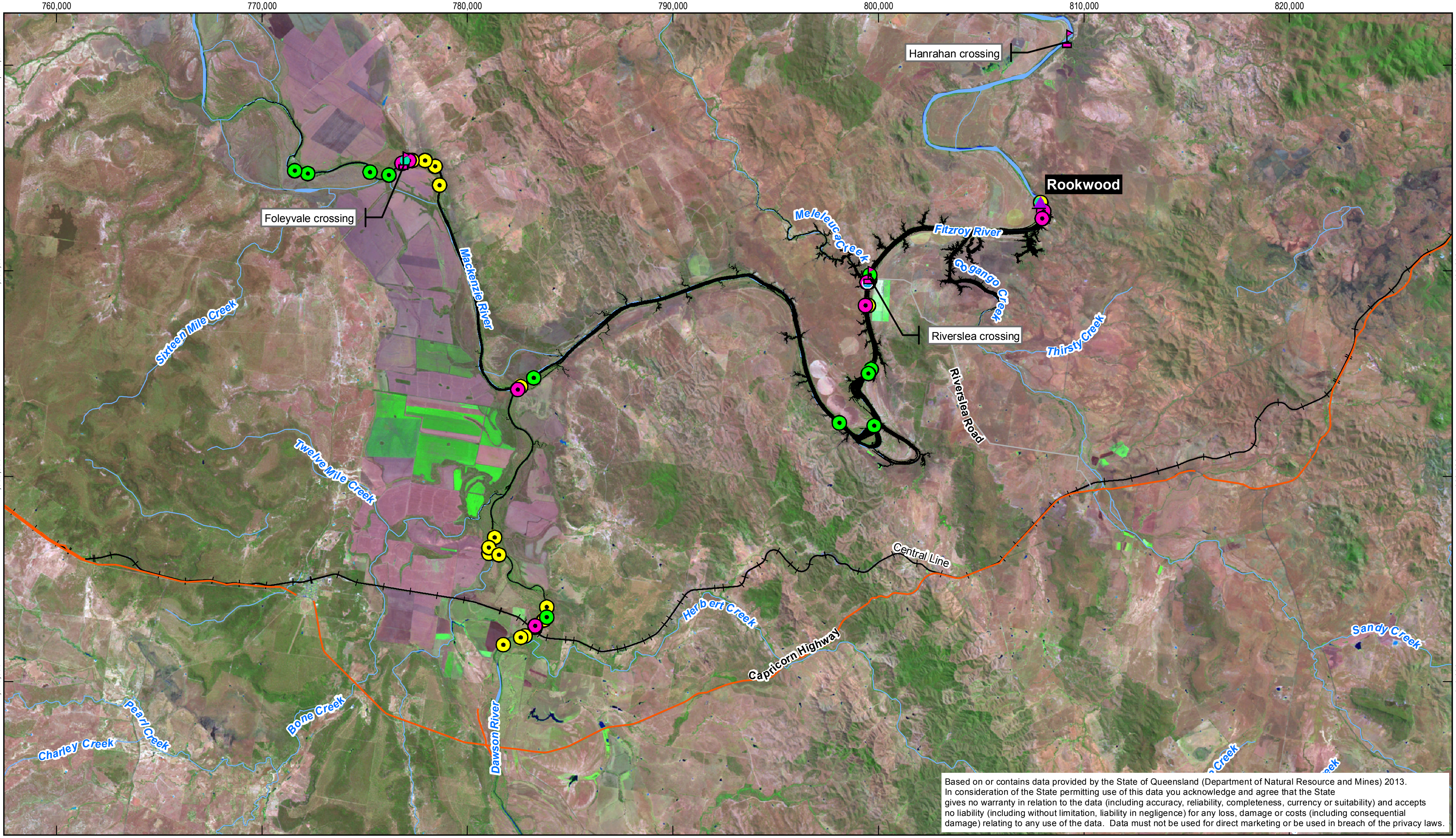
Eden Bann Weir Aquatic Ecology Footprint and Aquatic Survey Sites

Figure 7-1

G:\41\20736\GIS\Projects\MXD\900_Baseline Terrestrial Fauna Report\4120736_909_Eden_Bann_Survey_Sites_Rev_C.mxd

Level 9, 145 Ann St Brisbane QLD 4000 T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com.au W www.ghd.com.au

Data Source: © Copyright Commonwealth of Australia (Geoscience Australia): Waterways, State (2007); Sunwater: Waterways, Weir Locations - 2008; DNRM: Roads - 2010, Railways - 2010, Imagery/2005; GHD Fauna Survey - 2009. Created by IH,MS



1:250,000 (at A4)

0 2.5 5 7.5 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA94)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Weir Location
- River Crossing
- Highway
- Minor Road
- Railway
- Impoundment Area
- Waterway
- Aquatic Fauna Trapping (GHD)
- Habitat and Turtle Nesting Bank Assessment (GHD)
- Turtle Nesting Bank Assessment (GHD)
- Macroinvertebrate articial substrate sites (GHD)
- Principal study sites (Limpus et al 2011)

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Gladstone Area Water Board

SunWater Making Water Work

Gladstone Area Water Board, SunWater
Lower Fitzroy River Infrastructure Project

Job Number	41-20736
Revision	C
Date	01 Aug 2014

Rookwood Aquatic Ecology Project Footprint and Aquatic Survey Sites

Figure 7-2

G:\41\20736\GIS\Projects\MXD\900_Baseline Terrestrial Fauna Report\4120736_912_Rookwood_Survey_Sites_Rev_C.mxd

Level 9, 145 Ann St Brisbane QLD 4000 T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com.au W www.ghd.com.au

Data Source: © Copyright Commonwealth of Australia (Geoscience Australia): Waterways, State (2007); Sunwater: Waterways, Weir Locations - 2008; DNRM: Roads - 2010, Railways - 2010, Imagery/2005; GHD Fauna Survey - 2009. Created by IH

Freshwater turtles

An assessment of freshwater turtle populations within the Fitzroy Basin catchment was conducted by the (then) Department of Environment and Resource Management (DERM) in 2007, with a specific focus on the proposal for raising Eden Bann Weir and constructing a new weir at Rookwood (Limpus et al. 2011a). The DERM assessment (Limpus et al. 2011a) involved field studies (along with a review of past studies within the catchment since 1997) and sampled an extensive range of habitats including: isolated spring fed pools, farm dams, backwaters, weir pools and natural river habitats. Survey locations relevant to Project areas are included in Figure 7-1 and Figure 7-2, for Eden Bann Weir and the proposed Rookwood Weir, respectively. The field surveys (Limpus et al. 2011a) involved a combination of tag and release turtle capture techniques including: snorkelling; dip netting, trapping (various designs); seine netting and muddling. Data collected (Limpus et al. 2011a) included turtle abundance, diversity and density; distribution and habitats; life history parameters (sex, age, maturity, reproductive status); mortality and injury; and nesting characteristics. Turtle population surveys (Limpus et al. 2011a) were taken to be in accordance with the Commonwealth's Survey guidelines for Australia's threatened reptiles (Commonwealth of Australia 2011).

Additional trapping for turtles was not undertaken during Project field surveys carried out in 2009. Where freshwater turtles were captured in fish nets they were identified to species level with sex, size and age class recorded along with any tag information (as present).

To supplement the freshwater turtle population assessment (Limpus et al. 2011a), and in particular the distribution and abundance of the Fitzroy River turtle, targeted nesting bank surveys were undertaken within the Eden Bann Weir and proposed Rookwood Weir Project footprints in accordance with standard DERM methodology (Limpus et al. 2011a) and as discussed with the Department of Environment and Heritage Protection's (DEHP's) Chief Scientist, Aquatic Threatened Species Division, Dr Col Limpus. Turtle nesting bank survey effort is summarised in Table 7-1. Figure 7-1 and Figure 7-2 show freshwater turtle nesting bank survey locations relative to Eden Bann Weir and the proposed Rookwood Weir, respectively.

Freshwater turtle nesting bank surveys along stream bank margins comprised single strip transects parallel to the water's edge with the following parameters recorded:

- Bank length
- Bank width
- Approximate slope
- Substrate type
- Per cent vegetation cover
- Distance from and height above the water's edge
- Evidence of turtle activity and/or nesting (turtle tracks, diggings, predated egg shells)
- Evidence of disturbance (for example by cattle and/or pigs).

Based on an assessment of the above parameters each bank identified was assigned a broad turtle nesting habitat suitability rating (low, medium, high or confirmed) (Appendix J, Appendix K and Appendix L).

Fish species

Fish species in riverine habitats (main stream) were surveyed using single wing fyke nets, with the cod end anchored and protruding from the water at the stream bank to allow any inadvertently captured non-fish species access to the surface. Fyke nets were deployed by boat to allow the wing panel to be deployed 10-15 m into the stream, perpendicular to the bank. At each site, a minimum of two fyke nets were deployed in the afternoon, left overnight, and checked the following morning.

Small collapsible baited traps were deployed along the margins of lentic (still water) habitats at Eden Bann Weir and lotic (flowing water) habitats at the proposed Rookwood Weir site to sample small and cryptic fish species (and macroinvertebrates) that were less likely to be captured in fyke nets. Three to four bait traps were deployed at the same location as the fyke nets, thereby allowing different microhabitats to be sampled within the same riverine habitat. Traps were also left overnight and checked the following morning.

Trapping effort is summarised in Table 7-1. Figure 7-1 and Figure 7-2 show survey locations relative to Eden Bann Weir and the proposed Rookwood Weir site, respectively.

Captured fish were identified to species and the number of individuals of each species level was recorded.

Macroinvertebrates

Opportunistic sampling for large macroinvertebrates occurred during fish trapping whilst small and cryptic macroinvertebrates were sampled by deploying artificial substrates. Artificial substrates were utilised at the time of the surveys, due to the inability to undertake kick-sampling as a result of flooding and other logistical and workplace health and safety concerns.

The artificial substrates comprised ‘rock basket’ substrates based upon De Pauw et al. (1986) substrates. These substrates were placed into the water at depths no greater than five metres and allowed to be colonised for three to six weeks. Five substrates were deployed at each survey site. Individuals were identified to family level.

Survey effort is summarised in Table 7-1. Figure 7-1 and Figure 7-2 show survey locations relative to Eden Bann Weir and proposed Rookwood Weir site, respectively.

Opportunistic recordings

Estuarine crocodile (*Crocodylus porosus*) populations (including abundance) and habitat utilisation in the Project area are described in Britton 2007a and Britton 2007b. While estuarine crocodiles were not directly targeted during field surveys, opportunistic sightings as well as any signs of crocodile presence, such as characteristic slides on sand banks, were recorded.

Targeted searches for platypus (*Ornithorhynchus anatinus*) were not undertaken. Aquatic habitat assessments were used to characterise potentially suitable habitat. Opportunistic recordings (as applicable) were made.

Aquatic plant assemblages (macrophytes) were recorded at habitat assessment sites, where present.

7.1.2.4 Ecological risk assessment

The Fitzroy Basin Draft Water Resource Plan Environmental Assessment – Stage 2 Assessment Report (DERM 2010) was used as the basis for determining the ecological risks, their potential impacts and the relevant mitigation measures relevant to the Project. These potential impacts and their associated level of risk were further informed and refined by incorporating information from the above listed desktop resources, and the results of the field surveys.

While the Fitzroy Basin Draft Water Resource Plan Environmental Assessment – Stage 2 Assessment Report (DERM 2010) provided a broad assessment of a number of environmental and ecological values within the Fitzroy Basin, it also specifically addressed risks to the following species/values relevant to this report in the context of river regulation:

- Olive perchlet (*Ambassis agassizii*)
- Purple-spotted gudgeon (*Mogurnda adspersa*)
- Eastern rainbowfish (*Melanotaenia splendida splendida*)
- Barramundi (*Lates calcarifer*)
- Fitzroy golden perch (*Macquaria ambigua oriens*)
- Black catfish (*Neosilurus ater*)
- Hyrtl's catfish (*Neosilurus hyrtlii*)
- Leathery grunter (*Scortum hillii*)
- Floodplain riparian vegetation communities (with specific emphasis on *Eucalyptus coolabah*)
- Key habitats – riffles and waterholes
- Wetlands

These risk assessments used the Benchmarking Methodology (Brizga et al. 2003) to evaluate environmental flow objectives for the Fitzroy River under a range of management scenarios (flow regimes) (DERM 2010). These Benchmarking Models were then used to identify the level of risk for each species/ecological value for each flow regime (DERM 2010). Bayesian Network Spatio-Temporal Dynamics simulations were then developed to further understand the more complex ecological risks for the Fitzroy golden perch.

7.1.2.5 Design process

Fish passage

Under the *Fisheries Act 1994* (Qld), dam and weir proposals require approval to undertake waterway barrier works. Approval will only be given if fish passage is satisfactorily addressed (Chapter 3 Legislation and project approvals). Provision of fishways was determined to be the likely method for providing fish passage at Eden Bann Weir and the proposed Rookwood Weir.

To address this, a fishway design process was undertaken in accordance with Queensland Fisheries (then Department of Employment, Economic Development and Innovation (DEEDI)) Design Process criteria. This process involved the selection of fishway design specifications and success criteria and the development of fishway designs for both Eden Bann Weir and the proposed Rookwood Weir.

To facilitate the process, a Fishway Design Team was established (Appendix D). Further detail with regard to the fishway design process and waterway barrier works approval requirements is provided in Appendix X.

The fishway design process undertaken for the Project was based on the process used for both Paradise Dam and Wyaralong Dam as recommended by DEEDI due to the high level of consultation that occurs between stakeholders.

The key stages in the fishway design process included:

- Data collection and review:
  - Desktop literature review
  - Reporting on fish assemblages at, up and downstream of the sites and any relevant behavioural data for those species including:
    - Movement biology (time of the year that upstream and downstream migration takes place, triggers for migration)
    - Breeding ecology, swimming ability (depth and velocity required for upstream and downstream migration)
    - Fish habitat at, up and downstream of the sites
    - Hydrology for the sites including the existing and projected headwater / tailwater levels at a range of flows (flow duration curves, annual exceedance probabilities, flow event curves)
    - Water management impacting on the sites (environmental flow release requirements)
    - Other constraints such as upstream and downstream conditions and impediments; and likely weir operation.
- Establishment of a fish passage issues register
- Site visit
- Development of design specifications and identification of success criteria as per Table 7-2 which included consideration of:
  - The operating range and conditions for operation to facilitate upstream and downstream passage
  - Identification of target species and particular passage requirements
  - Performance requirements during spilling
  - Entry and exit conditions (flow velocities, turbulence, interference)
  - Interaction with outlet works and attraction flows
  - Construction aspects
  - Cost
  - Safety in design and engineering design considerations
  - Energy and power supply
  - Weir operational requirements, including flow availability and volumes for downstream users.
- Fishway concept design and evaluation (including ecological risk assessment).

Table 7-2 Fishway design specifications and success criteria

Issue	Criteria – Eden Bann Weir (Stages 2 and 3)	Criteria – Rookwood Weir (Stages 1 and 2)
Design life for fishway structure and components does not compromise operational time.	Mechanical / electrical 10-20 years. Structural 100 years.	Mechanical / electrical 10-20 years. Structural 100 years.
Fishway does not compromise structural integrity or hydraulic performance of weir.	New fish lock is located on right side. High flow fish passage subject to geotechnical conditions on either bank. Structures do not protrude above abutment height (*or other height to be determined after resolving siltation vs afflux issues*) – to be resolved during detailed design process. Structures do not limit spillway capacity.	Fish passage structures are located on right bank. Structures do not protrude above abutment height (*or other height to be determined after resolving siltation vs afflux issues*) -– to be resolved during detailed design process. Structures do not limit spillway capacity.
Procurement and construction costs are minimised.	Optimal costs without sacrificing other criteria.	Optimal costs without sacrificing other criteria.
Operational costs are minimised.	Optimal costs without sacrificing other criteria.	Optimal costs without sacrificing other criteria.
Health and Safety is not compromised.	Operation and maintenance requirements do not introduce Health and Safety risk. Confined space entry requirements are minimised.	Operation and maintenance requirements do not introduce Health and Safety risk. Confined space entry requirements are minimised.
Upstream and downstream passage for small, medium and large fish (15-800 mm long) is provided.	Able to operate at flow velocities from 0.15 m/s to 1.8 m/s. Provides protection from predation for small fish. Holding chamber dimensions are the same as in the current fish lock at Eden Bann Weir.	Able to operate at flow velocities from 0.15 m/s to 1.8 m/s. Provides protection from predation for small fish. Holding chamber dimensions are the same as in the current fish lock at Eden Bann Weir.
Larval mortality is minimised.	Undershot crest gates are not used on the spillway or close to the surface. Late summer flood flows are passed over the weir in accordance with the provisions of the Fitzroy Basin Resource Operations Plan 2004 (Fitzroy ROP) as updated during detailed design.	Undershot crest gates are not used on the spillway or close to the surface. Late summer flood flows are passed over the weir in accordance with the provisions of the Fitzroy ROP as updated during detailed design.

Issue	Criteria – Eden Bann Weir (Stages 2 and 3)	Criteria – Rookwood Weir (Stages 1 and 2)
Fish mortality is minimised.	Downstream spillway face is largely a "smooth formed surface finish" (allow for roughness on bank edges / abutments for turtles). Fish screens are provided on outlet works (20 mm screens, 0.3 m/s velocity). Avoid strong transverse flows as tailwater rises. Energy dissipater and stilling basin / plunge pool design to minimise injury and mortality to fish. Avoid spilling directly onto rocks downstream of Eden Bann Weir. Features (such as road crossings) that may become downstream barriers to fish movement under low flow regimes to be modified if appropriate.	Avoid creating pools downstream of spillway where fish get trapped as flows recede. Provide fish passage across tailwater control structures. Downstream spillway face is largely a "smooth formed surface finish" (allow for roughness on bank edges / abutments for turtles). Fish screens are provided on outlet works (20 mm screens, 0.3 m/s velocity). Provide deeper stilling basin floor levels. Avoid strong transverse flows as tailwater rises. Energy dissipater and stilling basin / plunge pool design to minimise injury and mortality to fish. Features (road crossings) that may become downstream barriers to fish movement under low flow regimes to be modified if appropriate.
Period of operation is maximised.	Routine maintenance is not required during fish migration season. Maximum likely downtime due to unplanned maintenance requirements is minimised. Capable of operating at all times when there is a release. Capable of operating on an inflow / outflow basis if required under the Fitzroy ROP. Can operate at lower end of regular release levels. Time that fishway is not operational due to siltation and debris is minimised by location and upstream design treatments to minimise silt and debris entering. Access to fishway is available as soon as possible after a flood event, subject to external road network. Mechanism for flushing / scouring of fishway is provided. High level fishway (as necessary and applicable) is not rendered inoperable by debris during flood flows.	Routine maintenance is not required during fish migration season. Maximum likely downtime due to unplanned maintenance requirements is minimised. Capable of operating at all times when there is a release. Capable of operating on an inflow / outflow basis if required under the Fitzroy ROP. Can operate at lower end of regular release levels Time that fishway is not operational due to siltation and debris is minimised by location and upstream design treatments to minimise silt and debris entering. Access to fishway is available as soon as possible after a flood event, subject to external road network. Mechanism for flushing / scouring of fishway is provided. High level fishway (as necessary and applicable) is not rendered inoperable by debris during flood flows.

Issue	Criteria – Eden Bann Weir (Stages 2 and 3)	Criteria – Rookwood Weir (Stages 1 and 2)
Downstream operating range is maximised.	Fish passage is provided from minimum operating level to drownout (*subject to determining fish movements and downstream hydraulic conditions on high flows during detailed design).* Upper operating limit of fish lock to result in minimum number of consecutive days of non operation in high flow conditions *(to be refined during detailed design*).	Fish passage is provided from dead storage to drownout (*subject to determining fish movements and downstream hydraulic conditions on high flows during detailed design).* Upper operating limit of fish lock to result in minimum number of consecutive days of non operation in high flow conditions *(to be refined during detailed design*).
Upstream operating range is maximised.	Fish passage is provided from minimum operating level to drownout (*subject to downstream operating range, downstream hydraulic conditions and fish swimming ability).* Upper operating limit of fish lock to result in minimum number of consecutive days of non operation in high flow conditions (to be refined during detailed design).	Fish passage is provided from dead storage (*level to be determined)* to drownout (*level to be determined*) (*subject to downstream operating range, downstream hydraulic conditions and fish swimming ability).* Upper operating limit of fish lock to result in minimum number of consecutive days of non operation in high flow conditions (to be refined during detailed design).
Upstream exit / entrance optimise fish passage.	Exit / entrance is accessible at all operating water levels. Fish can exit at or below water level throughout operating range. Fish exiting do not become entrained in outlet works. Fish exiting are not carried back over spillway (when spilling). Exit is close to bank or cover is provided to facilitate fish moving close to bank. Weed assemblage is avoided at exit.	Exit / entrance is accessible at all operating water levels. Fish can exit at or below water level throughout operating range. Fish exiting do not become entrained in outlet works. Fish exiting are not carried back over spillway (when spilling). Exit is close to bank or cover is provided to facilitate fish moving close to bank. Weed assemblage is avoided at exit.
Downstream entrance / exit optimise fish passage.	Exit / entrance is accessible at all water levels (within specified operating range). Fish can get to the entrance no matter which way they approach without returning downstream. Refugia for small fish is provided in entrance channel.	Exit / entrance is accessible at all water levels (within specified operating range). Fish can get to the entrance no matter which way they approach without returning downstream. Refugia for small fish is provided in entrance channel.
Upstream passage requirements of fish species are met.	Specify flow conditions under which upstream passage is critical	Specify flow conditions under which upstream passage is critical
Downstream passage requirements of fish species are met.	Specify flow conditions under which downstream passage is critical.	Specify flow conditions under which downstream passage is critical.

Issue	Criteria – Eden Bann Weir (Stages 2 and 3)	Criteria – Rookwood Weir (Stages 1 and 2)
Water releases (other than spilling) optimise fish movement.	Releases in the following range are via fishway: • Lower limit of flow to be specified • Upper limit of flow to be specified. Flows are directed through the fishway in preference to the outlet works. Water releases through the fishway are of surface water quality. Water quality of releases from outlet to fishway entrance area: • Dissolved oxygen > 5 mg/L; • Temperature change is -1 ^{o}C to +2^{o}C from ambient • Water releases are drawn from 2 m below surface during late summer / high flow events to minimise larval entrainment.	Releases in the following range are via fishway: • Lower limit of flow to be specified • Upper limit of flow to be specified Flows are directed through the fishway in preference to the outlet works. Water releases through the fishway are of surface water quality Water quality of releases from outlet to fishway entrance area: • Dissolved oxygen > 5 mg/L; • Temperature change is -1 ^{o}C to +2^{o}C from ambient • Water releases are drawn from 2 m below surface during late summer / high flow events to minimise larval entrainment.
Outlet works are located to complement fishway operation.	Adjacent to fishway. Outlet works do not interfere with or mask attraction flows. Outlet flows enhance attraction to the fishway. Able to balance releases through fishway and outlet works. Allow for selective withdrawal to manage water quality.	Adjacent to fishway. Outlet works do not interfere with or mask attraction flows. Outlet flows enhance attraction to the fishway. Able to balance releases through fishway and outlet works. Allow for selective withdrawal to manage water quality.
Disruption to fish passage during spilling conditions is minimised.	As levels fall, flows can be transferred to fishway and outlet works to reduce low level spilling. Spilling flows do not confuse fish and prevent them from entering fishway. Fishway operation ceases when level above spillway reaches threshold (maximum is drownout).	As levels fall, flows can be transferred to fishway and outlet works to reduce low level spilling. Spilling flows do not confuse fish and prevent them from entering fishway. Fishway operation ceases when level above spillway reaches threshold (maximum is drownout).

Issue	Criteria – Eden Bann Weir (Stages 2 and 3)	Criteria – Rookwood Weir (Stages 1 and 2)
Attraction flows maximise fish passage.	Turbulence is minimised even at high attraction flows. Attraction flows are parallel to lock walls / entrance axis. Diffusers create air bubbles and water noise (noise is an attractor). Capable of providing continuous attraction flows when fishway is operating, i.e. including on the emptying cycle. Attraction flow velocities can be varied between: 0.15-1.8 m/s – for the fish lock; around 1.9 m/s for the high flow vertical slots. 250 mm slots for vertical slot – 350 mm slots for the fish locks. Allow for variable attraction flows between phases of the cycle.	Turbulence is minimised even at high attraction flows. Attraction flows are parallel to lock walls / entrance axis. Diffusers create air bubbles and water noise (noise is an attractor). Capable of providing continuous attraction flows when fishway is operating, i.e. including on the emptying cycle. Attraction flow velocities can be varied between: 0.15-1.8 m/s – for the fish lock; around 1.9 m/s for the high flow vertical slots. 250 mm slots for vertical slot – 350 mm slots for the fish locks. Allow for variable attraction flows between phases of the cycle.
Fish can pass readily from entrance to exit.	Avoid overcrowding in any holding chambers (area to be based on existing Eden Bann Weir); provide refugia for small fish, provide flows within structure suitable for fish likely to be present, low turbulence.	Avoid overcrowding in any holding chambers (area to be based on existing Eden Bann Weir); provide refugia for small fish, low velocity flows, low turbulence.
Effect of construction works on fish passage is minimised.	Continue to operate existing fish lock during construction. Provide fish passage under (or over) any temporary roads etc. used for construction. Pipes used in diversion and under temporary road crossings must be suitable for fish passage particularly in relation to light levels.	Provide temporary fish passage during construction (*method to be developed along with diversion strategy during detailed design*). Provide fish passage under (or over) any temporary roads used for construction. Pipes used in diversion and under temporary road crossings must be suitable for fish passage particularly in relation to light levels.
Commissioning and post commissioning allows for ongoing management and maintenance.	Allow for handover from construction to operator. Allow for adjustments to be made in commissioning and post commissioning including entrance / exit slot, diffuser orientation and velocity. Allow for monitoring and response in first 3 years of operation (assuming these are not very low flow years). Embed fishway operation, management and maintenance requirements in operations and maintenance manual.	Allow for handover from construction to operator. Allow for adjustments to be made in commissioning and post commissioning including entrance / exit slot, diffuser orientation and velocity. Allow for monitoring and response in first 3 years of operation (assuming these are not very low flow years). Embed fishway operation, management and maintenance requirements in operations and maintenance manual.

Species management

The Fitzroy River turtle is known to occur within Project areas. At Project inception, it was acknowledged that a set of practical actions for the avoidance, mitigation and management of Project impacts on the species during Project planning and design, construction and commissioning, and operation were required.

To facilitate this and to inform design elements, the following activities were undertaken:

- Desktop literature review to reflect on learnings from, and consistency across, projects within the Fitzroy Basin in relation to protection and enhancement of the species, specifically the Connors River Dam and Pipelines Project EIS and Nathan Dam and Pipelines Project EIS
- Discussions and meetings with DEHP (specifically Chief Scientist, Aquatic Threatened Species Division, Dr Col Limpus) to:
  - Inform survey design
  - Inform impact identification
  - Facilitate integration of mitigation measures into weir design

  The Fitzroy River turtle SPM (Appendix M) includes details of the design criteria adopted.
- Development of a framework for planning, implementing, maintaining and reviewing Fitzroy River turtle management requirements for the Project.

7.1.3 Regulatory framework

Chapter 3 Legislation and project approvals, provides detail in regard to regulatory requirements for aquatic fauna matters. In summary, with regard to aquatic fauna conservation values, the following apply:

- EPBC Act
- *Environmental Offsets Act 2014* (Qld) (EO Act) and the Queensland Government Environmental Offsets Framework
- *Environmental Protection Act 1994* (Qld)
- *Fisheries Act 1994* (Qld)
- *Land Protection (Pest and Stock Route Management) Act 2002* (Qld) (LP Act)
- NC Act and Nature Conservation (Wildlife Management) Regulation 2006
- SP Act and Sustainable Planning Regulation 2009
- *Water Act 2000* (Qld)
- Queensland Government Back on Track species prioritisation framework (Back on Track framework)
- Queensland State Planning Policy and State Development Assessment Provisions , namely:
  - Module 5 Fisheries resources
  - Module 11 Wetland protection and wild river areas.

7.2 Existing environment

7.2.1 Aquatic habitat

7.2.1.1 Aquatic habitats within the project footprints

Currently approximately 35 per cent of the Fitzroy, Dawson and Mackenzie sub-catchments have been impounded as a result of in-stream water infrastructure as illustrated in Table 7-3.

Table 7-3 Current level of impoundment in rivers relative to the Project

River	Existing infrastructure	Length of river (km AMTD)	Level of impoundment (km AMTD)	Percentage %
Dawson River	Neville Hewitt Weir, Moura Weir, Theodore Weir, Orange Creek Weir, Gyranda Weir, Glebe Weir	356. 5	125.2	35%
Nogoa and Mackenzie Rivers	Tartrus Weir, Bingegang Weir, Bedford Weir, Fairbairn Dam	427.2	143.7	34%
Fitzroy River	Eden Bann Weir, Fitzroy Barrage	250.7	97.6	39%

Eden Bann Weir Project footprint

Approximately 282 ha of natural (not impounded) aquatic habitat occurs within the Eden Bann Weir Project footprint. Aquatic habitat types within the Eden Bann Weir Project footprint are described in Table 7-4. The linear extent of aquatic habitats, as determined through analysis, is shown in Figure 7-3. Figure 7-4 shows the spatial distribution of Eden Bann Weir Project footprint aquatic habitats.

Eden Bann Weir is located on the Fitzroy River at 141.2 km adopted middle thread distance (AMTD). The upper limit of the impoundment associated with the proposed raising of the structure to Stage 3 is at approximately 211 km AMTD. The Fitzroy River currently impounded upstream of the existing Eden Bann Weir (to 184 km AMTD) is deep, wide and slow-flowing. The river bed substrate is generally clay/slit with smaller amounts of gravel and sand. The abundance and diversity of macrophytes is reduced and those that do occur are generally restricted to the shallow margins. The river banks are generally stable to moderately stable and on average approximately 7 m high. The riparian zone has been partially inundated and in many cases the river connects directly to the terrestrial vegetation on the flood plain. The inundated riparian vegetation that remains along the margins appears in relatively good condition in the upstream reaches but deteriorates in health downstream, with only dead woody remnants/debris remaining adjacent to the spillway at the weir itself.

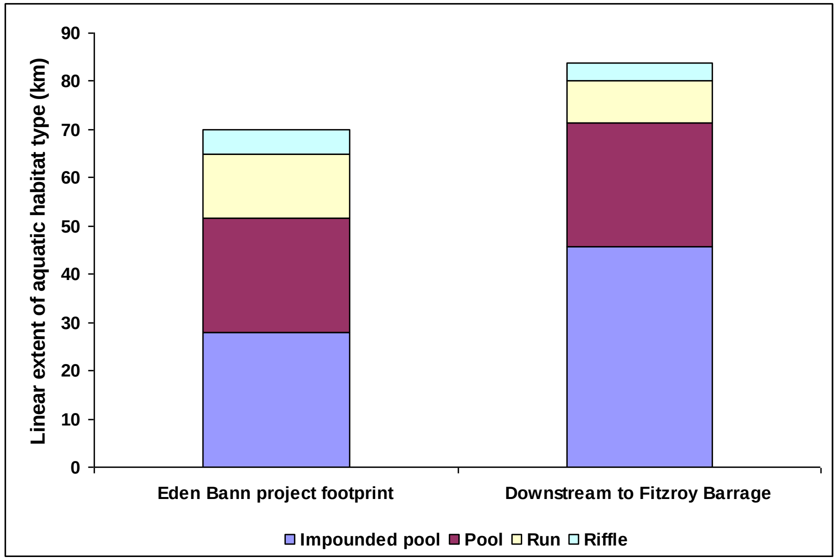
Table 7-4 Aquatic habitat types – Eden Bann Weir

Habitat type	Habitat description	Characteristics	Representative example of habitat
Impounded pool	• Non-flowing, typically deep water impounded within the bed and banks of the river upstream of the existing Eden Bann Weir • Depth and linear extent is variable, and dependent on local to catchment-wide climatic factors and infrastructure operations.	• Average stream width 172.5 m (range 120 - 250 m) • Average channel depth 8.7 m (6.5 - 10 m) • Average bank height 7.8 m (3 - 20 m) • Typical substrate - clay/silt (<0.006 mm) • Logs and coarse-woody debris occur at the margins • Aquatic macrophytes encountered occasionally (at four of eight sites) and generally attached to the substrate rather than free floating • Generally non-flowing • Bottom substrate/available cover generally poor, with habitat features such as submerged logs and rocks largely confined to the margins • Bank stability and bank vegetative stability ranked as being good to excellent with few areas of exposed/unstable banks • High grass/weed cover on the river banks served to stabilise banks, the low abundance of trees and shrubs resulted in 13 of the 16 banks assessed as having a poor streamside covering rating.	 Impounded (weir) pool upstream of Eden Bann Weir (August 2009)
Pool	• Relatively deep, still/very slow flowing water over variable substrates (silt, sand, stony or rocky) that occur naturally within the riverine environment (AusRivAs 2001) • Occurs in the main channel, and may become isolated into a series of discrete water holes during dry conditions when flow ceases and water levels drop • The low (or zero) velocity of water flow differentiates a pool habitat from a faster flowing run habitat.	• Pool habitat converted to run habitat during the wet season • Access constraints during the dry season prevented further field survey • Field observations indicate characteristics not dissimilar to pools within the Rookwood Weir Project footprint • Significant habitat features are concentrated along the margins • Provide a variety of habitat resources and microhabitats due to the presence of undercut banks, woody debris, macrophytes, variable substrates and overhanging and inundated vegetation.	 Pool habitat (August 2009)

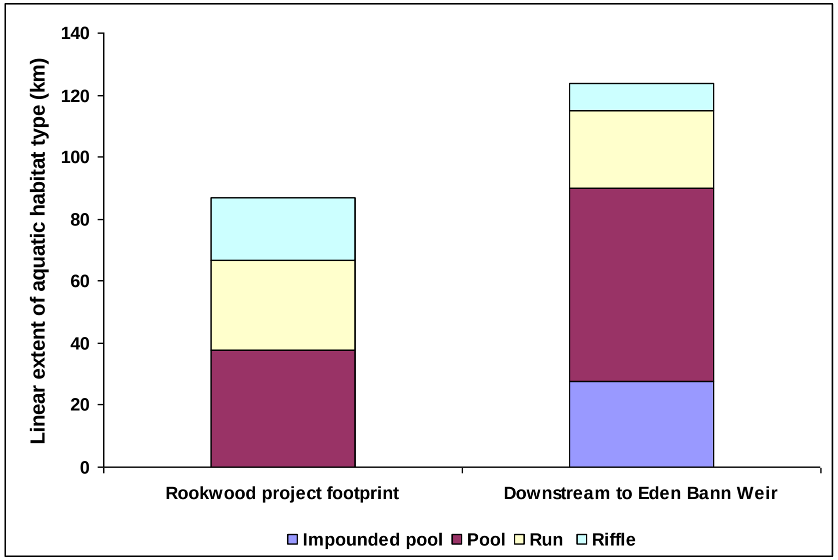
Habitat type	Habitat description	Characteristics	Representative example of habitat
Run	• Relatively deep, flowing unbroken water over a sandy, stony or rocky bed (AusRivAs 2001) • May occur immediately upstream and downstream of a riffle zone • Fast flowing water during high flow/flood conditions may result in the conversion of sluggish pool habitats and shallow riffle habitats into runs.	• Average stream width 113.5 m (range 60 - 200 m) • Average channel depth 4.15 m (3 - 6 m) • Average bank height 5.8 m (2 - 13.5 m) • Typical substrate: clay/silt (<0.006 mm), some sites also had a combination of clay/silt and sand (2 - 0.006 mm) • Logs and coarse-woody debris occur at the margins • Aquatic macrophytes were absent at all sites assessed • Water velocity generally slow to moderate during assessments • Run habitats were typically shallower and narrower than the downstream impounded pool habitat • Bottom substrate/available cover generally ranked as being poor, however bank vegetative stability was typically excellent along the riparian zone. Bank stability and streamside cover were variable, and rankings are likely to reflect site specific land uses (intensity of cattle grazing) in the riparian zone adjacent to run habitats • Habitat complexity greatest at the margins • In the wet season these habitats provide a linkage between slower-flowing (typically wider and deeper) pool habitats • As water flow decreases during the dry season, it is likely that the run habitats revert to pool habitats.	 Run habitat upstream of impounded pool (February 2009)
Riffle	• Shallow (<0.3 m), fast-flowing (>0.2 m/s) reaches over a stony bed (AusRivAs 2001) • The unique combination of shallow, fast flowing water that is (relatively) highly oxygenated and flows over hard substrate differentiates this habitat type from pool and run habitats.	• Substrate dominated by cobble (256 - 64 mm), gravel (16 - 2 mm) and pebbles (64 -16 mm) • Plentiful woody debris in the margins • Fast flowing water • The riffle zone assessed was typical of this aquatic habitat type throughout the study area • Habitats tended to occur immediately downstream of runs, and were narrow, shallow and featured a rocky substrate • Aquatic macrophytes infrequently observed.	 Riffle habitat

Habitat type	Habitat description	Characteristics	Representative example of habitat
Off-stream water body	• Defined as palustrine wetlands (vegetated swamps, billabongs), oxbow lakes, and farm dams (lacustrine habitats) in the floodplain adjacent to the main channel of the lower Dawson, lower Mackenzie and Fitzroy Rivers • No formal assessment during field surveys with the general characteristics deduced based on observations throughout the wider study area.	• One large off-stream water body to the west of Marlborough Creek assessed • Macrophytes and woody debris were prevalent with a good bottom substrate/available cover rating • The shallow, wide water body was observed to have excellent bank stability and bank vegetative stability, while streamside cover was assessed as being fair.	 Off stream water body
Creek	• Small tributaries adjoining the main river channel that persist for varying distances across the adjacent floodplain and beyond • The variable geomorphology of these habitats (depth, width, and length), adjacent land use and proximity to water infrastructure varies the characteristics and potential fauna habitat values these waterways feature.	• Average width of 20 m (range 15 m - 25 m) • Average depth at 2.2 m (range 1 m - 4 m) • Average bank height of 3.5 m (range 1.5 m - 7 m) • Substrate is typically clay/silt • Woody debris present • Macrophytes were noted from one of three sites • Habitats assessed were variable. General findings indicate excellent bank stability and bank vegetative stability, fair streamside cover and poor bottom substrate/available cover. The results of the bottom substrate/available cover assessment at the specific habitat assessment sites were not representative of what was observed throughout the wider study area. In general, creek habitats observed often supported notable in-stream cover and structure in the form of woody debris, inundated and overhanging vegetation, and also supported more macrophytes (especially floating and emergent) when compared with the main stream of the Fitzroy River.	 Creek adjoining the main river channel

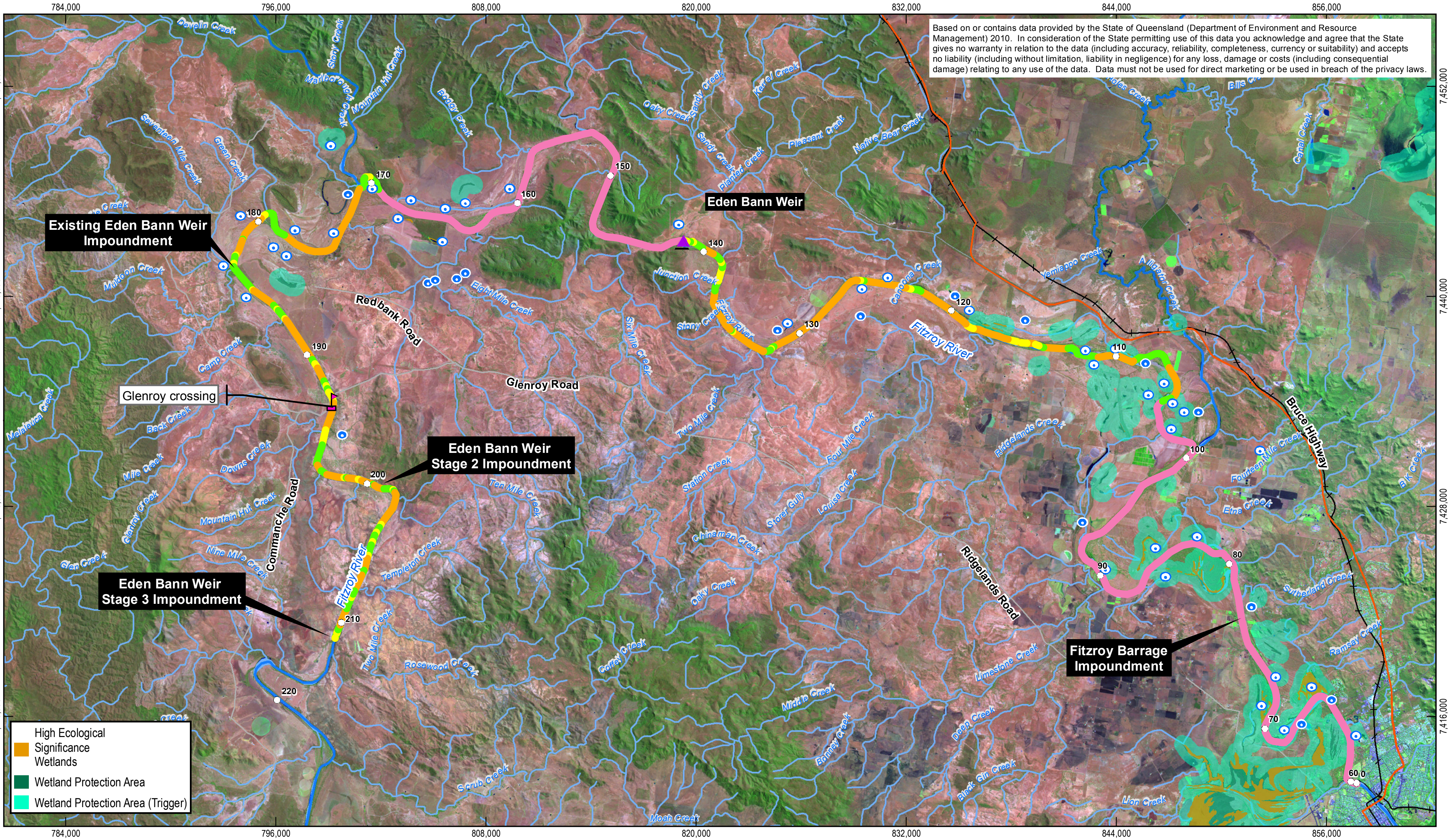
Figure 7-3 Linear extent of in-channel aquatic habitats



(a) Within and downstream of the Eden Bann Weir Project footprint



(b) Within and downstream of the Rookwood Weir Project footprint



1:290,000 (at A4)

0 3 6 9 12

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA94)
Grid: Map Grid of Australia 1994, Zone 55

N

Legend

- AMTD (km)
- Weir Location
- River Crossing
- Highway
- Minor Road
- Watercourse (Major)
- Watercourse (Minor)
- Railway
- Waterway
- Off-stream Waterbodies
- Lacustrine
- Palustrine
- Aquatic Habitat
- Impounded Pool
- Pool
- Riffle
- Run

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Spatial distribution of in-channel aquatic habitats within and downstream of the Eden Bann Weir footprint

Figure 7-4

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Level 9, 145 Ann St Brisbane QLD 4000 T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com.au W www.ghd.com.au

Data Source: GHD: Fauna Survey/2009; © Copyright Commonwealth of Australia (Geoscience Australia): Waterways, State (2007); Sunwater: Waterways, Weir Locations - 2008; DNRM: Roads - 2010, Railways - 2010, Imagery - 2005, WPA v2.1 (2011). Created by MS.

Upstream of the impoundment, the Fitzroy River exists as a series of pool-riffle-run sequences. The river channel is generally narrower than the impounded pool and water depth and velocity vary from deep, slow-moving conditions in the natural pools to shallow and fast-flowing conditions in the riffle zones. Substrates within the natural river channel vary from soft clay/silts and sands to harder gravel, pebble, cobble and bedrock. Macrophyte abundance and diversity is generally higher than that of the impoundment with the greatest quantities occurring within the creeks, riffle zones and off-stream billabongs. The river banks within this section of the Project footprint are generally moderately stable and contain a relatively larger amount of overhanging vegetation than the impounded area downstream. The riparian zone ranges in width from narrow highly degraded strips to wide sections of well-developed large growth vegetation that joins directly to the terrestrial vegetation behind (Chapter 6 Flora).

Based on the assessment of aerial photography and field survey observations, the impoundment created as a result of the existing Eden Bann Weir is the dominant aquatic habitat type in this section of the Fitzroy River (approximately 40 per cent of the main river channel in the Eden Bann Weir Project footprint). Natural pools account for approximately 34 per cent of the main river channel and are the most abundant aquatic habitat type beyond the weir impoundment. Riffle and run habitats represent approximately five per cent and approximately 13 per cent of the main river channel respectively (Figure 7-3). Off-stream billabongs occur in linear depressions within the riparian zone, typically 20 – 50 m from the rivers' edge. Billabongs vary in size from small ephemeral ponds to large permanent to semi-permanent water bodies.

There are no wetlands of high ecological significance directly associated with the Eden Bann Weir Project area. Three Great Barrier Reef wetland protection areas are located adjacent (within 2 km to the Eden Bann Weir Project footprint (Figure 7-4). There are a number of creeks joining the river channel upstream of Eden Bann Weir, the largest of these being Marlborough Creek.

Rookwood Weir Project footprint

Approximately 660 ha of aquatic habitat occurs within the Rookwood Weir Project footprint. Aquatic habitat types within the Rookwood Weir Project footprint are described in Table 7-5. The linear extent of aquatic habitats, as determined through analysis, is shown in Figure 7-3. Figure 7-5 shows the spatial distribution of Rookwood Weir Project footprint aquatic habitats.

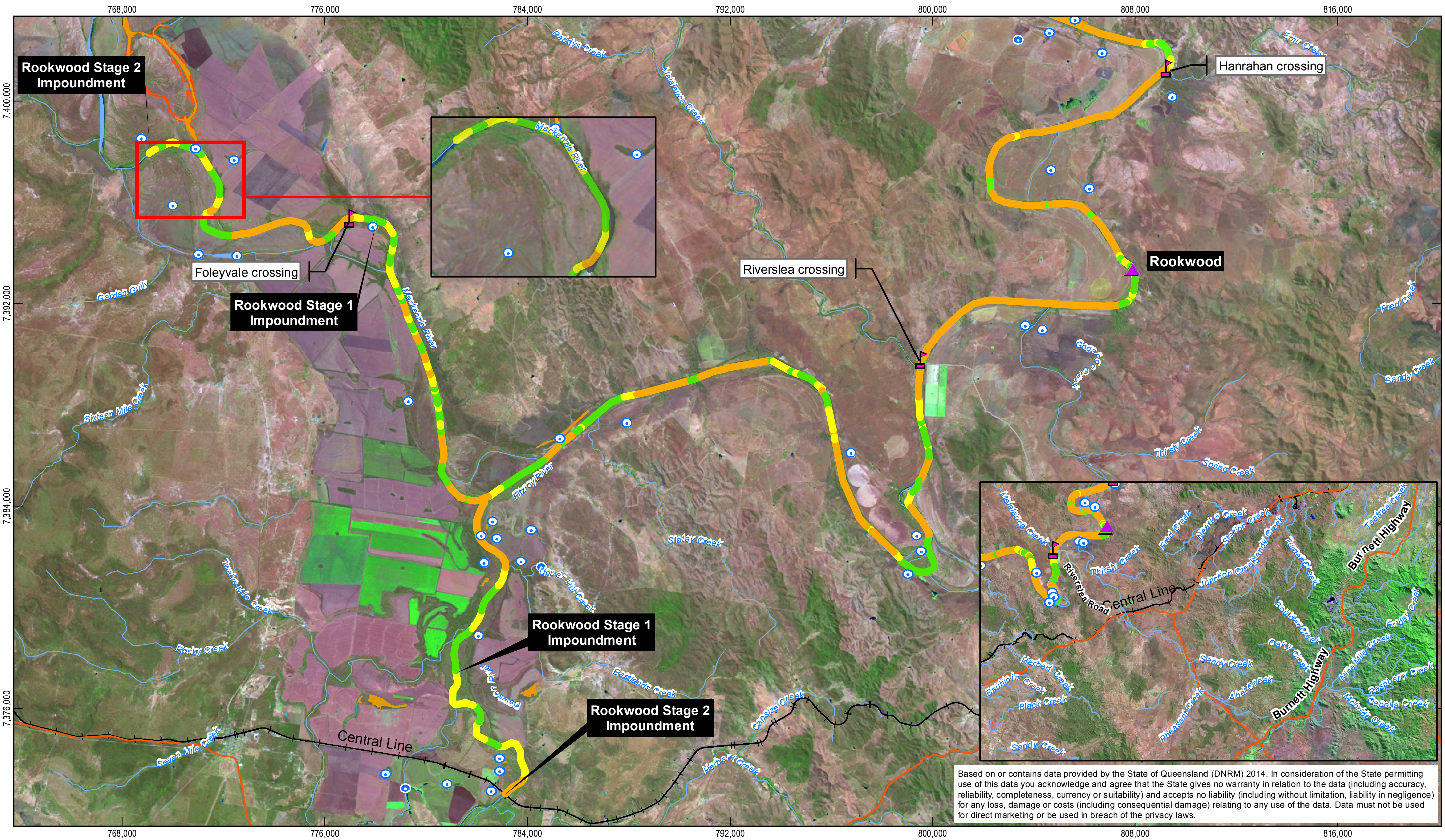
The proposed Rookwood Weir is located on the Fitzroy River at 265.3 km AMTD. The impoundment associated with the proposed Rookwood Weir Stage 2 extends approximately 337 km AMTD into the Mackenzie River and approximately 15 km AMTD into the Dawson River. The Fitzroy River in the Rookwood Weir Project footprint is generally more narrow and dynamic than areas further downstream which have been altered as a result of impoundments (namely, Eden Bann Weir and the Fitzroy Barrage). There are no existing weirs or other water storage infrastructure within the Rookwood Weir Project footprint. Consequently, it retains many of the features of a natural riverine system and contains a greater diversity of lotic habitats. The river banks within the Rookwood Weir Project footprint are generally moderately stable and contain a relatively larger amount of overhanging vegetation. The riparian zone ranges in width from narrow highly degraded strips to wide sections of well-developed large growth vegetation that joins directly to the terrestrial vegetation extending out onto the floodplain (Chapter 6 Flora). Land use adjacent to the Rookwood Weir Project footprint is dominated by low density pastoral grazing land and cropping. The landscape is predominantly flat and has been extensively cleared for grazing. However, low undulating rocky hills and uncleared alluvial plains occur in places and retain remnants of native woodland vegetation.

Table 7-5 Aquatic habitat types – Rookwood Weir Project footprint

Habitat type	Habitat description	Characteristics	Representative example of habitat
Pool	• Relatively deep, still/very slow flowing water over variable substrates (silt, sand, stony or rocky) that occur naturally within the riverine environment (AusRivAs 2001) • Occurs in the main channel, and may become isolated into a series of discrete water holes during dry conditions when flow ceases and water levels drop • The low (or zero) velocity of water flow differentiates a pool habitat from a faster flowing run habitat.	• Average stream width 43 m (range 15 - 100 m) • Average channel depth predicted to be >1.5 metres • Average bank height 11.2 m (range 3 - 20 m) • Typical substrate - gravel (2 - 16 mm) • Logs and coarse-woody debris occur at the margins • Aquatic macrophytes were encountered at only one of five sites • Rankings for bottom substrate/available cover, bank stability, bank vegetation stability and stream side cover were generally good or excellent • Habitat features in pool habitats concentrated around river margins, and typically comprised a combination of submerged logs, undercut banks, overhanging/inundated vegetation, and less frequently, macrophytes.	 Pool at Riverslea Crossing on Fitzroy River (July 2009)
Run	• Relatively deep, flowing unbroken water over a sandy, stony or rocky bed (AusRivAs 2001) • May occur immediately upstream and downstream of a riffle zone • Fast flowing water during high flow/flood conditions may result in the conversion of sluggish pool habitats and shallow riffle habitats into runs;	• Average stream width 28.2 m (range 6 - 60 m) • Average channel depth predicted to be >1.5 metres • Average bank height 8 m (4 - 12 m) • Typical substrate: clay/silt (<0.006 mm), clay/silt and sand (0.006 - 2 mm), gravel (2 - 16 mm) • Logs and coarse-woody debris occur at the margins • Aquatic macrophytes were absent at all but one site • Water velocity generally slow to moderate during assessments • Habitat quality largely dependent on adjacent land use. The most notable influence being the extent of cattle access to the riparian zone and river margins. Where cattle were able to access the waterway, potential habitat quality for aquatic fauna was noted to be reduced	 Run habitat in Mackenzie River (December 2008)

<table>
<tr><th>Habitat type</th><th>Habitat description</th><th>Characteristics</th><th>Representative example of habitat</th></tr>
<tr><td></td><td></td><td>Run habitats typically narrower (and likely shallower) than pool habitats
In-stream habitat features most prevalent in the shallow margins, particularly in the Dawson River, where bottom substrate /available cover (namely submerged logs and undercut banks) was ranked as being good or excellent
Bank stability generally rated good with small areas of erosion occurring infrequently
Bank vegetative stability considered good to excellent and a relatively high abundance of trees and shrubs generally resulted in excellent streamside cover.</td><td></td></tr>
<tr><td>Riffle</td><td>Shallow (<0.3 m), fast-flowing (>0.2 m/s) reaches over a stony bed (AusRivAs 2001)
The unique combination of shallow, fast flowing water that is (relatively) highly oxygenated and flows over hard substrate differentiates this habitat type from pool and run habitats.</td><td>Average stream width 13.4 m (range 5 - 30 m)
Riffle depth generally less than 0.3 m (up to a maximum of 0.75 m)
Substrate dominated by cobble (256 - 64 mm), gravel (16 - 2 mm) and pebbles (64 - 16 mm)
Woody debris at the margins of all but one site
Macrophytes present at only one of seven sites
Fast flowing water
Occur immediately downstream of runs, and are narrow, shallow and feature a rocky substrate
Submerged logs generally associated with riffle zone habitats while aquatic macrophytes were infrequently observed
Bottom substrate/available cover rated good to excellent while banks were considered moderately stable (good)
Bank vegetative stability was generally good (50 - 79% cover) or excellent (> 80% cover)
Streamside cover was predominately shrub form (good).</td><td>
Riffle zone on Mackenzie River downstream of Foleyvale Crossing (July 2009)</td></tr>
</table>

Habitat type	Habitat description	Characteristics	Representative example of habitat
Off-stream water body	• Defined as palustrine wetlands (vegetated swamps, billabongs), oxbow lakes, and farm dams (lacustrine habitats) in the floodplain adjacent to the main channel of the lower Dawson, lower Mackenzie and Fitzroy Rivers • No formal assessment during field surveys with the general characteristics deduced based on observations throughout the wider study area.	Feature a variety of habitat resources including inundated and overhanging riparian vegetation, woody debris, variable depth, and a relatively greater abundance of macrophytes.	 Off-stream water body
Creek	• Small tributaries adjoining the main river channel that persist for varying distances across the adjacent floodplain and beyond • The variable geomorphology of these habitats (depth, width, and length), adjacent land use and proximity to water infrastructure varies the characteristics and potential fauna habitat values these waterways feature.	• Average width of 20 m • Average depth at 1.2 m • Average bank height of 8 m • Substrate is typically clay/silt • Woody debris present • Macrophytes absent.	 Creek adjoining the main river channel



1:200,000 (at A4)

0 2 4 6 8 Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Legend

- Weir Location
- River Crossing
- Highway
- Minor Road
- Railway
- Waterway
- Waterway
- Stage 1 impoundment
- Stage 2 impoundment
- Off-stream Waterbodies
- Lacustrine
- Palustrine
- Aquatic Habitats
- Pool
- Riffle
- Run
- Wetland Protection Area
- High Ecological Significance Wetlands

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Spatial distribution of in-channel aquatic habitats and off-stream water bodies and creeks within the Rookwood Weir Project footprint

Figure 7-5

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G:\41\20736\GIS\Projects\MXD\200_Enviro\4120736_250_OffStreamWaterbaodies_Rev_E.mxd

Data Sources: Data Source: © Copyright Commonwealth of Australia (Geoscience Australia): Waterways, State (2007); Sunwater: Waterways, Weir Locations - 2008; GHD: Waterbodies - 2010; DNRM: Roads - 2010, Railways - 2010, Imagery/2005. Created by IH,MS

The river channel is less defined than areas downstream, with greater seasonal changes in river flow attributable to the lack of anthropogenic regulation of the system. Open riverine sections (natural pools) are interspersed with more confined sections of riffles and runs. Water depth and velocity vary from deep, slow-moving conditions in the natural pools to shallow and fast-flowing conditions in the riffle zones. Substrates are predominately gravel, pebble, cobble with smaller areas of clay/slits, sands and bedrock. Macrophyte abundance and diversity is greatest within the creeks, riffle zones and off-stream billabongs. Attached, filamentous and floating algae occur occasionally throughout the Rookwood Weir Project footprint.

The natural pool habitat is the most extensive aquatic habitat type, covering a total stream length of approximately 46 km (approximately 47 per cent of the main river channel within the Project footprint). The riffle and run habitats that connect the natural pools cover a total length of approximately 21 km (approximately 22 per cent) and approximately 29 km (approximately 30 per cent), respectively (Figure 7-3). Off-stream billabongs occur in linear depressions within the riparian zone, typically 20 – 50 m from the rivers' edge. Billabongs are relatively abundant and vary in size from small ephemeral ponds to large permanent to semi-permanent water bodies.

There are no wetlands of high ecological significance directly associated with the Rookwood Weir Project area. One Great Barrier Reef wetland protection area and wetland of high ecological significance is located between 100 m and 350 m from the proposed Rookwood Weir impoundment at 334 km AMTD on the Mackenzie River (Figure 7-5). There are several creeks joining the Fitzroy River in the Rookwood Weir Project footprint. The largest of these are Gogango Creek and Melaleuca Creek on the Fitzroy River.

7.2.1.2 Upstream aquatic habitat

Based on aerial photo interpretation, field observations and desktop assessment, aquatic habitats (in-channel, adjoining and off-stream) upstream of the Project footprints were inferred to be similar to those described within the Project footprints. As the landscape (topography, gradient) and adjacent human land use upstream of the Project footprints are similar to that within the Project footprints, it is considered likely that the aquatic habitat types, and the general characteristics of these habitats (including value to fauna) would persist upstream of the Project footprint.

7.2.1.3 Downstream aquatic habitat

Freshwater habitat

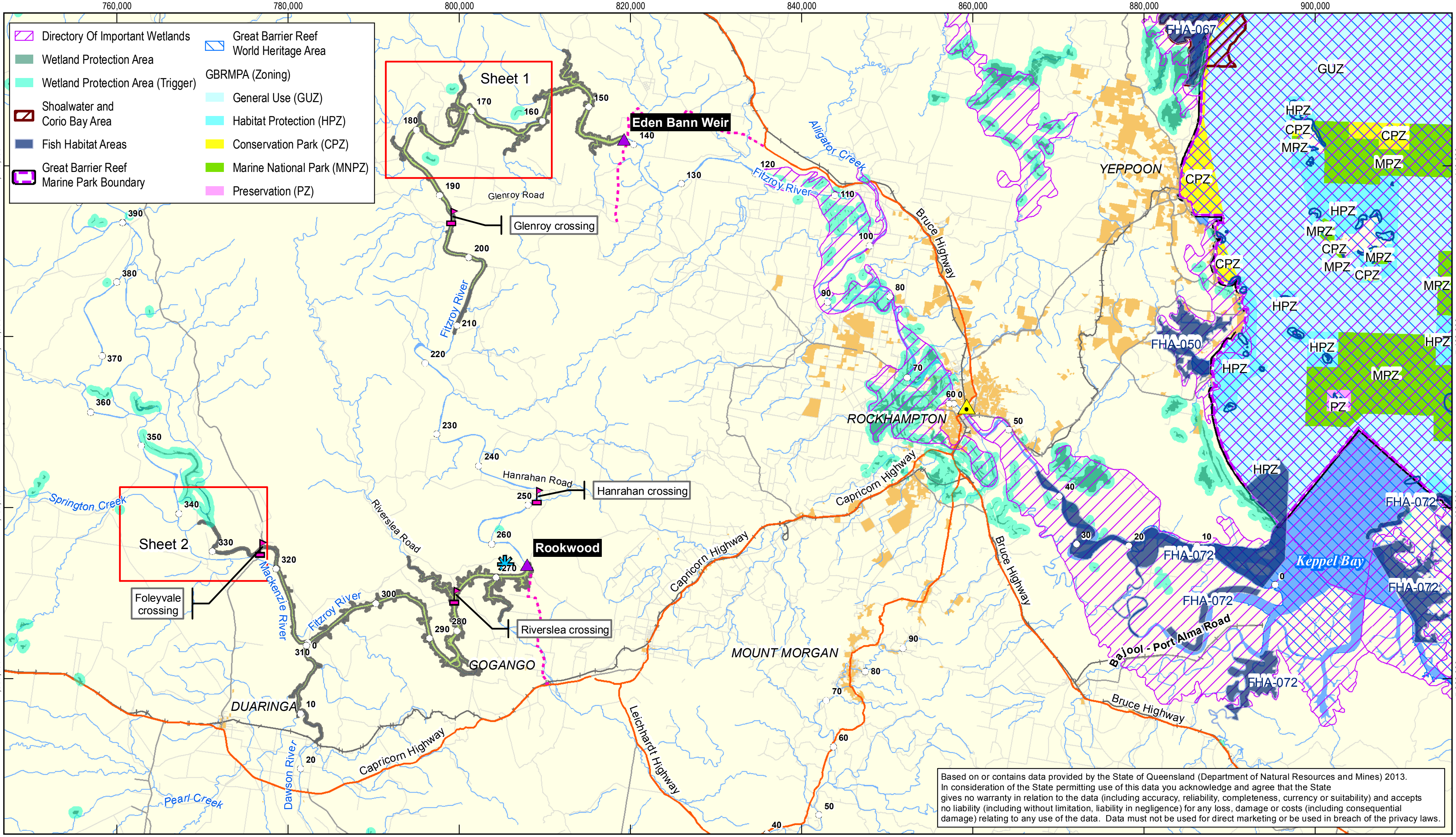
The Fitzroy River downstream of Eden Bann Weir has been modified by human land-use practices. The landscape predominantly consists of alluvial plains that have been extensively cleared for grazing, agriculture and urban development. Population density is higher along this section of the river than within the Eden Bann Weir or Rookwood Weir Project footprints.

Aquatic habitats within this section of the Fitzroy River are regulated by operational releases from the existing Eden Bann Weir and impoundment associated with the Fitzroy Barrage. Releases made from the existing Eden Bann Weir in accordance with the Water Resource (Fitzroy Basin) Plan 2011 (Fitzroy WRP) are discussed further in Chapter 9 Surface water resources. The Fitzroy Barrage is located adjacent to the town of Rockhampton at 59.6 km AMTD and forms a barrier between the freshwater and tidal reaches of the Fitzroy River (Figure 7-4). The Fitzroy Barrage holds a maximum of 80,000 ML of water in a 55 km long impoundment confined to the river and some tributary creeks (SunWater 2008). Based on the assessment of aerial photography and field survey observations, the impoundment created as a result of the Fitzroy Barrage is the dominant aquatic habitat type in this section of the Fitzroy River (approximately 55 per cent of the main river channel). Natural pools account for approximately 30 per cent of the main river channel and are the most abundant aquatic habitat type beyond the weir impoundment. Riffle and run habitats represent approximately four per cent and approximately 11 per cent of the main river channel respectively (Figure 7-3).

The Fitzroy River downstream of Eden Bann Weir also supports a number of old oxbow lakes and off-stream billabongs. Many of these are identified as Great Barrier Reef wetland protection areas and/or wetlands of high ecological significance (Figure 7-4). There are several creeks joining this section of the Fitzroy River, the largest of which is Alligator Creek. The river banks at the junction of the Fitzroy River and Alligator Creek provide important nesting habitat for the Fitzroy River turtle.

Estuarine and marine habitat

The Fitzroy Barrage at Rockhampton (59 km AMTD) (constructed in the early 1970s) bisects the Fitzroy River delta. The aquatic environment downstream of the Fitzroy Barrage is tidally dominated and fresh water entering the estuary is regulated by releases from the Fitzroy Barrage (under normal flow conditions) in accordance with the Fitzroy WRP (Chapter 9 Surface water resources). Events sufficiently large enough to produce major delivery of fresh water downstream (flood flows) typically occur only one to two times per year (Chapter 9 Surface water resources). The Fitzroy River discharges into the southern end of the Great Barrier Reef at Keppel Bay in the Capricorn-Bunker Group. Figure 7-6 shows downstream estuarine and marine environs.



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0 5 10 15 20
Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA94)
Grid: Map Grid of Australia 1994, Zone 55

LEGEND

- AMTD (km)
- Weir Location
- Fitzroy Barrage
- River Crossing
- Saddle dams
- Access Road
- Highway
- Major Road
- Streets (Local)
- Urbanised Area
- Rookwood Weir Stage 1 impoundment
- Rookwood Weir Stage 2 impoundment
- Eden Bann Weir Stage 2 impoundment
- Eden Bann Weir Stage 3 impoundment

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Gladstone Area Water Board

SunWater Making Water Work

Gladstone Area Water Board, SunWater
Lower Fitzroy River Infrastructure Project

Job Number 41-20736
Revision D
Date 13 Feb 2015

Sensitive environmental areas

Figure 7-6

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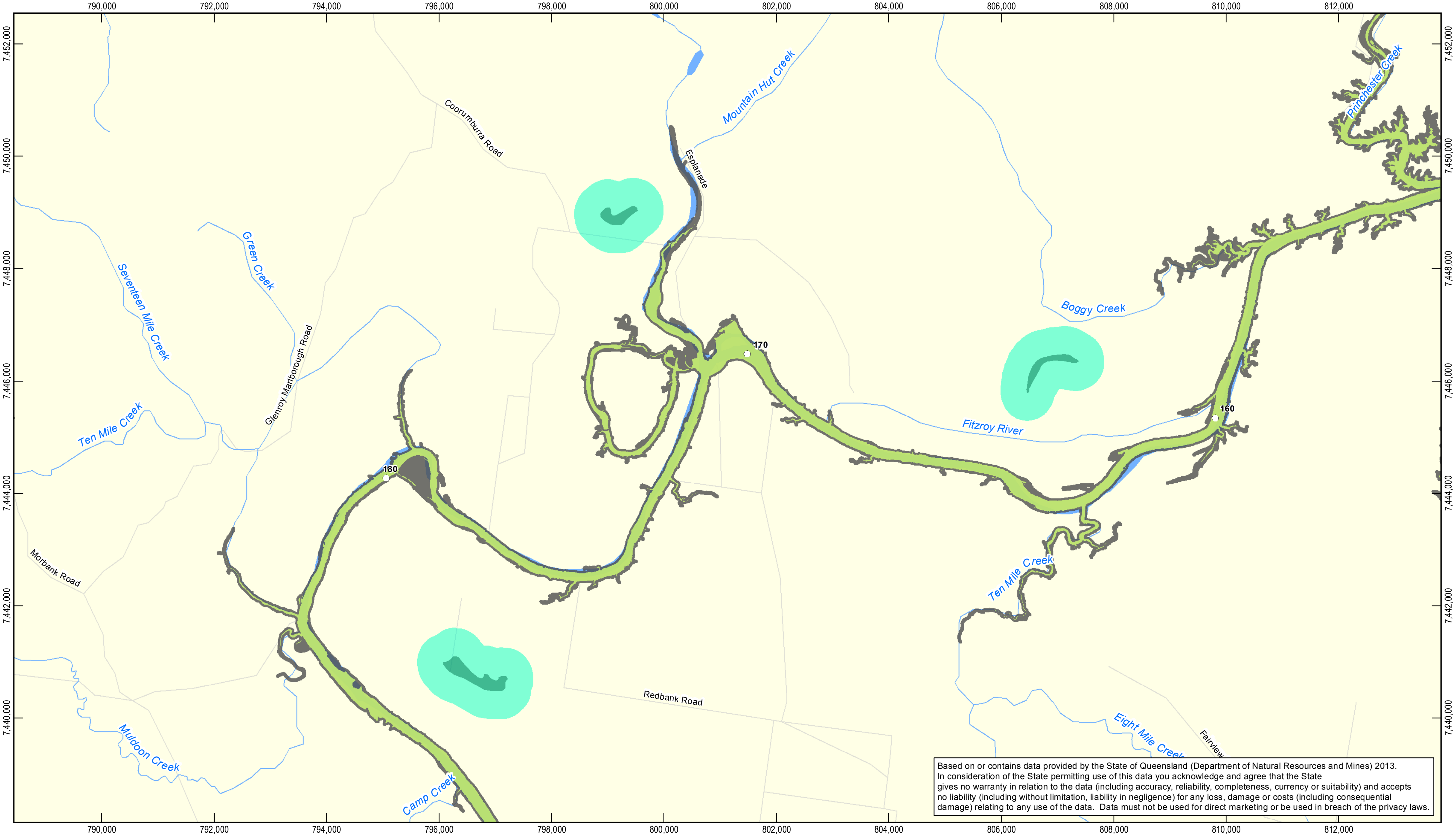
Level 9, 145 Ann Street Brisbane QLD 4000 Australia T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: © Copyright Commonwealth of Australia (Geoscience Australia): Places, Waterways (2007); Sunwater: Waterways, Weir Locations - 2008; DERM: Railways, Roads (2010). DNRM: DOIW, WHA, RAMSAR (2010), WPA, WPA Trigger (2011), Fish Habitat Area (2014); GBRPMA: Zoning, Boundary (2013). Created by: MS *See Appendix for disclaimers and copyrights.



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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA94)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- AMTD (km)
- Streets (Local)
- Waterway
- Urbanised Area
- Eden Bann Weir Stage 2 impoundment
- Eden Bann Weir Stage 3 impoundment
- Directory Of Important Wetlands
- Wetland Protection Area
- Wetland Protection Area (Trigger)

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Gladstone Area Water Board

SunWater Making Water Work

Gladstone Area Water Board, SunWater
Lower Fitzroy River Infrastructure Project

Job Number	41-20736
Revision	E
Date	11 Feb 2015

Sensitive environmental areas downstream of the Project footprint

Figure 7-6 Sheet 1

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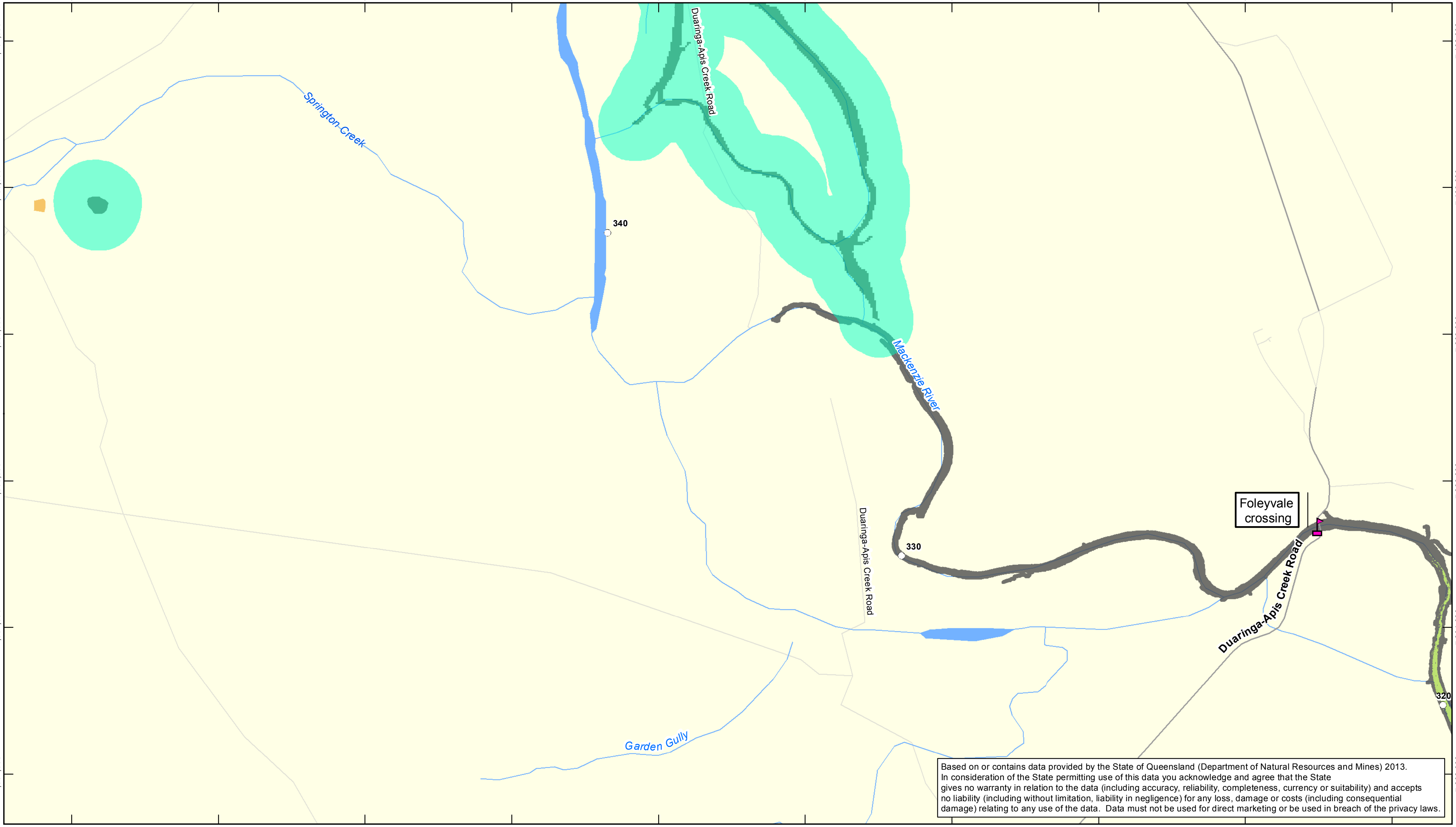
Data Source: © Copyright Commonwealth of Australia (Geoscience Australia): Places, Waterways (2007); Sunwater: Waterways, Weir Locations - 2008; DERM: Railways, Roads; DNRM: DOIW (2010), WPA, WPA Trigger (2011). Created by: MS *See Appendix for disclaimers and copyrights.



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0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA94)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- AMTD (km)
- River Crossing
- Major Road
- Streets (Local)
- Waterway
- Urbanised Area
- Rookwood Weir Stage 1 impoundment
- Rookwood Weir Stage 2 impoundment
- Directory Of Important Wetlands
- Wetland Protection Area
- Wetland Protection Area (Trigger)

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Gladstone Area Water Board

SunWater Making Water Work

Gladstone Area Water Board, SunWater
Lower Fitzroy River Infrastructure Project

Job Number	41-20736
Revision	E
Date	11 Feb 2015

Sensitive environmental areas downstream of the Project footprint

Figure 7-6
Sheet 2

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Data Source: © Copyright Commonwealth of Australia (Geoscience Australia): Places, Waterways (2007); Sunwater: Waterways, Weir Locations - 2008; DERM: Railways, Roads; DNRM: DOIW (2010), WPA, WPA Trigger (2011). Created by: MS *See Appendix for disclaimers and copyrights.

A number of sensitive environmental areas occur within or adjacent to the aquatic environments downstream of the Fitzroy Barrage (Figure 7-6). These include:

- Great Barrier Reef World Heritage Area (GBRWHA)
- Great Barrier Reef Marine Park (GBRMP)
- Great Barrier Reef Coast Marine Park (GBR Coast MP)
- Fitzroy River Fish Habitat Area (FHA) (FHA-072)
- Four Directory of Important Wetlands - Fitzroy River Delta, GBRMP Wetland, Northeast Curtis Island Wetland, Narrows Wetland
- A number of Great Barrier Reef wetland protection areas and area of high ecological significance.

The marine environment downstream of the Project is characterised by a relatively homogenous habitat of soft-sediment, sparse algae not unique to the region, with highly variable water depths partitioned by shoals and channels with surrounding creeks being comparatively shallow. Open mudflats, mangrove forests and samphire forblands dominate the intertidal communities.

The waters within the Fitzroy River estuary provide habitat for a range of marine species that are also known to occur throughout the wider coastal waters of northern Australia. The GBRWHA, GBRMP and GBR Coast MP support habitats for listed and threatened marine species as well as soft-sediment benthic communities, seagrass beds and coral reefs. Specifically, the Keppel Bay area is known to support a low to medium density dugong population (Marsh et al. 2005; Grech and Marsh 2007), marine turtles and coastal dolphin species (GHD 2011a;b). The area also supports internationally and nationally important populations of migratory shorebirds (GHD 2001c).

The GBR Coast MP is a State marine park running the length of the GBRMP providing protection for Queensland tidal lands and tidal waters. The GBR Coast MP supports the creation of a zoning system within, and complimentary to, the GBRMP; habitat protection, conservation park, marine national park and preservation zones as shown in Figure 7-6. Zoning aims to protect the Great Barrier Reef's unique biodiversity, while continuing to provide opportunities for the use of and access to the marine park.

A valuable commercial and recreational fishery exists within the region as recognised through the establishment of the Fitzroy River FHA (Figure 7-6). The Fitzroy River FHA includes parts of the Fitzroy River estuary, Raglan Creek and the wetland systems surrounding North Curtis Island (DNPRSR 2014). Habitat values include extensive saltpans and saline grasslands fed by mangrove-lined creeks as well as mangrove forests, mud and sand flats, rocky headlands and brackish lagoons (DNPRSR 2014).The Fitzroy River transports sediments and nutrients, from natural and anthropogenic sources, from the upstream catchment through the estuary to Keppel Bay (Webster et al. 2006). Transport of sediments from the Fitzroy Basin catchment to the Fitzroy River estuary and Keppel Bay primarily occurs during episodic, generally short-lived flood events in the wet season. The strong tidal, shallow-water environment that characterises Keppel Bay results in sediments remaining in a constant state of suspension and re-suspension (Webster et al. 2006). As a result, suspended sediment concentrations remain high year-round, particularly near the mouth of the Fitzroy River where tidal flows are particularly vigorous (Webster et al 2006). This in turn severely limits opportunities for primary producers (i.e. phytoplankton, algae, seagrass and coral) to inhabit the Fitzroy River delta environment.

The Fitzroy Basin and estuary have been identified as a major source of pollutants into the Great Barrier Reef lagoon (The State of Queensland and Commonwealth of Australia 2003). Long term annual sediment exports from the Fitzroy Basin into the Great Barrier Reef lagoon (2 - 4 Mt/y) account for one third of the lagoon's total input (Packett et al. 2009). This represents a substantial increase from pre-industrial modelled input values. Studies have highlighted the negative effects of increased nutrient, sediment and pesticide loads on the health of key marine habitats such as seagrasses, corals and algae (Packett et al. 2009). Water quality characteristics (including sedimentation) are discussed further in Chapter 11 Water quality.

7.2.1.4 Habitat dynamics

Aquatic habitats in the Dawson, Mackenzie and Fitzroy rivers are highly dynamic. The temporal distribution and spatial extent of the aquatic habitat types is related to fluctuating water levels driven by factors including:

- Rainfall (or lack thereof) within the sub-catchments and upstream catchments
- Management of water storages, for example, Eden Bann Weir and the Fitzroy Barrage
- Extraction of water from waterways by adjacent land holders
- Evaporation and ground seepage.

Due to the highly unpredictable nature of these individual drivers, and the combined influence of the variable interactions of these factors, aquatic habitat distribution and extent is in a constant state of flux. Chapter 9 Surface water resources, provides detail on hydrological catchment characteristics and flow regimes prevalent within the Project areas.

A generalised description of the typical seasonal dynamics of aquatic habitats within the system, as described in the literature and observed in the field (both within the Project footprints, and throughout the wider study area) are described in Table 7-6 and summarised as follows:

- During and post-wet season

  During and post-wet season (approximately November to April), the lower Dawson, lower Mackenzie and Fitzroy rivers primarily exist as deep fast-flowing channels (run habitat) in which in-channel aquatic habitats such as pools and riffles are inundated as a result of a significant increase in water depth and velocity. This was particularly evident in the Rookwood Weir Project footprint during wet season field surveys. Depending on localised rainfall patterns, creek habitats may increase in depth and width as flow rates increase. Off-stream water body habitats such as billabongs may also be inundated during flooding events as river levels rise above bank height (observed downstream of the Eden Bann Weir during wet season surveys). This periodic flooding is important to off-stream water bodies to recharge water levels, provide flushing and allow for biological connectivity with the main stream.

- Dry and pre-wet seasons

  In the dry and pre-wet seasons (approximately April/May to October/November, respectively) as flows decline following the wet season, the river channel is transformed into a series of pool-riffle-run sequences. These sequences were prevalent within the Rookwood Weir Project footprint during dry season field surveys. Off-stream water bodies lose connection with the main channel, and, unless recharged by groundwater or unseasonal rainfall, begin to recede. As the dry season persists, many riffle and run habitats dry out and much of the river exists as a series of isolated non-flowing pools (Limpus et al. 2011a; Marsden and Power 2007). These pools act as refugia for aquatic fauna during the dry season (Limpus et al. 2011a).

Table 7-6 Aquatic habitat seasonal dynamics

Habitat type	Wet season and post-wet (November to April)	Dry-season (May to September)	Pre-wet season (October to November)
Impounded pool (pond)	Linear extent maximised and maximum storage attained, weir may overtop	• Linear extent dependent on management of storage with drawdown (to maintain environmental flows and water security objectives for downstream users) reducing length of impounded pool habitat • Other factors including extraction by adjacent land users, evaporation and ground seepage influence the extent of habitat.	• Linear extent dependent on management of storage • Weir pool may be significantly reduced through drawdown.
Pool	Flowing water converts pools to runs	Predominant habitat type	Likely to become isolated as lack of run-off and water level in river channel declines (evaporation, ground seepage, extraction)
Run	Predominant aquatic habitat type upstream of impounded pool	Flowing water that links deeper natural pools	May dry out, or become narrower and shallower
Riffle	Drowned out due to increased water level in river (runs)	Where stream bed geomorphology is suitable (rocky substrate), shallow water between natural pools (often preceded and immediately followed by runs)	Dry out
Off-stream water body	Recharge through rainfall and flooding	Water levels decrease, unless water body is recharged by groundwater (or unseasonal rainfall)	Water levels decrease to the point where habitats may dry out completely, unless water body is recharged by groundwater (or unseasonal rainfall) – also dependent on size and depth of water body
Creek	Increased depth and flow – dependent on rainfall within creek catchment. Lower reaches may also be inundated by flood waters moving downstream along the main river channel	Reduced rate of flow and depth due to lack of runoff	Reduced rate of flow and depth – creek may become series of isolated pools

7.2.1.5 Habitat disturbance and sensitivity

As one of the largest catchments on the eastern seaboard of Australia, the Fitzroy Basin has a large agricultural production base, accounting for almost 90 per cent of land use in the Basin area (Johnston et al. 2008). These activities, combined with point source inputs from mining operations, reduced or altered flows from dams and weirs and the natural climatic variability of the region, have the potential to affect water quality and cause habitat degradation for aquatic fauna in the lower Dawson, Mackenzie and Fitzroy rivers. Aquatic habitats within the Project footprints feature levels of total suspended solids, turbidity, total nitrogen and total phosphorus above guideline values. The Fitzroy River Partnership for River Health (2013) rates the health of waterways in the Fitzroy, lower Dawson and lower Mackenzie rivers as fair; a mix of good and poor levels of water quality and biological health indicators. Similarly the estuary waterways are rated as being in fair health. The marine zone is rated as being in poor condition; few water quality or biological indicators meet desired levels. Land use is addressed in Chapter 5 Land and water quality conditions within the catchment and Project areas are discussed further in Chapter 11 Water quality.

Changes to water quality and habitat degradation can impact the ability of the river system to support flora and fauna ecosystems, and may impact environmental values downstream in the Fitzroy estuary and within Keppel Bay. The environment is highly dynamic, and interactions between human activities and environmental drivers are complex.

7.2.2 Aquatic species

7.2.2.1 Overview

Aquatic species predicted to occur or recorded in the study area include:

- Thirty-four fish species: No EPBC Act or NC Act listed-threatened species have been previously recorded or are predicted to occur in the study area. Endemic species are present and discussed in Section 7.2.2.2
- Seven reptiles: including the Fitzroy River turtle (vulnerable under the EPBC Act and NC Act) and estuarine (or salt-water) crocodile (migratory/marine under the EPBC Act and vulnerable under the NC Act) that are known to occur in the Project areas (Section 7.2.2.3)
- One aquatic mammal: platypus (listed as special least concern under the NC Act) was predicted to occur within the Project areas (Section 7.2.2.4)
- Eighty-six taxa of macroinvertebrates (Section 7.2.2.5)
- One hundred and five species of macrophytes and 52 species of algae (Section 7.2.2.6).

Table 7-7 summarises the total number of aquatic species recorded according to information sources and surveys conducted for Eden Bann Weir and Rookwood Weir Project footprints.

Marine species predicted to occur or recorded downstream of the Project footprints and within the Fitzroy River estuary are discussed in Section 7.2.2.7.

Database searches and field survey results are presented in aquatic fauna baseline reports in Appendix J and Appendix K for Eden Bann Weir and the proposed Rookwood Weir, respectively.

Table 7-7 Summary of aquatic fauna species predicted to occur or recorded during field surveys

Value	Predicted to occur	Previously recorded			Field surveys
		Wildlife Online	Queensland Museum specimen database	Previous studies	
Eden Bann Weir project footprint					
Species diversity	n/a	24 fish 5 reptiles	2 reptiles	34 fish 7 reptiles 1 mammal (predicted) 86 macroinvertebrate taxa 105 macrophytes* 52 algaes*	10 fish 3 reptiles 59 macroinvertebrate taxa
EPBC Act/NC Act threatened species	1 reptile	3 reptiles	1 reptile	3 reptiles	2 reptiles
EPBC Act marine/ migratory species	1 reptile	1 reptile	-	1 reptile	1 reptile
Endemic/ range restricted species	1 reptile	2 fish 2 reptiles	1 reptile	3 fish 2 reptiles	1 reptile
Introduced/pest species	-	-	-	3 fish	-
Rookwood Weir project footprint					
Species diversity	n/a	8 fish 4 reptiles 1 mammal	1 fish 1 reptile	34 fish 7 reptiles 1 mammal 86 macroinvertebrate taxa 105 macrophytes* 52 algaes*	18 fish 2 reptiles 59 macroinvertebrate taxa
EPBC Act/NC Act threatened species	1 reptile	2 reptiles	1 reptile	3 reptiles	1 reptile
EPBC Act marine/migratory species	1 reptile	-	-	1 reptile	-
Endemic/ range restricted species	1 reptile	1 fish 2 reptiles	1 fish 1 reptile	3 fish 2 reptiles	2 fish 1 reptile
Introduced/pest species	n/a	-	-	3 fish	1 fish

*The number of macrophyte and algae species represents those recorded in the Fitzroy Basin.

7.2.2.2 Fish

Species composition

Thirty-four species of fish have been previously recorded in the study area as listed in Table 7-8. No EPBC Act or NC Act listed-threatened species have been previously recorded or are predicted to occur in the study area. Species considered to have local conservation value due to their restricted geographic range include: southern saratoga (*Scleropages leichardti*); leathery grunter; and golden perch (*Macquaria ambigua oriens*). These species, while not recorded during field surveys within the Project footprints, have previously been recorded in the study area (Stuart 1997, Berghuis and Long 1999, Long and Meager 2000, Heindenreich and Broadfoot 2001, Marsden and Power 2007 and Stuart et al 2007).

The fish community within the Project area is dominated by potamodromous species; however, several diadromous species (specifically catadromous and amphidromous species) are represented (Table 7-8). Potamodromous fish migrate wholly within freshwater for the purpose of breeding or otherwise, while diadromous fish migrate between freshwater and marine environments as follows:

- Catadromous species reside in freshwater and migrate to the sea to breed
- Amphidromous species migrate between freshwater and the sea as part of the species life cycle, but not for breeding purposes (Marsden and Power 2007).

The Fitzroy Basin catchment has a relatively low diversity of introduced and noxious fish species, with the mosquitofish (*Gambusia holbrooki*), goldfish (*Carassius auratus*) and guppy (*Poecilia reticulata*) known to occur. The highly invasive and destructive European carp (*Cprinus caripio*) has been recorded in a lagoon adjacent to Tartrus Weir on the Mackenzie River (Limpus et al. 2007) upstream of the Project area.

Table 7-9 lists the catch composition from season field surveys. Ten species were recorded during field surveys within the Eden Bann Weir Project footprint, and 18 species were recorded within the Rookwood Weir Project footprint. No listed threatened species or species of local conservation value were encountered during the field survey program. All fish species recorded are relatively common species.

The most abundant fish species within the Eden Bann Weir Project footprint was the western carp gudgeon (*Hypseleotris klunzingeri*). The most commonly encountered fish within the Rookwood Weir Project footprint was the Agassiz's glassfish (*Ambassis agassizii*). The blue catfish (*Arius graeffei*) was the most commonly encountered large-bodied (>100 mm) fish species captured within both Project footprints.

Table 7-8 Fish species previously recorded within the study area

Family	Species – scientific name	Species - common name
Catadromous		
Anguillidae	*Anguilla reinhardtii*	Long-finned eel
Centropomidae	*Lates calcarifer*	Barramundi
Scorpaenidae	*Notesthes robusta*	Bullrout
Synbranchidae	*Ophisternon spp.*	Swamp eel
Amphidromous		
Ariidae	*Arius graeffei*	Blue catfish
Belonidae	*Strongylura krefftii*	Freshwater longtom
Gobiidae	*Redigobius bikolanus*	Speckled goby
Hemiramphidae	*Arrhamphys sclerolepis*	Snub-nosed garfish
Megalopidae	*Megalops cyprinoides*	Oxeye herring
Mugilidae	*Mugil cephalus*	Sea mullet
Potamodromous		
Apogonidae	*Glossamia aprion*	Mouth almighty
Atherinidae	*Craterocephalus stercusmuscarum*	Fly-specked hardyhead
Chandidae	*Ambassis agassizii*	Agassiz's glassfish
Clupeidae	*Nematalosa erebi*	Bony bream
Cyprinidae	*Carassius auratus*	Goldfish[3]
Cyprinidae	*Cprinus caripio*	European carp[3]
Eleotridae	*Hypseleotris compressa*	Empire gudgeon
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon
Eleotridae	*Hypseleotris species*[1]	Midgley’s carp gudgeon
Eleotridae	*Mogurnda adspersa*	Purple-spotted gudgeon
Eleotridae	*Oxyeleotris lineolata*	Sleepy cod
Eleotridae	*Hypseleotris klunzingeri*	Western carp gudgeon
Melanotaeniidae	*Melanotaenia splendida splendida*	Eastern rainbowfish
Osteoglossidae	*Scleropages leichardti*	Southern saratoga[1]
Percichthyidae	*Macquaria ambigua oriens*	Golden perch[2]
Plotosidae	*Neosilurus ater*	Black catfish
Plotosidae	*Tandanus tandanus*	Freshwater catfish
Plotosidae	*Neosilurus hyrtlii*	Hyrtl's tandan
Plotosidae	*Porochilus rendahli*	Rendahl’s catfish
Poeciliidaee	*Gambusia holbrooki*	Mosquitofish[3]

Family	Species – scientific name	Species - common name
Poeciliidaee	*Poecilia reticulata*	Guppy[34]
Pseudomugilidae	*Pseudomugil signifer*	Pacific blue-eye
Terapontidae	*Amniataba percoides*	Barred grunter
Terapontidae	*Bidyanus bidyanus*	Silver perch[4]
Terapontidae	*Scortum hillii*	Leathery grunter[1]
Terapontidae	*Hephaestus fuliginosus*	Sooty grunter
Terapontidae	*Leiopotherapon unicolor*	Spangled perch

[1] endemic species; [2] endemic sub-species; [34] introduced species [4] translocated species

Source: Stuart et al. 2007; Marsden and Power 2007; Long and Meager 2000; Berghuis and Long 1999; Stuart 1997.

Table 7-9 Catch composition from seasonal field surveys

Species	Number of individuals				
	Eden Bann Weir		Rookwood Weir		Total abundance
	Wet	Dry	Wet	Dry	
Agassiz's glassfish	-	-	-	137	137
Barred grunter	-	-	-	1	1
Blue catfish	86	3	4	-	93
Bony bream	5	-	-	-	5
Eastern rainbow fish	-	-	1	10	11
Flathead gudgeon	6	-	1	2	9
Fly-speckled hardyhead	-	-	-	40	40
Freshwater catfish	6	-	-	1	7
Freshwater longtom	-	-	-	1	1
Golden perch	-	-	2	7	9
Hyrtl's tandan	5	-	1	1	7
Leathery grunter	-	-	-	1	1
Long-finned eel	1	1	-	-	2
Midgley's carp gudgeon	-	2	-	79	81
Mosquitofish	-	-	2	-	2
Mouth almighty	-	-	3	6	9
Purple-spotted gudgeon	-	-	-	4	4
Sleepy cod	2	1	2	7	12
Snub-nosed garfish	-	-	-	1	1
Speckled goby	1	-	-	-	1
Western carp gudgeon	-	28	-	102	130

Species with significant fisheries values previously recorded within the Project footprints include the barramundi, a catadromous species that is a key target of the Queensland East Coast Inshore Fin Fish Fishery (DEEDI 2009). Whilst commercial fishing does not occur upstream of, or within, the Project footprints, the life-history traits of the barramundi include the use of both freshwater and saltwater habitats. As such, barramundi occurring in the Project footprints areas are considered to be a potential component of the downstream commercial fishery. Other commercially important species known to occur include sea mullet (Eden Bann Weir Project footprint only) and the long-finned eel (both Project footprints).

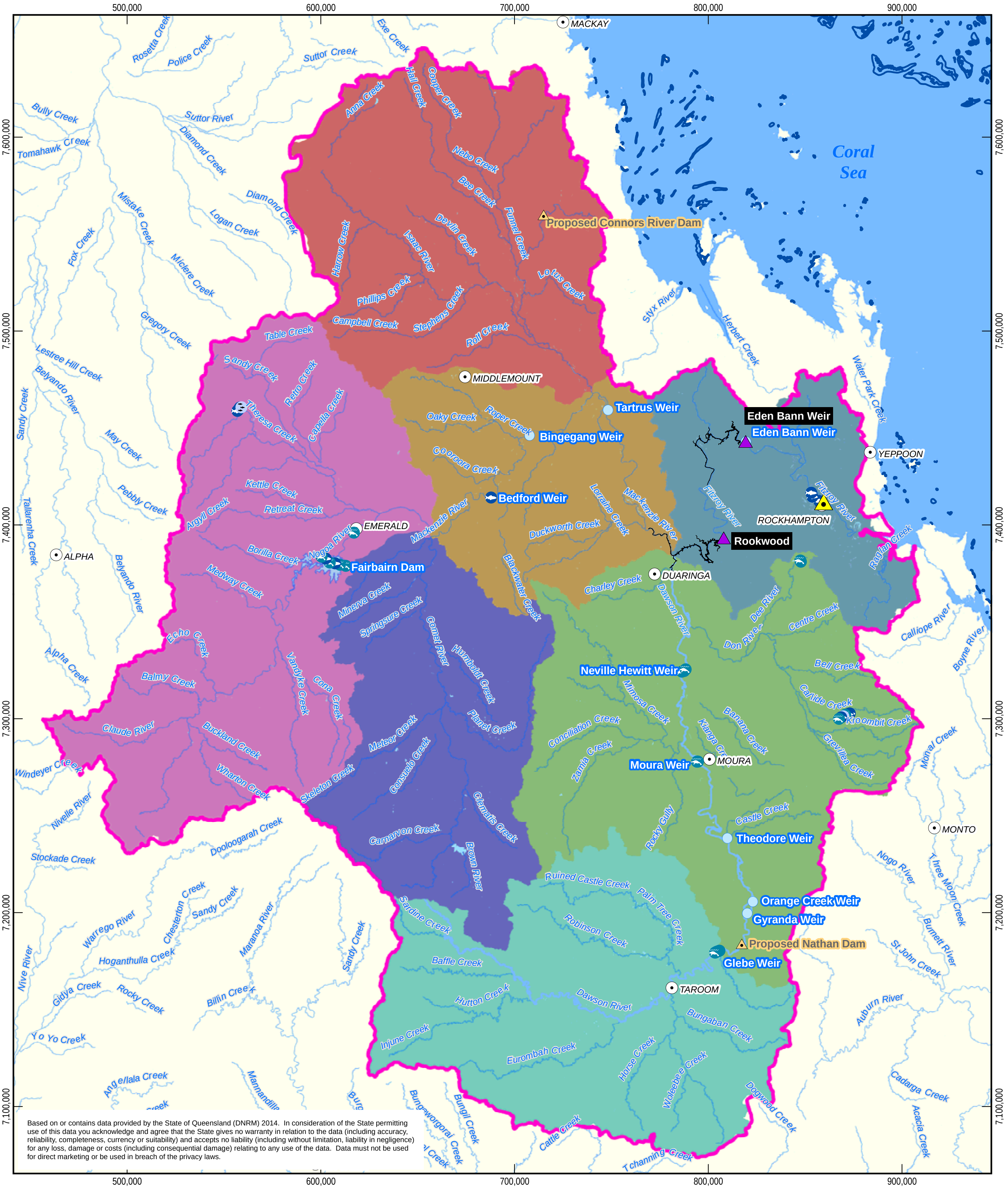
Recreational target species previously recorded in the study area include barramundi, southern saratoga, golden perch, blue catfish, freshwater catfish, sleepy cod, oxeye herring and snub-nosed garfish (DERM 2010).

The (then) Department of Agriculture, Fisheries and Forestry (Queensland Fisheries) stocking records for the period January 2009 to February 2013 indicate that barramundi and golden perch are stocked within dams and weirs throughout the Fitzroy catchment. With reference to the Project, barramundi in particular is stocked within the Fitzroy River Barrage impoundment and within the lower reaches of the Fitzroy River. Golden perch stocking occurs further upstream on the Dawson and Mackenzie rivers outside of the Project areas (with Neville Hewitt Weir and Bedford Weir being the closest stocking locations, respectively). Saratoga is stocked at a single location (Theresa Creek Dam) upstream of Project areas. Figure 7-7 shows stocking locations and species stocked.

Habitat occupancy

Species of fish in the Fitzroy Basin catchment have adapted to the highly dynamic and variable nature of this system (Long 2000). These adaptations are represented by the specific foraging, breeding and sheltering preferences of the species within the system. Most species occur in (or are tolerant of) the still or slow flowing conditions that are present in pool habitats (Pusey et al. 2004; Allen et al. 2003; Marsden and Power 2007). The relatively deep water areas of large pools provide habitat for larger-bodied species that occur in the water column (for example, southern saratoga and golden perch) and benthic habitats (for example, freshwater catfish and Rendahl’s catfish). Within the shallow water areas, smaller bodied species such as western carp gudgeon, eastern rainbowfish and fly-specked hardyhead are more common. Whilst widely distributed species such as the long-finned eel and barred grunter are known to inhabit the fast-flowing conditions of riffles and runs, few species in the Fitzroy Basin catchment are specifically adapted to these habitats. Species previously recorded in the study (but not recorded during field surveys) that are known to prefer flowing conditions include silver perch and sooty grunter.

The foraging and breeding habits in the majority of riverine species of fish are associated with in-stream microhabitats in the form of fallen logs, undercut banks, root masses and macrophytes. Creeks and off-stream habitats such as floodplains and billabongs generally contain a high diversity of in-stream microhabitats. As a result, such areas provide habitat for a wide range of species. Off-stream water bodies also provide breeding and nursery habitat for an array of fish species. The breeding season of a number of species (such as barramundi, long-finned eel, oxeye herring, spangled perch, eastern rainbowfish and empire gudgeon) is known to occur during the wet season when flows within the river are high and off-stream water bodies are connected to the river system (Reynolds 1983; Pusey et al. 2004; Stuart 1999; Stuart and Berghuis 1997).



LEGEND

- Fitzroy Barrage
- Weir Location
- Populated places
- Impoundment area
- Fitzroy Catchment
- Waterway (Major)
- Existing weir
- Proposed dam

Freshwater stocking records from 2009 to 2013

- Barramundi
- Golden Perch
- Saratoga

Sub Catchment (DNRM)

- Lower Dawson River
- Comet River
- Isaac - Connors Rivers
- Fitzroy River
- Noga River
- Mackenzie River
- Upper Dawson River

1:2,650,000 (at A4)

0 12.5 25 50 75 100

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Lower Fitzroy River Infrastructure Project

Job Number 41-20736
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Fitzroy Catchment fish stock locations

Figure 7-7

G:\41\20736\GIS\Projects\MXD\200_Report\4120736_349_rev_b.mxd
145 Ann Street Brisbane QLD 4000 Australia T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: © Copyright Commonwealth of Australia (Geoscience Australia): Places, Waterways (2007); Sunwater: Weir Locations - 2008; DNRM: Railways, Roads, Dam, Existing Weir - 2010, Sub-catchments - 2012; GHD: Fish Stocks (2012). Created by: MS *See Appendix for disclaimers and copyrights.

Field surveys conducted within the Project footprints confirmed the general habitat occupancy detailed from the literature review. The relatively deep, slow-flowing habitat in natural pools housed species such as the blue catfish, golden perch (Figure 7-8), Hyrtl's tandan (Figure 7-8) and freshwater catfish. Flowing water habitats including runs and upstream and downstream of riffles, supported sleepy cod (Figure 7-8) and mouth almighty (Figure 7-8). Along the margins of wide natural pools small native species dominated catches, including the Agassiz's glassfish, western carp gudgeon, Midgley's carp gudgeon, fly-speckled hardyhead (Figure 7-8), purple-spotted gudgeon (Figure 7-8), and eastern rainbowfish. Whilst off-stream water bodies were not sampled within the Project footprints, surveys of these habitats within the study area (downstream of Eden Bann Weir) demonstrated that these habitats support predominantly small-bodied native fish, such as Agassiz's glassfish, Midgley's carp gudgeon, fly-speckled hardyhead, purple-spotted gudgeon, spangled perch and eastern rainbowfish.

Fish migrations

The Fitzroy Basin catchment is typical of many dry tropical rivers in northern Australia where fish migrations are strongly cued with hydrology (Hogan et al. 1997; Renfree and Marsden 2006). Other factors, or combinations of environmental factors, which stimulate migration include water temperature, length of day, food availability, fish biomass and water chemistry. The hydrology cue, however, is recognised as one of the most important for influencing tropical river fish communities and their migrations (Baran 2006; Sheaves et al. 2007; DERM 2010).

In the Fitzroy Basin catchment, a general model of migration includes the first spring flows (for migration of leathery grunter, Rendahl's catfish and golden perch in particular), flood flows associated with the wet season (for migration of golden perch, Rendahl's catfish, spangled perch, barramundi and empire gudgeon), flow recession (for migration of juvenile fish) and low flows (for migration of blue catfish and eels) (DERM 2010).

Figure 7-9 depicts the relationship between fish migration and flow in the Fitzroy Basin catchment. The ecology of freshwater fish in the Fitzroy River is one of migration during flooding.

The first post winter flood is likely to trigger spawning and dispersal migrations for a number of species and these are likely to continue during summer flows (Marsden and Power 2007). For catadromous fish (such as barramundi and eels), high flows and floods are especially important for spawning migrations to downstream estuarine and marine waters (DERM 2010). Barramundi have shown increased recruitment and strong year-classes associated with high flows when fish can migrate laterally into off-stream water bodies (Staunton-Smith *et al*., 2004). Low flow events are important for the upstream dispersal migrations of the juvenile stage of several species including sea mullet, juvenile leathery grunter, juvenile Hyrtl's tandan and juvenile empire gudgeon (Marsden and Power 2007; DERM 2010).

Taxonomically, golden perch appear to be the species most sensitive to high flow and flood migration triggers (DERM 2010). Figure 7-9 shows that fish species in the Fitzroy River (in the order of 30 per cent of species) migrate strongly on large floods (defined as being more than 120,000 ML/d) and many others respond to increasing flows.

Figure 7-8 Fish species encountered during seasonal field surveys

(a) Golden perch

(b) Purple-spotted gudgeon

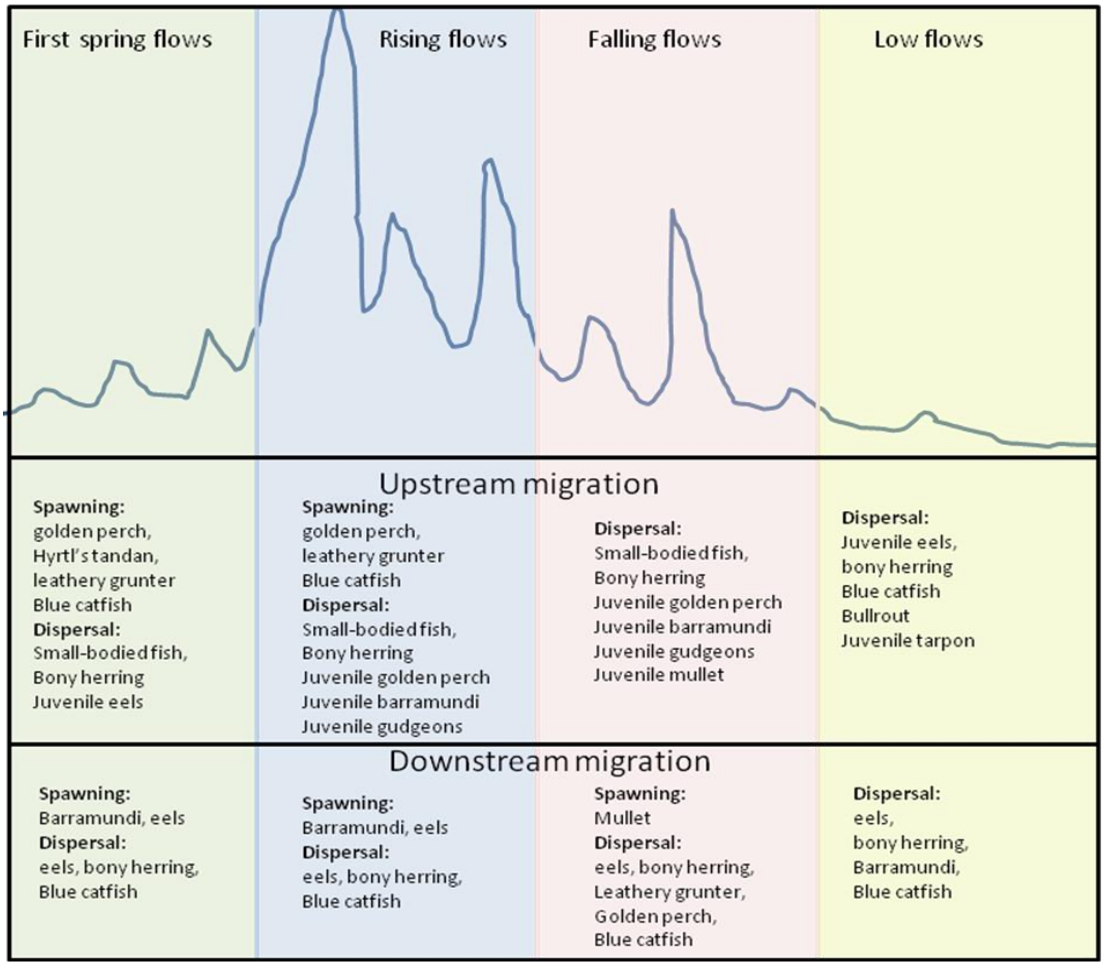
(c) Fly-speckled hardyhead

(d) Sleepy cod

(e) Mouth almighty

(f) Hyrtl's tandan

Figure 7-9 Relationship between fish migration and flow in the Fitzroy Basin catchment



Source: modified from Marsden and Power 2007

The ecology of freshwater fish in the Fitzroy River is one of migration during flooding.

Taxonomically, golden perch appears to be the species most sensitive to high flow and flood migration triggers. However in the order of 30 per cent of species in the Fitzroy River migrate strongly on large floods (defined as being more than 120,000 ML/d) and many others respond to increasing flows as described in Appendix J and Appendix K, which also provide further detail on movement behaviour and hydrological requirements of fish species. Chapter 9 Surface water resources details hydrological regimes.

Barriers to fish movement

Physical barriers such as dams and weirs, can compromise the ability of fish to freely move within the freshwater environment or between the freshwater and estuarine/marine environment. A vertical-slot fishway at the Fitzroy Barrage and a fish lock at Eden Bann Weir facilitate the upstream and downstream movement of many fish species on the Fitzroy River (at and downstream of the Project footprints, respectively):

- Fitzroy Barrage

  The vertical slot-fishway (or fish ladder) (Figure 7-10) at the Fitzroy Barrage (on the southern bank of the Fitzroy River) represents a successful upgrade to the 'weir-and-pool' fishway that was originally in place. The fishway comprises 16 pools (1.95 m x 1.83 m x 1.3 m (usual operating pool depth)) with a head difference of 0.097 m between pools. Vertical slots separating each pool extend the full depth of the pool, with a width of 0.15 m. (Stuart and Mallen-Cooper 1999). The fishway operates when the water level is within 600 mm of the full supply level.

  Stuart and Mallen-Cooper's 1999 assessment of the modified fishway at the Fitzroy Barrage revealed that it was far more effective in facilitating upstream movement of a wide variety of fish species than the original 'pool-and-weir' structure. Notably, over 80 per cent of native freshwater fish identified in previous studies from the Fitzroy Basin, including catadromous, amphidromous and potamodromous species were recorded utilising the fishway (a total of 24 species) (Stuart and Mallen-Cooper, 1999). Whilst the study highlighted that large fish such as blue catfish could ascend the fishway in as little as two hours, many juveniles and small fish species (Agassiz's glassfish, fly-speckled hardyhead and several gudgeon species) were incapable of moving upstream via the passage (Stuart and Mallen-Cooper, 1999). Upstream movement through the fishway was observed to cease in bony bream at the onset of nightfall, with fish moving downstream if they had not ascended the fishway before dark (Stuart and Mallen-Cooper, 1999). Stuart and Mallen-Cooper recommended that resting pools be incorporated into future fishway designs to ameliorate this problem.

  The relative success of the vertical-slot fishway on the Fitzroy Barrage compared with the original 'pool-and-weir' structure was largely attributed to reductions in water velocity and turbulence, which increased the operational capability of the fishway with regard to the headwater and tailwater range over which the fishway can effectively facilitate fish movement.

  The design of the modified fishway was such that fish species boasting a range of behavioural (i.e. benthic to pelagic) and physiological (small to large) attributes could successfully move upstream beyond the Barrage (Stuart and Mallen-Cooper, 1999).

  However, the smallest fish species, and small size-classes (i.e. immature and juveniles) of larger species were unable to negotiate the structure, probably as a result of their inability to swim against the high velocity water flow at the downstream entrance of the fishway (Stuart and Mallen-Cooper, 1999). Furthermore, macroinvertebrates such as crabs and shrimps were unable to ascend the fishway (Stuart and Mallen-Cooper, 1999).

Figure 7-10 Fitzroy Barrage fishway

- Eden Bann Weir

  Eden Bann Weir currently incorporates an automated fish lock (Figure 7-11) to facilitate upstream movement of fish beyond the 7.6 m high barrier. The fish lock and outlet works are located on the left bank whilst the main river channel and the majority of spillway flows occur adjacent to the right bank. A 110 m long channel (6 m wide x 1 m deep) connects the fish lock and outlet works to the main river channel downstream of the weir. The fish lock comprises an entrance chamber, a vertical lock chamber and an exit channel (Stuart et al., 2007).

  The lock operates through four major phases, with a complete cycle taking approximately 90 minutes. In a typical 24 hour period, 16 cycles take place. The four phases in each cycle are attraction (at the downstream entrance of the fishway), filling of the vertical lock chamber, exit (upstream of the weir) and draining of the vertical lock chamber (Stuart et al., 2007). Originally, the design of the fish lock, and its operational control via a computerized Programmable Logic Controller (PLC) only catered for low river flows (up to 6,000 ML/day), thereby limiting upstream movement of fish beyond Eden Bann Weir during periods of increased flow (Stuart et al., 2007). Reprogramming of the PLC software in the late 1990s increased its operational threshold to a daily river discharge amount of 50,000 ML/day, thus allowing the fish lock to operate under flow conditions that persist for 94 per cent of the time (i.e. all but the highest flow events) (Stuart et al., 2007).

  Sampling conducted between 1996 and 2000 recorded 17 freshwater fish species entering the fish lock (Stuart et al., 2007). Sampling at the upstream exit of the lock over the same period recorded only 13 species. The freshwater longtom, eastern rainbowfish, barramundi and saratoga were recorded entering the fish lock but did not remain in the structure to complete the transfer cycle (Stuart et al., 2007). Two species constituted 92 per cent of total captures: blue catfish (52 per cent) and bony bream (40 per cent) (Stuart et al., 2007).

  During low flows, a broad size range of species (35 – 710 mm total length) have been observed being transferred through the Eden Bann Weir fish lock. However, as with the Fitzroy Barrage, passage efficiency is reduced during times of high flow, due to a reduction in the accessibility to the fishway entrance (Long and Meager 2000; Stuart et al. 2007). Of the total number of fish sampled (11,835 individuals during 1996 and again between September 1999 and March 2000), blue catfish (52.1 per cent) and bony bream (42.3 per cent) dominated. Barred grunter (1.6 per cent) and leathery grunter (1.5 per cent) were also present. Two and a half per cent of fish sampled were not identified at species level).

  The actual design of the fish lock (notwithstanding its site-specific application at Eden Bann Weir) was found to successfully facilitate fish passage above the weir, when analysed in the context of the five most commonly caught species (Stuart et al., 2007). Notably, most fish belonging to a variety of size-classes of these five species that were recorded entering the lock chamber, successfully exited the chamber during the exit phase (Stuart et al., 2007).

  The life history traits of fish species recorded using the fish lock at Eden Bann Weir indicates that it provides a conduit for a diversity of native fish. Benthic (blue catfish), mid-water (bony bream) and pelagic (snub-nosed garfish) species were captured during surveys by Stuart et al. (2007). A variety of catadromous (long-finned eel), amphidromous (blue catfish) and potamodromous (bony bream) species were identified as using the fish lock (Stuart et al., 2007).

Figure 7-11 Eden Bann Weir fish lock

Based on a review of studies in other parts of the world, in conjunction with the findings of a study on the migratory biomass ascending the fishway at the Fitzroy Barrage (Stuart and Mallen-Cooper, 1999), Stuart et al. (2007) deduced that the existing fish lock at Eden Bann Weir has the potential to provide passage for the migratory biomass of freshwater fish in the Fitzroy River. However, the ability of some fish to find the entrance of the fish lock was compromised by the site-specific attributes of the Eden Bann Weir site. Whilst a diversion weir that was built in the late 1990s to direct fish towards the fish lock entrance increased the number of fish locating the fishway, some species including golden perch and long-finned eel were still found to concentrate below the weir when water was overtopping the structure (Stuart et al., 2007). The relatively low discharge from the fish lock (0.08 per cent of total river flow during medium flows of up to 50,000 ML/d) was identified as a factor limiting its attractiveness to fish (Stuart et al., 2007). The geography of the site further hinders the ability of fish to locate the fishway, with the main river channel (and thus the area of major flow during spillway flows) isolated from the fishway by a rocky ridge of raised bedrock.

Species including blue catfish, leathery grunter, bony bream and Hyrtl's tandan were found to migrate during periods of increased river flow (i.e. > 32,000 ML/d) (Stuart et al., 2007). More generally, high flows are believed to be an important environmental cue for fish movement in many freshwater species in northeast Australia (Stuart et al., 2007). The difficulties of attracting fish to the fishway at Eden Bann Weir during such high flow periods, when the majority of water flow is concentrated on the opposite (right) bank to the fishway, limits operability of the existing Eden Bann Weir fish lock, which was specifically designed for low flow operation.

An assessment of various cycle times of the fish lock at Eden Bann Weir did not return conclusive results regarding which cycle duration was optimal for successful fish passage (Stuart et al., 2007). Stuart et al. (2007) suggested that an observed increase in migratory movements of blue catfish coincident with rising water temperatures may allow for increased cycle durations (and thus less strain on the components of the fish lock) to be implemented during the cooler winter months when fish migratory biomass is lower.

Downstream passage of fish across Eden Bann Weir may be facilitated by incorporating a downstream mode into the PLC system that controls the operation of the fish lock (Stuart et al., 2007). However, doing this would reduce the facilitation of upstream passage, as the lock cannot operate in an upstream and downstream mode concurrently.

Whilst site-specific issues relating to the location of the fishway at Eden Bann Weir were identified by Stuart et al. (2007), in general, their study found that the fish lock provides a suitable mechanism by which a wide array of species and fish size-classes can travel upstream beyond Eden Bann Weir during periods of low flow.

7.2.2.3 Reptiles

Freshwater turtles

The Fitzroy Basin catchment supports a high diversity of freshwater turtles including the: the Fitzroy River turtle (Figure 7-12); white-throated snapping turtle (*Elseya albagula*); saw-shelled turtle (*Elseya latisternum*); Krefft's river turtle (*Emydura macquarii krefftii*); broad-shelled river turtle (*Chelodina expansa*) and eastern snake-necked turtle (*Chelodina longicollis*).

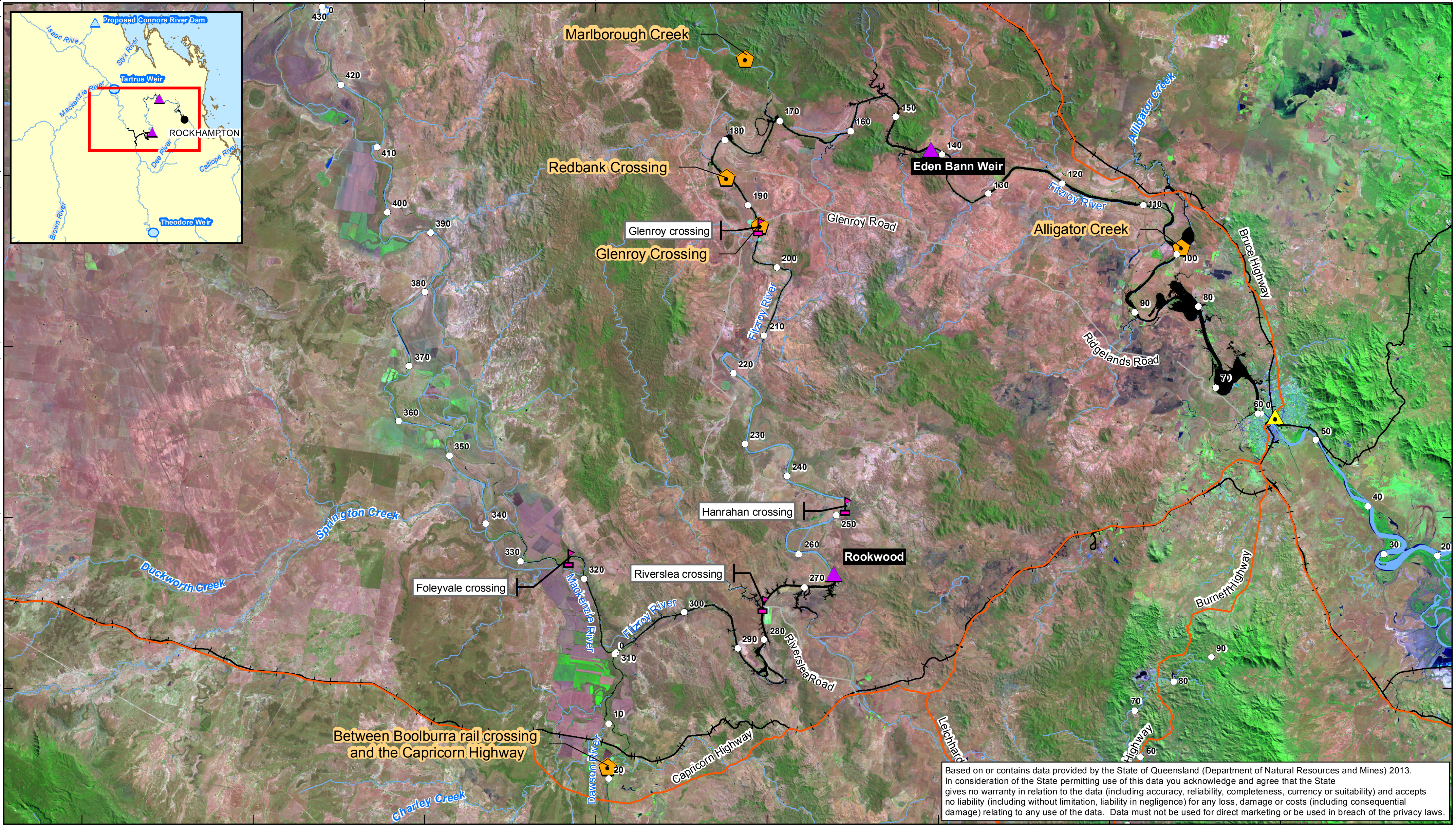
The Fitzroy River turtle is regionally endemic; listed as vulnerable under the NC Act and the EPBC Act; and is considered as high priority for conservation under DEHP's Back on Track framework. The Fitzroy River turtle is known from the Project footprints and discussed in detail in Appendix L. Figure 7-13 illustrates important habitat areas relevant to the Project footprint. Figure 7-14 and Figure 7-15 show the location of nesting banks within the Eden Bann Weir and Rookwood Weir Project footprints, respectively. Figure 7-16 shows potential nesting bank habitat.

Figure 7-12 Fitzroy River turtle

The white-throated snapping turtle is endemic to the Fitzroy, Burnett and Mary river catchments; is listed as least concern under the NC Act; and is ranked as high priority under DEHP's Back on Track framework. The white-throated snapping turtle was listed as critically endangered under the EPBC Act on 24 October 2014. However, it should be noted that the species was not listed prior to the release of ToR for the Project. The white-throated snapping turtle has been previously recorded within the Project footprints.

Saw-shelled turtles, Kreft's river turtles, broad-shelled river turtles and eastern snake-necked turtles are native species listed as least concern under the NC Act. All these species have been previously recorded within the Rookwood Weir Project footprint. All species, except for the eastern snake-necked turtle have been recorded within the Eden Bann Weir Project footprint.

The known distributions of freshwater turtle species within the Fitzroy Basin catchment and a description of species' ecology are provided in baseline aquatic fauna reports presented in Appendix J and Appendix K for Eden Bann Weir and the proposed Rookwood Weir, respectively



1:600,000 (at A4)

0 10 20

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA94)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- AMTD (km)
- Weir Location
- Fitzroy Barrage
- River Crossing
- Highway
- Minor Road
- Waterway
- Railway
- Impoundment Area
- Fitzroy river turtle important habitat areas
- Essential Habitat fitzroy river turtle
- Existing weir
- Proposed Connors River Dam

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Fitzroy River turtle important habitat areas

Figure 7-13

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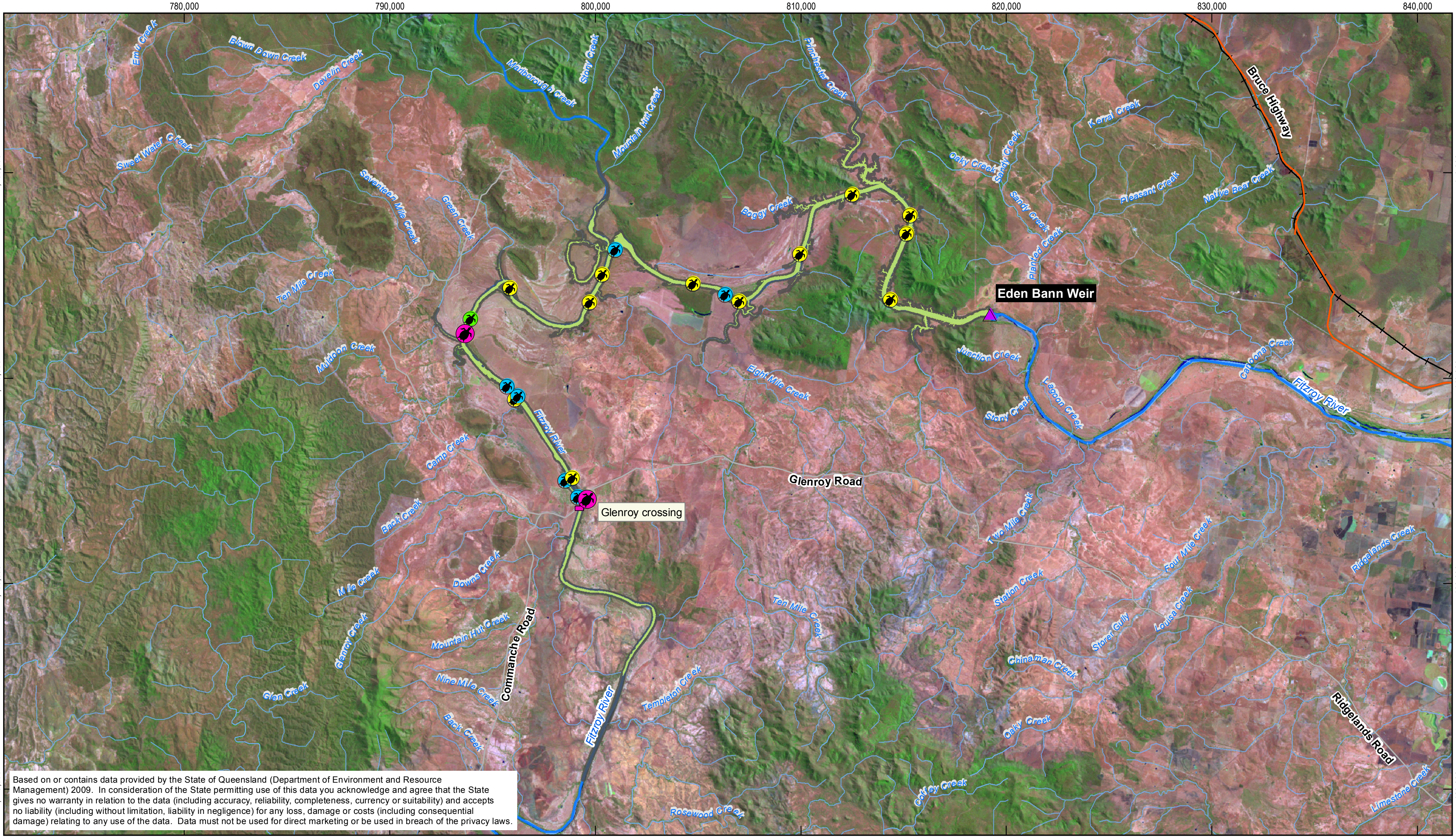
Level 9, 145 Ann St Brisbane QLD 4000 T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com.au W www.ghd.com.au

Data Source: © Copyright Commonwealth of Australia (Geoscience Australia): Waterways, State (2007); Sunwater: Waterways, Weir Locations - 2008; DNRM: Roads - 2010, Railways - 2010, Weirs - 2010, Imagery/2005, Essential Habitat /2011; GHD: Proposed Dam - 2014. Created by: MS



1:250,000 (at A4)

0 2.5 5 7.5 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Weir Location
- River Crossing
- Highway
- Minor Road
- Waterway
- Waterway
- Railway
- Eden Bann Weir Stage 2 impoundment
- Eden Bann Weir Stage 3 impoundment
- High Potential Turtle Nesting Suitability
- Medium Potential Turtle Nesting Suitability
- Low Potential Turtle Nesting Suitability
- Historical Turtle Nesting Site

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Location of potential turtle nesting banks within the Eden Bann Weir Project footprint

Figure 7-14

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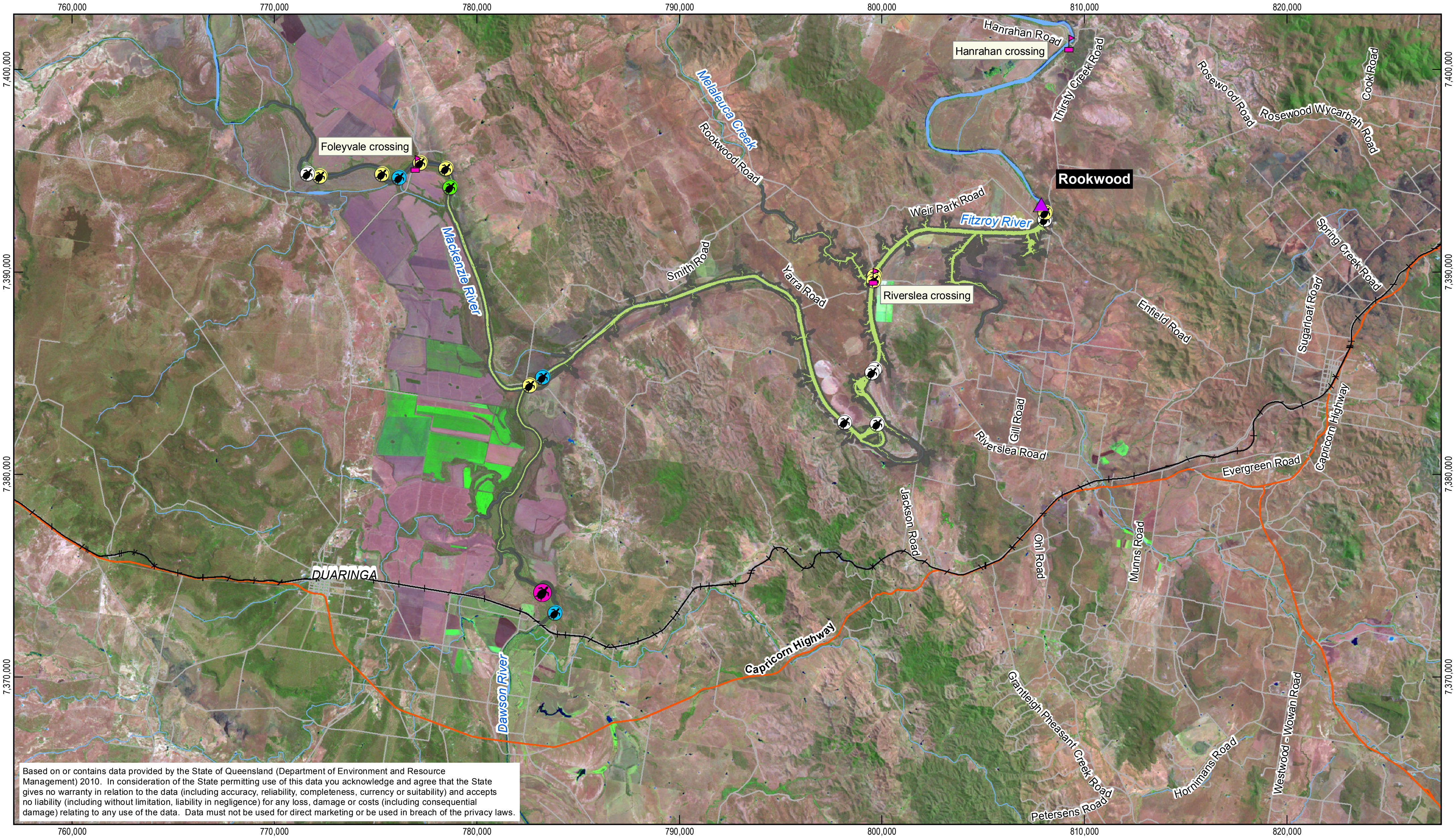
Level 9, 145 Ann St Brisbane QLD 4000 T 61 7 3316 3000 F 61 7 3316 3333 E bnemail@ghd.com.au W www.ghd.com.au

Data Source: © Copyright Commonwealth of Australia (Geoscience Australia): Waterways, State (2007); Sunwater: Waterways, Weir Locations - 2008; DNRM: Roads - 2010, Railways - 2010, DERM - Imagery/2005; GHD: Fauna Survey - 2009. Created by AJ



1:250,000 (at A4)

0 2.5 5 7.5 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Weir Location
- River Crossing
- Railway
- Highway
- Minor Road
- Waterway
- Rookwood Weir Stage 1 impoundment
- Rookwood Weir Stage 2 impoundment
- Confirmed Turtle Nesting Site
- High Potential Turtle Nesting Suitability
- Medium Potential Turtle Nesting Suitability
- Low Potential Turtle Nesting Suitability
- Historical Turtle Nesting Site

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Location of potential turtle nesting banks within the Rookwood Weir Project footprint

Figure 7-15

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Data Source: © Copyright Commonwealth of Australia (Geoscience Australia): Waterways, State (2007); Sunwater: Waterways, Weir Locations - 2008; DNRM: Roads - 2010, Railways - 2010, Imagery/2005; GHD: Fauna Survey - 2009. Created by MS

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Figure 7-16 Fitzroy River turtle potential nesting bank habitat

(a) Eden Bann Weir Project footprint **(b) Rookwood Weir Project footprint**

Crocodiles

The estuarine crocodile is listed as vulnerable under the NC Act and marine and migratory under the EPBC Act. The species ranges from Gladstone in southern Queensland across to north-western Australia and south-east Asia. The Fitzroy River represents marginal habitat for the estuarine crocodile, and is at the southern extent of the species' range in Queensland. The estuarine crocodile is usually associated with tidal, coastal and estuarine environments but is known from inland areas with its physiology allowing the species to move readily between salt- and freshwater environments.

Breeding peaks during October and November. Nesting occurs from December through to April. Eggs laid in mounds of vegetation and soil constructed in close proximity to permanent water. Dispersal is dependent on access to resources and/or competition. Adult males tend to dominate particular home ranges but overlapping homes ranges is not uncommon (EPA 2007). Estuarine crocodiles are faithful to their home ranges and while some natural migration (hundreds of kilometres) does occur, translocated crocodiles are known to travel considerable distances back to their original locations (Walsh and Whitehead 1993). Seasonal migrations between lotic habitats and ephemeral swamps and billabongs occur during the wet season.

The estuarine crocodile is an opportunistic ambush predator with adults feeding on fish, turtles, birds and mammals (including livestock).

While present in low numbers, indications are that the existing Eden Bann Weir impoundment supports a greater abundance of estuarine crocodiles than upstream and downstream reaches of the Fitzroy River (Britton 2007b). Reasons underlying this observation include the availability of permanent, deep water and shelter and foraging resources within Eden Bann Weir (Britton 2007b). Although crocodiles are occasionally observed upstream of the proposed Rookwood Weir site (Limpus et al. 2011a) they are uncommon beyond Glenroy Crossing. Individuals observed in the upper reaches are likely to be transient individuals from the downstream Eden Bann Weir impoundment population (Britton 2007b).

Britton (2007b) reports 43 non-hatchling crocodiles were sited (at an estimated density of 0.7 crocodiles per kilometre) upstream of Eden Bann Weir and the proposed Rookwood Weir site. Two nests were observed upstream of Eden Bann Weir (Britton 2007b). Seasonal flooding of nests and low recruitment from other populations is thought to restrict population growth despite the abundance of food and suitable habitat (Britton 2007b).

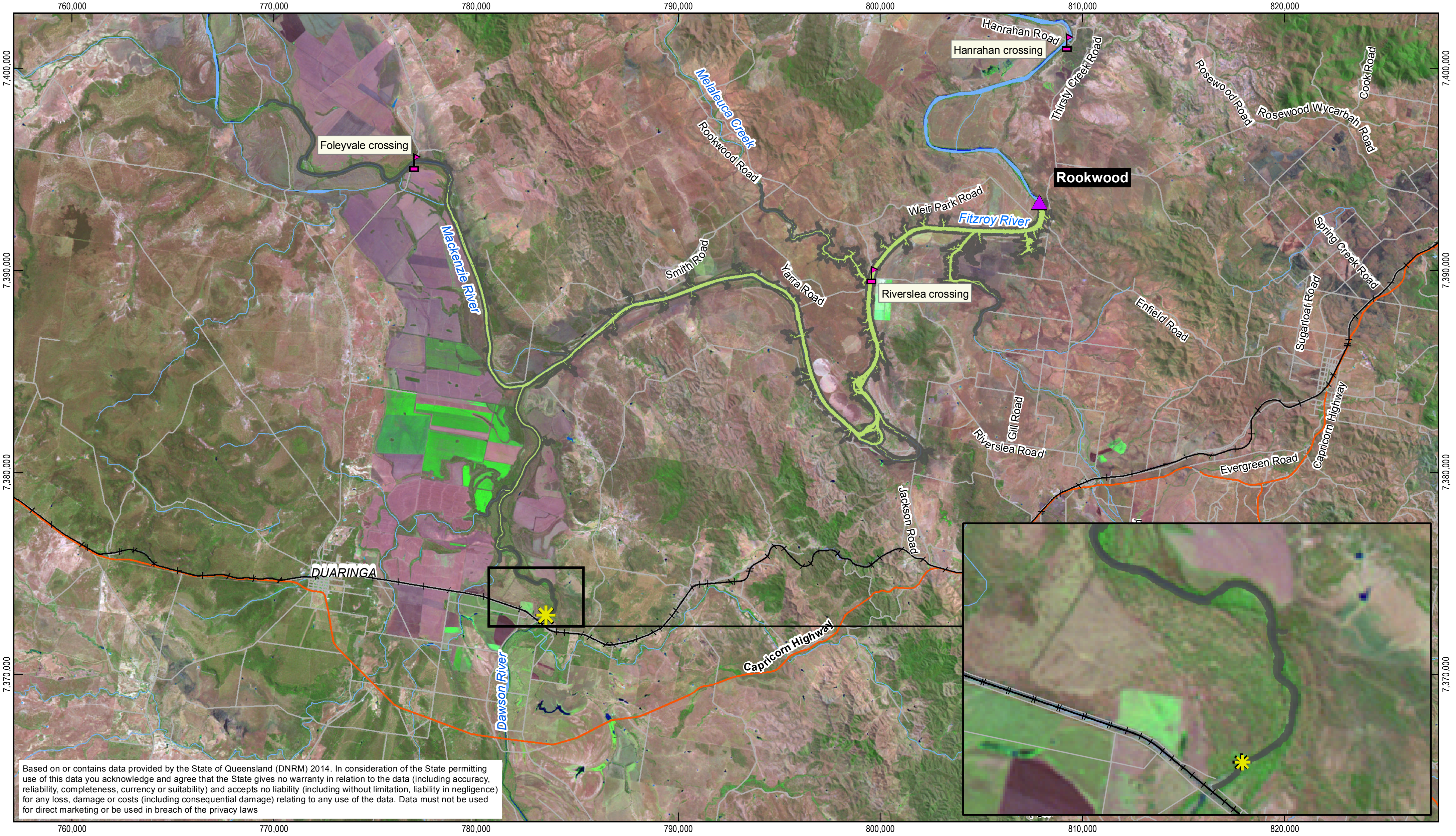
Five crocodiles were observed within the Eden Bann Weir Project footprint during the wet season field survey and three individuals were observed during dry season field surveys. Generally, crocodiles were observed on the bank with individuals moving into the water upon approach of the survey boat. A large crocodile (approximately 3.5 m) was observed approaching the survey boat during nocturnal spotlighting. As well as direct sightings, crocodile slides were observed at numerous locations upstream of Eden Bann Weir (Figure 7-17). All crocodile and crocodile slide sightings were within the existing impounded pool area. No crocodiles or evidence of crocodiles (for example slides or nests) were observed within the Rookwood Weir Project footprint.

Figure 7-17 Crocodile slide (Eden Bann Weir Project footprint)

7.2.2.4 Mammals

A single record (March 2000) for platypus exists within the Project footprints at the upstream extent of the Rookwood Weir Stage 2 inundation on the Dawson River. The location is shown on Figure 7-18. Platypus was not observed during seasonal field surveys. Downstream (primarily estuarine/marine) aquatic mammals are discussed in Section 7.2.2.7.

Some potential habitat may exist in the lower reaches of creeks that adjoin the main river channels on the Dawson River (Appendix K). Platypus is however considered likely to be limited in abundance with a low potential to occur or are absent within Project areas as burrowing habitat is not prevalent.



1:250,000 (at A4)

0 2.5 5 7.5 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Weir Location
- River Crossing
- Railway
- Highway
- Minor Road
- Waterway
- Rookwood Weir Stage 1 impoundment
- Rookwood Weir Stage 2 impoundment
- Platypus Wildlife Online record location

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Wildlife Online Platypus record location

Figure 7-18

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Data Source: © Copyright Commonwealth of Australia (Geoscience Australia): Waterways, State (2007); Sunwater: Waterways, Weir Locations - 2008; DNRM: Roads - 2010, Railways - 2010, Imagery/2005; Wildnet: Platypus Record - 2009. Created by MS

7.2.2.5 Macroinvertebrates

A total of 4,270 individuals from 59 families of macroinvertebrates were collected from artificial substrates in the study area[1] during the wet season and 233 individuals from 28 families during the dry season.

Dominant macroinvertebrate families collected from artificial substrates were:

- Diptera, Chironominae (non-biting midge)
- Diptera, Tanypodinae (non-biting midge)
- Ephemeroptera, Baetidae (mayfly)
- Ephemeroptera, Caenidae (mayfly)
- Ephemeroptera, Leptophlebiidae (mayfly)
- Gastropoda, Hydrobiidae (coiled snails)
- Ostracoda (seed shrimps)
- Gastropoda, Thiaridae (sculptured snails)

Further, fish trapping within the Project footprint identified the following species: freshwater shrimp (*Paratya australiensis*, family: Atyidae), freshwater prawn (*Macrobrachium spp.,* family: Palaemonidae) red-claw crayfish (*Cherax quadricarinatus,* family: Parastacidae), freshwater mussels (family: Hyriidae).

Sampling in the current study did not seek to identify temporal and spatial trends in taxa diversity or abundance, but rather provide additional information about macroinvertebrate diversity in the study area. Several studies have characterised the macroinvertebrate diversity of the Fitzroy Basin catchment. Data collected from three sites in the lower Fitzroy Basin catchment returned 66 macroinvertebrate taxa (frc environmental 2008) while over 70 families of macroinvertebrate were observed from the major drainages of the Fitzroy River during a study in 1997 (Duivenvoorden and Roberts 1997). The most prevalent taxa recorded in 1997 included: Coleopteran (beetles), Diptera (flies), Ephemeroptera, Hemiptera (sucking bugs), Odonata (dragon and damsel flies), Trichoptera (caddis flies), Bivalvia (mussels), Gastropoda (snails), Decapoda (shrimps and crayfish) and Isopoda (shrimp-like taxa) (Duivenvoorden and Roberts 1997). As well as sampling riverine habitats, Duivenvoorden and Roberts (1997) investigated macroinvertebrate assemblages in off-stream wetland habitats and lower order adjoining streams. The off-stream habitats had relatively high macroinvertebrate diversity (> 30 species), with relative abundance higher than adjoining streams. The results obtained from creek habitats were similar to off-stream water bodies, excluding a creek site in a semi-urban landscape (Duivenvoorden and Roberts 1997).

A study of macroinvertebrate diversity in the Dawson River returned 86 taxa from four sites (Duivenvoorden et al. 2000). The species assemblages among sites differed significantly across the temporal scale (Duivenvoorden et al. 2000). Spatial variability was also shown to be significantly different, most notably, there was a significantly different taxa richness between impounded sites and riverine sites (Duivenvoorden et al. 2000). A major conclusion of the study was that macroinvertebrate populations at impounded sites had fewer taxa, appeared to be generally lower in abundance and featured fewer pollution sensitive taxa when compared with

[1] Rookwood Weir Project footprint downstream to the Fitzroy Barrage.

riverine sites (Duivenvoorden et al. 2000). The impacts of rapid and extreme water level fluctuations within weir environments on food and habitat availability were hypothesised as a potential explanation for the observed spatial trend (Duivenvoorden et al. 2000). The loss of more specialist taxa, that were less tolerant of sudden habitat changes, was thought to account for observed temporal variability in macroinvertebrate assemblages, and may have contributed towards the lower taxon richness in weir environments (Duivenvoorden et al. 2000). The relatively lower numbers of taxa sensitive to poor water quality (Ephemeropteran and Trichopteran) was also speculated to be a reflection of the modified and highly variable aquatic environment within impounded pool habitats (Duivenvoorden et al. 2000).

7.2.2.6 Macrophytes and algae

One hundred and five species of macrophytes have been previously recorded in the Fitzroy Basin catchment (Duivenvoorden 1992) with species from the genera *Persicaria*, *Cyperus*, *Juncus* and *Potamogeton* most commonly recorded.

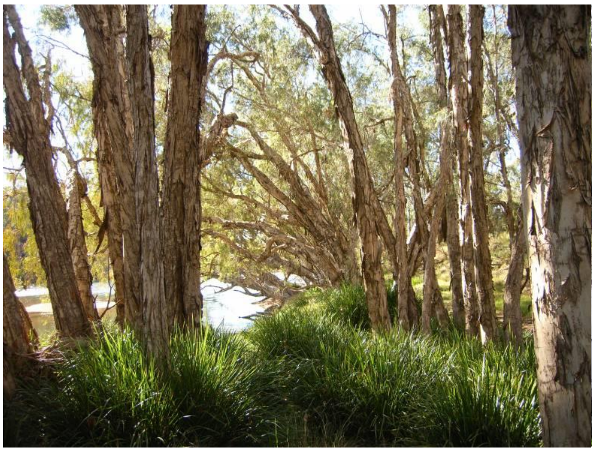
Habitat assessments and field observations revealed that macrophytes were uncommon in riverine (in-channel) habitats within the Eden Bann Weir Project footprint. Of 19 sites in which habitat assessments were undertaken, macrophytes were recorded from only five (four of which were within the impounded pool). Unlike the main channel, creeks and off-stream water bodies were observed to support more notable macrophyte assemblages. As shown in Figure 7-19 floating and emergent macrophytes were particularly prevalent.

Macrophytes were generally in low abundance at sites assessed within the Rookwood Weir Project footprint. Of 18 sites, macrophytes were recorded at only three. Submergent and floating aquatic vegetation was scarce, whilst emergent macrophytes occurred in shallow margins of some less disturbed pools, particularly along the shallow and narrow Dawson River. While in-stream aquatic vegetation was generally scarce, semi-aquatic vegetation belonging to the genus *Lomandra* was ubiquitous in less disturbed riparian habitats. In some locations along the lower Dawson and Mackenzie Rivers, *Lomandra* (Figure 7-19) dominated the groundcover above the waterline.

The general low diversity and abundance of macrophytes in the Fitzroy Basin catchment has been related to factors including the highly variable climate (and its influence on the hydrology of the system), high turbidity levels and cattle grazing/degradation in marginal and riparian habitats (Nergus 2007). Fluctuating water levels in impoundments and turbidity were cited as potential explanations of an observed lack of submerged macrophytes upstream of weirs on the Dawson River (Duivenvoorden et al. 2000).

Aquatic weeds recorded within the catchment include salvinia (*Salvinia molesta*) and *Hymenachne amplexicaulis.* Salvinia is an exotic weed that can rapidly infest waterways and severely degrade aquatic ecosystems. It is a declared Weed of National Significance and is listed as a Class 2 Declared Plant under the LP Act. This species has been recorded downstream of Eden Bann Weir within the Fitzroy Barrage pond (Limpus et al. 2011a) and is predicted to occur upstream of Eden Bann Weir based on bioclimatic modelling. The replacement of native aquatic vegetation by the exotic semi-aquatic grass *Hymenachne amplexicaulis* has markedly altered the ecology of waterways adjoining the Fitzroy River. Like salvinia, this species is a declared Weed of National Significance and is listed as a Class 2 Declared Plant under the LP Act.

Figure 7-19 Macrophytes and algae



(a) *Lomandra spp.* under fringing *Melaleuca*

(b) Macrophytes present in a large off-stream water body

(c) Macrophytes present along the margins of a creek adjoining the Fitzroy River

(d) Filamentous algae present run habitat downstream of a riffle zone (Mackenzie River)

Algae diversity is relatively low within the Fitzroy Basin catchment with a total of 52 species previously recorded (Noble et al. 1997). Within the Rookwood Weir Project footprint, filamentous algae (Figure 7-19) were particularly prevalent in riffle and run habitats where clear, shallow water occurred. Potentially toxic blue-green algae blooms are known to occur throughout the Fitzroy Basin catchment in response to high pH, high nutrients and low flows (Noble et al. 1997). Since October 2007, only low levels of blue-green algae have been recorded from the existing Eden Bann Weir impoundment (frc environmental 2008). Blue-green algae is discussed in detail in Chapter 11 Water quality.

7.2.2.7 Marine fauna species

The following listed marine species occur within the estuarine and marine environment of the Fitzroy delta:

- Endangered:
  - Loggerhead turtle (*Caretta caretta*)
  - Olive Ridley (*Lepidochelys olivacea*). The olive Ridley turtle occurs worldwide throughout tropical and sub-tropical waters. No records of nesting have been found on the eastern Australian coast (SEWPaC 2013)
  - Leatherback turtle (*Dermochelys coriacea*). The leatherback turtle is found in tropical, subtropical and temperate waters throughout the world. No major nesting has been recorded in Australia, although scattered isolated nesting occurs in southern Queensland (SEWPaC 2013). The Fitzroy River estuary does not contain habitat critical to the survival of the species.
- Vulnerable:
  - Dugong (*Dugong dugon*). The Fitzroy River estuary has not been observed to support high numbers of dugong consistent with the absence of seagrass for the area. The waters do, however, provide habitat observed to support low density dugong populations (Marsh et al. 2005; Grech and Marsh 2007).
  - Green turtle (*Chelonia mydas*). Green turtles nest, forage and migrate across tropical northern Australia. Curtis Island is a key breeding area south-east of Keppel Bay (SEWPaC 2013)
  - Hawksbill turtle (*Eretmochelys imbricata*). The hawksbill turtle has a wide range and migrates up to 2,400 km between foraging areas and nesting beaches (SEWPaC 2013). The Fitzroy River estuary does not contain habitat critical to the survival of the species
  - Flatback turtle (*Natator depressus*). The flatback turtle inhabits all coastal waters of Queensland with breeding records down to south-east Queensland (Wilson 2005). Species may utilise adjacent marine waters off the coast at the Fitzroy River mouth for feeding. Nesting habitat for the flatback turtle exists on Curtis Island and Peak Island south east of the estuary
  - Humpback whale (*Megaptera novaeangliae*). The humpback whale principally occurs in oceanic waters and is a migratory species. Humpback whales are not known to feed, rest or calve in Keppel Bay. If present, humpback whales are likely to be only transient visitors to the marine area.
- Near threatened:
  - Australian snubfin dolphin (*Orcaella heinsohni*)
  - Indo-Pacific humpback dolphin (*Sousa chinensis*)

    The Fitzroy River estuary region is a habitat of relatively important conservation value for the Australian snubfin dolphin and is home to the southernmost resident population of this species in Australian waters (Cagnazzi 2013). Similarly, suitable habitat for Indo-Pacific humpback dolphin exists in the Fitzroy River estuary.

7.3 Potential impacts and mitigation measures

7.3.1 Overview

The augmentation/construction and operation of weir infrastructure at Eden Bann Weir and the proposed Rookwood Weir site has the potential to cause a number of direct and indirect impacts on local aquatic ecological values (DERM 2010). Construction activities are expected to occur over at least two consecutive dry seasons. Impoundment is expected to occur within a single wet season during which commissioning will take place (Chapter 9 Surface water resources).

It is anticipated that the following activities may have localised, short-term (construction period) impacts upon aquatic ecological values:

- Loss of vegetation and excavation within the river bed and banks
- Vehicle and plant movement to, from and around the construction site
- Inadvertent spillage of potentially hazardous materials
- Construction (excavation, dewatering, establishment of coffer dams) within the waterway
- Resource extraction.

Following construction, filling of the impoundments (commissioning) also has the potential to impact on aquatic ecological values.

During the operations phase of the Project, potential impacts may result from the following Project activities:

- Water capture and storage (impoundment)
- Releases of water captured and stored behind the weir to downstream reaches
- In-stream barrier operation.

Impacts associated with construction activities and impoundment may include:

- Loss of aquatic habitat
- Habitat degradation
- Fauna injury and mortality
- Restriction of movement
- Alteration of aquatic habitat
- Inundation of turtle nesting habitat
- Increased pest and weed species.

Potential impacts to aquatic ecological values associated with operation of the Project may include:

- Habitat degradation associated with changes to water quality
- Fauna injury and mortality
- Restriction of movement
- Changes in downstream flow regimes
- Increased pest and weed species.

All the potential impacts specifically identified below for the Project were considered in the context of the modelled results and critical flow requirements detailed in the Fitzroy Basin Draft Water Resource Plan Environmental Assessment – Stage 2 Assessment Report (DERM 2010).

7.3.2 Loss of aquatic habitat

7.3.2.1 Potential impacts

Project construction will require the removal of vegetation, excavation of the bed and banks and resource extraction. These activities will result in the direct loss of aquatic habitat at the sites of impact. Aquatic habitat within the Eden Bann Weir construction area has been modified as a result of the existing weir while the aquatic habitat within the Rookwood Weir construction area includes natural pool-riffle-run habitats. The area of habitat to be lost as a result of construction activities is, however, relatively small in size (1.4 ha) compared to the availability of similar habitat upstream and downstream of the sites.

Nesting of the white-throated snapping turtle has been confirmed within the Rookwood Weir construction footprint and the area is While Project areas are considered suitable for Fitzroy River turtle nesting, there is no aggregated nesting at the construction sites and only isolated nesting has been recorded. This loss of habitat is not expected to impact on the turtles.

Additional loss of habitat has the potential to occur within the river crossing construction areas. Redbank and Glenroy crossings are known important habitat areas for the Fitzroy River turtle. The construction area at all river crossing sites will be kept to the minimum amount necessary to in order to minimise impact to aquatic flora and fauna. Due to the relatively small area of habitat to be impacted at these sites (up to 0.03 ha) and the availability of suitable habitat upstream and downstream of the construction works, impacts to aquatic fauna are not expected as a result of this loss. Resource extraction for use in construction will be sourced from excavations within the construction footprints and future inundation areas and areas immediately downstream where ever possible, to avoid impact to additional aquatic habitat.

7.3.2.2 Mitigation measures

The following measures would be implemented to minimise aquatic habitat loss during construction:

- The construction schedule of river crossing construction at Glenroy Crossing will be designed to avoid construction works that may impact on turtle habitat during the peak turtle nesting and hatching season (September to March)
- The construction footprints will be kept to the minimum amount necessary
- The construction footprints will be clearly marked with construction tape
- Resource extraction will not occur in Fitzroy River turtle important habitat areas (e.g. mapped essential habitat) or from within historical, confirmed or high potential turtle nesting habitat
- All construction personnel will be informed of environmental responsibility with respect to the protection of aquatic fauna and their habitat. Site inductions will include information on the location of important habitat and potential turtle nesting habitat to prevent disturbance and/or destruction of these areas. Management actions relevant to the protection of aquatic habitat will be discussed and responsible persons identified.

7.3.3 Alteration of aquatic habitats

7.3.3.1 Overview

Approximately 282 ha and 660 ha of natural aquatic habitat is estimated to be impacted by the Eden Bann Weir and Rookwood Weir impoundments, respectively. Currently approximately 35 per cent of the Fitzroy, Dawson and Mackenzie sub-catchments have been impounded as a result of in-stream water infrastructure (Table 7-3). The Project will result in the inundation of an additional 114.5 km, increasing the area of impacted aquatic habitat within the sub-catchment by 10 per cent:

- Raising of Eden Bann Weir (to Stage 3) is expected to inundate an additional 27.5 km of natural river habitat. Based on the aquatic habitat segment analysis, the reach of river to be inundated comprises approximately 14.5 km of natural pool habitat, 8.5 km of run habitat and 4.5 km of riffle habitat.
- Approximately 87 km of river habitat will be inundated as a result of the proposed Rookwood Weir Stage 2. Based on the aquatic habitat segment analysis, approximately 46.4 km of pool habitat, 29.1 km of run habitat and 21.2 km of riffle habitat along the lower Dawson, lower Mackenzie and Fitzroy rivers will be altered.

These habitats will be altered, primarily through conversion from a lotic (flowing) state to a more homogenous lentic-type habitat characterised by a deep, wide river channel. This will occur on commissioning and persist through operations as the weir fills and is drawn down annually.

The impounded habitat created as a result of the weirs will be generally characterised by a deep, wide river channel, slow to zero flow, poorer quality clay/silt substrate, lower density of in-stream debris and lower density of overhanging riparian vegetation. It is important to note, however, that due to the topography changing along the course of the river system, the depth and width of stream will change. The deep water benthic areas (in water depths > 5 m) that will dominate the weir pool habitat directly behind the weir wall are expected to be uninhabitable to most aquatic fauna species due to low oxygen levels, little or no light penetration and relatively colder temperatures. The upper water column within the more open inundation area is likely to provide very suitable habitat for species such as:

- Large bodied fish - blue catfish, golden perch, freshwater catfish and bony bream
- Krefft's river turtle
- Broad-shelled river turtle
- Estuarine crocodile.

Many other species are likely use the inundated habitat intermittently, the low abundance of micro-habitats and food resources will generally limit permanent occupancy of more open water habitats.

In general, suitable habitat for aquatic fauna will be limited to the shallow littoral habitats along the perimeter of the inundated areas. These areas will contain a higher diversity of in-stream micro-habitats such as fallen logs and root mats and food resources. Snag material along the existing margins of the river that will be inundated is likely to be replaced by drowned-out vegetation about the high water mark of the impoundment.

Overall, the alteration of natural riverine habitats within the Eden Bann Weir Project footprint and Rookwood Weir Project footprint will reduce the heterogeneity of the river system and therefore the diversity of habitats available to aquatic fauna. It is important to note that the extent and duration of aquatic habitat alteration will be related to the amount of water stored in the impoundment (driven by climatic conditions (rainfall/drought) and management of the storage). While aquatic habitats nearer the weirs are likely to be inundated more permanently, habitats in the upper reaches of the weir impoundment will revert back to pool-riffle-run sequences (characteristic of the unimpounded reaches of the lower Dawson, lower Mackenzie and Fitzroy rivers) as the weir is drawndown and the volume of water in the storage is reduced. The linear extent of the reversion will be, as mentioned above, largely related to rainfall and drawdown of the storage. While these habitats may become temporarily available, the quality of the habitats for aquatic fauna is likely to be reduced due to extended periods of inundation within the impoundment. Reduced habitat quality may result from a reduction in macrophytes, macroinvertebrates and changes to substrate.

The lower reaches of the 19 named creeks (and smaller unnamed creeks) in the Eden Bann Weir Project footprint and Rookwood Weir Project footprint, and the connectivity and hydrology of the 55 off-stream water bodies within 1 km of the lower Dawson, lower Mackenzie and Fitzroy Rivers are likely to experience varying degrees of alteration. This includes the inundation of creek bed and banks and the inundation of off-stream water bodies (palustrine wetlands). The extent of this alteration will be more notable in and adjacent to the lower reaches of the weir impoundment.

A Great Barrier Reef wetland protection area is mapped within 350 m of the upper most extent of the Rookwood Weir (Stage 2 only) impoundment on the Mackenzie River (at 334 km AMTD (Figure 7-5 and Figure 7-6). Coinciding with this area is a wetland defined as being of high ecological significance. The Stage 2 Rookwood Weir impoundment is not expected to inundate these wetland areas and will not directly impact the functioning of the wetland ecosystem at this location. No lacustrine wetland areas will be directly impacted by the Project (Figure 7-4 and Figure 7-5). Two off-stream water bodies (palustrine wetlands) located at approximately 270 km AMTD and 284 km AMTD associated with the Rookwood Weir impoundment (Figure 7-5) will be inundated. Given the nature of water storage within the main river channel bed and banks, it is not expected that the Project will adversely impact off-stream wetland connectivity with the river, or adversely alter the seasonality, duration, frequency and volume of water entering and leaving the off-stream water bodies. Consequently, it is not expected that the Project will impact the specific habitat characteristic of the off-stream water bodies and their value for aquatic flora and fauna. Those habitats replenished by large flood flows are not expected to be affected by the proposed infrastructure and hydraulic/hydrological modelling indicates that the Great Barrier Reef wetland protection areas located adjacent to the Eden Bann Weir and Rookwood Weir Project footprints will not be impacted by the Project. Additional information on inundation extents during flooding events is provided in Chapter 9 Surface water resources.

Impacts on aquatic fauna associated with changes to aquatic habitats are discussed below.

7.3.3.2 Potential impacts to freshwater turtles

Potential impacts on freshwater turtles due to alteration of aquatic habitats during commissioning may include:

- A reduction in overhanging vegetation that provides important food resources for freshwater turtles, particularly the white-throated snapping turtle
- A reduction in in-stream micro-habitats (fallen logs and root mats) and food resources such as macrophytes and macroinvertebrates for freshwater turtles

- Loss of niches, particularly for threatened species
- Alteration of in-stream aquatic habitats (transformation from a lotic (pool-riffle-run) river system to a lentic impoundment) (DERM 2010).

Impacts on the Fitzroy River turtle, while discussed herein are specifically addressed in Section 7.3.12.1 and Appendix L.

The pool-riffle-run sequences and off-stream habitats within the Eden Bann Weir Project footprint and Rookwood Weir Project footprint provide a range of micro-habitats and food resources for four common species of freshwater turtle (Krefft's river turtle, saw-shelled turtle, broad-shelled river turtle and eastern long-necked turtle).The aquatic habitat created within the impoundment as a result of the proposed Rookwood Weir is likely to be suitable for the Krefft's River turtle as this species is known to thrive in a range of habitat types including impoundments (Limpus et al. 2011a). The saw-shelled turtle and broad-shelled river turtle primarily inhabit areas with a high abundance and diversity of in-stream debris such as submerged roots, fallen logs and undercut banks (Cann 1998; Limpus et al. 2011a). Suitable shelter and foraging habitat for these species is likely to be restricted to the shallow water margins and upper reaches of the impoundment. The eastern long-necked turtle primarily inhabits off-stream water bodies such as wetlands, swamps, lagoons, man-made dams and billabongs (Cann 1998; Limpus et al. 2011a). Impacts to off-stream habitats are predicted to be limited (Section 7.3.3.1).

In comparison to the aforementioned species, the Fitzroy River turtle and the white-throated snapping turtle have relatively specific habitat requirements as they predominantly inhabit permanent habitats within the river channel (as opposed to off-stream habitats such as swamps and billabongs). Riffle zones are known to provide a particularly high abundance and diversity of food resources for these species as they provide highly oxygenated waters which can aid in aquatic respiration (Gordos 2004). While the Fitzroy River and white-throated snapping turtles are often referred to as riffle zone specialists, both species also inhabit pools, runs and creeks. Following construction, the conversion of natural habitats (pool-riffle-run sequences) into a large impounded pool habitat will result in the loss of heterogeneous lotic habitat that is favoured by these turtle species. Of particular importance is the loss of riffle zone habitat, flowing shallow-water habitat and micro-habitats (for example in-stream debris and overhanging riparian vegetation) which are used by these species for foraging and sheltering (Limpus et al. 2011a).

In general, suitable habitat for the Fitzroy River turtle and white-throated snapping turtle will be limited to the shallow littoral habitats along the perimeter of the storage and the shallow upstream margins. These areas will contain a higher diversity and abundance of in-stream micro-habitats (e.g. fallen logs and root mats) and food resources such as sponges and macroinvertebrates. The diversity and abundance of food resources is expected to differ to that available in pool-riffle-run habitats. In particular there is expected to be an increase in macroinvertebrate, macrophyte, and fish species that prefer slow-flowing conditions and a decrease in specialist species such as those found in rocky substrates and flowing waters. Due to the overall reduction in resources within the impoundments, the carrying capacity of these habitats is expected to be lower than that of the un-impounded pool-riffle-run sequences (Limpus et al. 2011a). A comparative study between natural and impounded habitats by Tucker (2000) found that turtle biodiversity was reduced within impoundments with a decline in specialist species, such as the Fitzroy River turtle, and an increase in generalist species, such as the Krefft's River turtle. Tucker associated this reduction in turtle biodiversity with a change in foraging resources, reduction in micro-habitats and change in water quality (Tucker 2000).

Since the publication of Tucker's report in 2000, surveys within impounded habitats have identified that pool-riffle-run sequences are not critical to the survival of the Fitzroy River turtle and that the species can persist within impounded habitats (Limpus et al. 2011a). While the availability of suitable habitat within the impoundments is expected to fluctuate over time (in accordance with storage operation and the associated level of impoundment) it is expected that suitable habitat within the impoundments will be retained within the shallow littoral habitats along the perimeter of the storage and the shallow upstream margins. Operationally it is intended that weir storages will remain impounded for approximately eight months of the year with draw down occurring in the drier period. This is most evident within the Fitzroy River Barrage impoundment where the stable, flowing waters in the upper reaches (at Alligator Creek) provide habitat for the largest known turtle nesting aggregation. Residual impacts on aquatic habitat are proposed to be offset in accordance with the provisions of the EO Act (Chapter 22 Offsets).

7.3.3.3 Potential impacts to estuarine crocodiles

The Project is not considered likely to adversely impact on the estuarine crocodile. Short-term impacts to nesting habitat are likely to be ameliorated by the creation of new nesting habitat over a time frame which is unlikely to detrimentally affect the viability of the population (namely due to the species' longevity). Habitat modification may in fact benefit the species as is evident from the existing Eden Bann Weir impoundment that is considered to be a highly productive system that supports one of the largest estuarine crocodile populations within the Fitzroy Basin. The provision of similar habitat upstream of the existing Eden Bann Weir impoundment and upstream of the proposed Rookwood Weir site may allow for a higher carrying capacity for the species in the study area. In particular, the provision of suitable foraging and sheltering habitat due to the presence of deep, permanent water may encourage greater utilisation of habitats upstream of the weirs by estuarine crocodiles. However, the paucity of suitable nesting habitat upstream of the proposed Rookwood Weir site is likely to limit recruitment and population growth in spite of the suitable aquatic habitat (Britton 2007b).

7.3.3.4 Potential impacts to fish

The pool-riffle-run sequences that characterise the aquatic environment within the Project footprint provide a diversity of potential habitats for native freshwater fish. Construction of Rookwood Weir will alter these aquatic habitats through conversion to an impounded pool. Alteration of aquatic habitats within the Eden Bann Weir inundation area will impact fish, through inundation of pool-riffle-run habitats upstream of the existing impoundment, and changes to littoral habitats at the margins of the impoundment (DERM 2010). Additionally, fish may be affected by short-term changes to resource availability immediately following the initial inundation of shallow aquatic and riparian habitats upstream of the structure (DERM 2010). Important resources that may be altered include:

- Aquatic, semi-aquatic and overhanging vegetation
- Macroinvertebrate diversity and abundance
- In-stream structure (woody debris, undercut banks)

A reduction in macrophyte communities following the initial inundation of shallow margin habitats may reduce shelter and feeding resources for fish and their prey. While macrophyte communities may re-establish in proximity to the new high water level of the impoundment, these communities are more likely to shift spatially within shallow water margins (where suitable habitat occurs) in response to fluctuations in the storage level. The extent of this spatial shift will be dependent on water level fluctuations occurring over a period that allows macrophytes to establish. Rapid fluctuations in water level in the storage are unlikely to allow for macrophyte reestablishment, thereby reducing a potentially important habitat resource for fish.

In terms of prey availability, macroinvertebrate species associated with riffle habitats are likely to be lost where riffle habitats are altered from inundation upstream of Eden Bann Weir and the proposed Rookwood Weir (DERM 2010). However, it is likely that macroinvertebrates that are tolerant to wider range of environmental conditions will persist in the weir impoundment.

Structures that provide shelter and foraging resources include in-stream woody debris, aquatic, semi-aquatic and overhanging vegetation and undercut banks. As part of the Project, these structures are likely to be lost in the short-term due to upstream inundation. Following inundation, riparian vegetation is likely to form structures that can provide shelter and food resources in the long-term within the margins of the storage. As in-stream debris contributes significantly to fish habitat use (Pusey et al. 2004), the spatial distribution and abundance of fish within the impoundment will be concentrated around these microhabitats. Such habitats are likely to be most prevalent at the margins of the impoundment following inundation.

Fish species in the Fitzroy Basin are adapted to the highly dynamic and variable nature of the system (Long 2000). These adaptations are represented by the specific foraging, breeding and sheltering preferences of the species that occur within the system. A review of the ecology of fish species known to occur within the Fitzroy Basin catchment (and are representative of those within the Fitzroy, Mackenzie and Dawson rivers) revealed that most species prefer (or are tolerant of) the still or slow flowing conditions that are present in pool habitats (Pusey et al. 2004; Allen et al. 2003; Marsden and Power 2007; DERM 2010). The conversion of approximately 87 km of pool-riffle-run sequences to a weir impoundment may adversely impact species that prefer flowing water habitats (DERM 2010). While such habitats are not a critical component of the life-history for the majority of species in the study area, populations of some fish species that favour this habitat, such as the endemic (although non-threatened) leathery grunter, may be affected (DERM 2010). It should be noted however, that flow conditions are likely to persist in the upper reaches of the impoundment.

Although changes in resource availability following the impoundment of water upstream of the Eden Bann Weir Project and Rookwood Weir Project are not expected to markedly change fish species diversity, the relative abundance of species may change. This is due to a reduction in foraging, sheltering and/or breeding resources that are required for individual species. For example, freshwater catfish may become less abundant due to a reduction in breeding habitat (cobble substrate) within the lower reaches of the impoundment (DERM 2010). A trend in the maintenance of species diversity but variations to the relative abundance between riverine and weir environments was observed in the Dawson River (Long 2000).

7.3.3.5 Potential impacts to macroinvertebrates

An upsurge in macroinvertebrate diversity and abundance within the Eden Bann Weir and Rookwood Weir Project footprints, is predicted to occur in the immediate aftermath of inundation due to the release of nutrients from newly inundated soil and vegetation (Baumgartner 2005). However, following this initial productivity, nutrient depletion and habitat homogeneity may result in a decline in macroinvertebrate diversity and abundance (Baumgartner 2005) (Chapter 10 Water quality).

Impounded habitats within the Fitzroy Basin catchment have been found to support a lower total abundance of macroinvertebrates and fewer pollution sensitive taxa when compared with riverine sites (Duivenvoorden et al. 2000). The impacts of rapid and extreme water level fluctuations on food and habitat availability are thought to result in the observed reduction in macroinvertebrate taxa within impounded habitats (Duivenvoorden et al. 2000).

Off-stream habitats have been recorded to support relatively high macroinvertebrate taxa diversity in the Fitzroy Basin (Duivenvoorden and Roberts 1997). No adverse impacts to these habitats are predicted (Section 7.3.3.1).

7.3.3.6 Mitigation measures

The following mitigation measures are proposed to avoid/minimise the potential impact of Project commissioning on aquatic ecological values:

- Riparian vegetation clearing within the impoundments prior to inundation will not take place and large woody debris will be retained. This will provide (in the short-term) sustained micro-habitats and resources. It is expected however that over time vegetation will dieback and new vegetation will emerge in riparian areas above the full supply level
- The re-establishment of aquatic habitat within the impoundment will be encouraged through the following actions:
  - Avoiding rapid drawdowns of the storage area to allow for the stabilisation of aquatic habitat around the margins of the impoundment
  - Promoting the natural regeneration of trees and shrubs
  - Controlling introduced weeds and feral animals in accordance with the Project Weed Management Plan and Feral Animal Control Program.

Chapter 10 Water quality, provides measures aimed at mitigating impacts of impoundment on water quality parameters.

7.3.4 Inundation of turtle nesting habitat

7.3.4.1 Potential impact

Nesting by Kreft’s river turtle, saw-shelled turtle, broad-shelled turtle and eastern snake-necked turtle occurs on a variety of river bank substrates (Cann 1998, Limpus et al 2011a). Nesting occurs within 5 m to 50 m from the water’s edge. Given the generalist nature of these species and the ability to utilise a variety of nesting habitats, it is not expected that adverse impacts will arise as a result of the Project.

In comparison, Fitzroy River turtle and white-throated snapping turtle nesting areas are primarily restricted to alluvial sand/loam banks with a relatively steep slope and low vegetation cover. Impacts on the Fitzroy River turtle are summarised below and discussed further in Section 7.3.12.1 and Appendix L.

Fitzroy River turtle and white-throated snapping turtle nesting habitat throughout the Fitzroy Basin catchment is impacted by adjacent land use practices and is, in general, highly disturbed. Degradation from cattle, pigs and weeds is widespread reducing the suitability of habitat for turtle nesting in many areas (DERM 2010). Where nesting does occur, extreme levels of nest predation, close to 100 per cent, result in little to no recruitment of hatchlings into the population (Limpus et al. 2011a; Limpus et al. 2011b).

Within the Fitzroy Basin catchment, important nesting habitat for the Fitzroy River turtle and white-throated snapping turtle occurs at Alligator Creek within the upper reaches of the Fitzroy Barrage impoundment (downstream of the Project footprint), immediately downstream of Tartrus Weir on the Mackenzie River (upstream of the Project footprint) and within the upper reaches of the Tartrus Weir impoundment on the Isaac River (upstream of the Project footprint) (Limpus et al. 2011b). Outside these areas, including within the Project footprints, isolated nesting occurs.

As described in Appendix L, nesting bank elevation data was compared to daily water levels in the impoundments during the nesting season to determine the potential availability of nesting banks for active protection of nests during this period. The assessment showed that during a wet year there is no possibility of protecting nests within the impoundment. In dry years there is limited potential to protect nests at some locations but an inflow that inundates all nesting banks could occur at any time.

As such, the Project will result in the inundation of known and potential Fitzroy River turtle nesting habitat within the Project footprints during commissioning. Nesting habitat to be impacted will include:

- Historical nesting banks at Redbank crossing, Glenroy crossing and Boolburra Rail crossing
- Six confirmed nesting banks between 266 and 329 km AMTD within the Rookwood Weir Project footprint
- Two high potential nesting banks at 182 km AMTD (Eden Bann Weir Project footprint) and 321 km AMTD (Rookwood Weir Project footprint).

Some water storages, such as Ben Anderson Barrage on the Burnett River, are able to manage water levels during nesting periods through regulated inflows from upstream storages to prevent nest inundation within the impoundment. At Rookwood Weir, there are no such structures upstream from which regulated releases can be made to maintain a stable water level. Similarly, while there is potential for Rookwood Weir to regulate flows to Eden Bann Weir to some degree, given the nature and operation of weir storages and reliance on natural inflows this ability would be limited and are likely to be superseded by naturally occurring high river flows that overtop the spillway. As such, the Project cannot feasibly manage water levels to effectively avoid or minimise impacts on existing nesting habitat.

The loss of nesting habitat within the Project footprints has the potential to disrupt the breeding cycle of the species by restricting nesting to sub-optimal habitats and reducing reproductive success (DERM 2010). Due to the specific nesting requirements of the species' and the extremely high nest predation rates throughout the catchment, the loss of Fitzroy River turtle and white-throated snapping turtle nesting habitat within the Project footprint is considered significant. The maximum total area of nesting habitat impacted by the Project (Eden Bann Weir Stage 3 and Rookwood Weir Stage 2) has been calculated as 5.71 ha (Appendix L).

Suitable nesting habitat for the Fitzroy River turtle and white-throated snapping turtle is expected to persist in the upper reaches of the impoundments with potential nesting habitat remaining above full supply level within the Rookwood Weir Project footprint. Suitable nesting habitat is also expected to be naturally created in flood deposition areas over time. The existence of aggregated nesting in the upper reaches of the Fitzroy River Barrage (Fitzroy River turtle and white throated snapping turtle) and the Tartrus Weir impoundment (Fitzroy River turtle), demonstrate that the species has the ability to colonise new habitat where suitable conditions do occur. The turtle species have also demonstrated adaptability to fluctuations in nesting habitat conditions following natural events such as flooding (Dr Col Limpus pers comm.). The implementation of a Weed Management Plan and Feral Animal Control Program will assist in increasing the quality of potential nesting habitat for turtle nesting and the potential for successful recruitment of hatchlings within the Project footprints. The establishment and success of Fitzroy River turtle and white-throated snapping turtle nesting in these areas is, however, unable to be assured. Residual impacts on the Fitzroy River turtle are proposed to be offset in accordance with the provisions of the EPBC Act (Chapter 22 Offsets).

7.3.4.2 Mitigation measures

The following mitigation measures are proposed to minimise the potential impact of the Project on turtle nesting habitat:

- The re-establishment of turtle nesting habitat within the impoundment will be encouraged through the following actions:
  - Avoiding rapid drawdowns of the storage area and controlling water levels to allow for the stabilisation of nesting habitat around the margins of the impoundment
  - Rehabilitating and restoring areas impacted by scouring, erosion and slumping.
- A Weed Management Plan will be developed and implemented for the Project. The management plan will detail the control and treatment of introduced weeds that may negatively impact habitat quality
- A Feral Animal Control Program will be developed and implemented for the Project or in collaboration with local council, community groups and landholders. Specific measures may include culling, baiting and trapping of pigs, foxes, wild dogs and feral cats.

Specific measures in relation to the Fitzroy River turtle are described in Section 7.3.12.1 and Appendix M.

7.3.5 Habitat degradation associated with construction activities

7.3.5.1 Potential impacts

Construction activities within the construction footprints have the potential to result in the degradation of habitat within and immediately downstream of these sites. Habitat degradation may occur as a result of:

- Sedimentation and erosion

  Unmitigated point-source pollution from sedimentation and run-off may alter the chemical and physical characteristics of habitat within and downstream of the construction areas. Specific impacts may include reduced water quality (increased turbidity; decreased oxygen levels; reduced light penetration), change in channel morphology, alteration of substrate composition and smoothing of aquatic vegetation and organisms (Wood and Armitage 1997; Wheeler et al. 2005). A Drainage, Erosion and Sediment Control Plan will be developed and implemented to minimise potential impact to aquatic habitat as a result of construction activities.
- Increased weed and pest species (Section 7.3.10)
- Light, noise and vibration disturbance

  During the period of construction, there is expected to be intermittent and localised increases in light, noise and vibration adjacent to the construction areas. This has the potential to cause short-term disruption to aquatic fauna behaviour in adjacent habitats during the period of construction causing fauna to move away from the area. It is not expected that this impact will detrimentally impact aquatic fauna species.

- Storage and spillage of hazardous materials

  Use of construction machinery in and around aquatic habitats has the potential to result in the spillage of contaminants, such as fuels and lubricants. In severe cases, chemical pollution of the aquatic environment could result in mortality of aquatic fauna and long-term degradation of aquatic habitat. The development of a Waste and Hazardous Materials Management Plan will substantially reduce the potential for spillage and likelihood of impact.

- Flow diversion and control

  Diversion of flow within the construction areas has the potential to degrade aquatic habitat immediately upstream and downstream (DERM 2010). Weir construction will be primarily undertaken over two consecutive dry seasons when flows within the river are low and natural/existing conditions will be maintained for as long as possible. A flow diversion strategy (Chapter 2 Project description) will maintain flows within the Rookwood Weir construction area while the existing fish lock will be used to maintain flows within the Eden Bann Weir construction area.

These impacts may have a localised effect on aquatic fauna by reducing habitat value (e.g. amount of refuges, microhabitats and food availability) within the immediate downstream area and disrupting fauna behaviours. Reduced water quality may also decrease the abundance of sensitive species and change aquatic fauna community structure. The potential ecological consequences may include a temporary and localised decrease in fauna abundance, reduction in health and disruption to breeding. The impacts however will be primarily restricted to the habitat areas directly adjacent to construction areas (at weir sites and river crossings) and are not expected to persist for significant distances away from these sites. The mitigation measures proposed are considered sufficient such that no significant adverse impact is expected.

7.3.5.2 Mitigation measures

The following measures would be implemented to avoid/minimise aquatic habitat degradation during construction:

- Water flows downstream of the construction areas will be maintained to prevent the drying of aquatic habitat and to maintain acceptable water quality conditions. A flow diversion strategy will be implemented at Rookwood Weir while the existing fish lock at Eden Bann Weir will remain in operation during construction of the right bank. Flows will be maintained within the natural river channel at river crossing construction areas
- Weir construction will be primarily undertaken over two consecutive dry seasons when flows within the river are low and natural/existing conditions will be maintained for as long as possible to minimise degradation of habitat downstream
- Night lighting will be minimised where practicable. No lighting shall be placed in the vicinity of a confirmed turtle nesting habitat adjacent to the Rookwood Weir construction area. Any lighting installed will be designed and mounted so that no spill over light occurs within these habitat areas (such as directional lighting with protective guards)
- A Weed Management Plan and a Feral Animal Control Program will be developed and implemented (Section 7.3.10.2)

- A Drainage, Erosion and Sediment Control Plan will be developed and implemented. Management actions will be in accordance with the Best Practice Erosion and Sediment Control Guidelines (IECA) 2008
- A Water Quality Management Plan will be developed and implemented in accordance with the Project Construction EMP. The Project Water Quality Monitoring Program will include pre, during and post construction monitoring in accordance with the Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC and ARMCANZ 2000)
- A Waste and Hazardous Materials Management Plan will be developed and implemented. Management actions will be in accordance with Australian Standards (Hazardous Material Management Programme)
- Aquatic habitats immediately upstream and downstream of the construction footprints and river crossing construction areas will be monitored for signs of degradation during the construction phase. Aquatic fauna in isolated pools will be relocated if conditions have deteriorated or are considered likely to deteriorate.

7.3.6 Habitat degradation associated with changes to water quality during operations

7.3.6.1 Overview

The water quality in the lower Dawson, Mackenzie and Fitzroy Rivers is highly dynamic, and is likely to be influenced by complex interactions between a range of local to basin-wide anthropogenic and environmental drivers (Chapter 11 Water quality). As such, the water quality of these rivers is likely to undergo significant temporal and spatial variability due to existing influences. Furthermore, the predominant drivers of water quality in the system are related to processes occurring in the adjacent terrestrial environment both within the study area and throughout the Fitzroy Basin, most notably agricultural production and mining.

Raising Eden Bann Weir is unlikely to significantly alter the water quality characteristics within the existing impoundment. As noted in Chapter 11 Water quality, the water quality within the existing Eden Bann Weir impoundment and water released downstream is generally comparable to that within unimpounded reaches of the Fitzroy River. The spatial extent of these characteristics associated with the raised weir will extend upstream beyond the existing impoundment to the proposed increased inundation extent associated with a raised weir. Operation of the proposed Rookwood Weir can be expected to result in similar limited impacts on water quality at the site. Unmitigated potential water quality impacts arising from the Project operation may include:

- Decomposition of plant material and subsequent release of nutrients in areas of inundation within the impoundment
- A reduction in dissolved oxygen and temperature stratification within the water column as a result of the riverine system changing to deep, slow flowing pools
- Mobilisation of contaminants in areas of contaminated land (if present) that currently occur within the impoundments
- An increase in the presence of blue-green algae.

A full assessment of water quality impacts is provided in Chapter 11 Water quality. Changes in water quality primarily occur within impoundments, however downstream habitats may also be affected due to releases of lower quality water from the impoundment (Tucker 1999; Hamann et al. 2007; Limpus et al. 2011a). At a taxon level, potential impacts of changes to water quality are described below.

7.3.6.2 Potential impacts to freshwater turtles

Changes in water quality conditions that will occur within deep water areas of the impoundment will result in the degradation of habitat (DERM 2010). The Fitzroy River turtle and white-throated snapping turtle are not expected to permanently inhabit these deep water areas. Where these species persist in upper reaches of the impoundment and along the margins, habitat degradation is expected to result in a change in the diversity and abundance of resources for the species. In particular there is expected to be an increase in macroinvertebrate, macrophyte, and fish species that prefer slow-flowing conditions and a decrease in specialist species such as those found in rocky substrates and flowing waters.

The change in environmental conditions has the potential to influence the physiology and behaviour of the Fitzroy River turtle and white-throated snapping turtle. For example, the behaviour of these species is largely influenced by the ability to extract oxygen from the water (aquatic respiration) which is in turn dependent upon environmental conditions (Gordos 2004).

Changes in water quality such as reduced oxygen levels and increased water temperature are known to decrease a turtle’s ability to respire aquatically (Clark 2008). By decreasing aquatic respiration, the amount of time the turtle can spend underwater is reduced and surfacing frequency increases. These changes in diving behaviour have the potential to result in reduced time available for foraging, increased energy expenditure during surfacing and increased predation levels. The increased predation levels associated with an increase in surfacing frequency are thought to be especially threatening to hatchling and juvenile turtles which have a higher reliance on aquatic respiration than adults and have a larger range of predators than adults as a result of their smaller body size (Clark 2008). Mitigation measures will be implemented to improve water quality conditions within the littoral margins and upper reaches of the Eden Bann Weir and Rookwood Weir impoundments as described in Chapter 11 Water quality.

Changes in water quality will primarily occur within the impoundments (albeit limited compared to unimpounded areas elsewhere in the system), however, downstream habitats may also be affected should waters of lower quality be released (Tucker 2000; Hamann et al. 2007; Limpus et al. 2011a). The mitigation measures proposed to avoid the degradation of water quality downstream (e.g. multi-level off-takes, selective withdrawal outlets), have the potential to benefit the Fitzroy River turtle and white-throated snapping turtle by improving the quality of habitat downstream during the dry season.

7.3.6.3 Potential impacts to estuarine crocodiles

The existing Eden Bann Weir impoundment supports the highest density of crocodiles in the Fitzroy River (Britton 2007b). Consequently it is considered that water quality within the existing weir impoundment adequately supports crocodile health. It can be expected that further impoundment associated with a raised Eden Bann Weir will continue to support crocodile populations. Similarly it is not expected that water quality within the proposed Rookwood Weir impoundment will adversely impact crocodiles or their habitat.

7.3.6.4 Potential impacts to fish

A comparative study of fish diversity in weir and riverine habitats on the Dawson River found that differences in water quality (e.g. higher median conductivity, lower median turbidity (Secchi depth) at riverine sites) did not drive a difference in fish diversity (Long 2000). However, the riverine habitats generally housed a greater abundance of individuals in comparison to the weir habitats. For example, golden perch and eel-tailed catfish were present in riverine habitats at an abundance approximately twice that of the weir habitats.

Dissolved oxygen levels found at depths greater than two metres were generally considered to be at levels less than those required to sustain fish populations (Long 2000). With respect to the Eden Bann Weir, increasing the upstream extent of the deep impounded pool habitat is likely to result in a greater proportion of less suitable physicochemical water properties (greater than 2 m) in the deeper sections of the impoundment. Similarly, the impounded pool associated with the proposed Rookwood Weir will reduce physiochemical water properties in the deeper sections.

Species such as the blue catfish, golden perch, Hyrtl's tandan and freshwater catfish can be expected to inhabit the deeper water areas associated with weir impoundments. Species such as sleepy cod and mouth almighty that prefer fast flowing runs and riffles can be expected to avoid the deep water areas. Small native species that generally frequent the margins of wide natural pools, including the Agassiz's glassfish, western carp gudgeon, Midgley's carp gudgeon, fly-speckled hardyhead, purple-spotted gudgeon and eastern rainbowfish can be expected to persist along the impoundment margins (DERM 2010).

7.3.6.5 Potential impacts to macroinvertebrates

Cooler water temperatures, low oxygen levels and little light penetration will prevent the occurrence of many macroinvertebrate taxa in the deep waters of the proposed impounded pool habitat. Changes in physicochemical water properties brought about by habitat alteration (conversion of fast-flowing, oxygenated riffles with hard substrate to slow and non-flowing impounded pool with soft substrate) will reduce the diversity of available macroinvertebrate habitats (DERM 2010). This has the potential to negatively impact on taxa diversity. While pool-riffle-run sequences will prevail in the upper reaches of the impoundment (linear extent dependent on level of storage), habitat quality is likely to be reduced as a result of extended periods of submersion. Therefore, while physicochemical (water quality) factors are likely to periodically revert back to a more suitable state for some specialist macroinvertebrate taxa, habitat quality may limit re-colonisation of these habitats for other species.

Overall macroinvertebrate taxon richness may be lower in the impounded habitat due, in part, to altered water quality (Duivenvoorden et al. 2000). The impacts of herbicide and pesticide run off on water quality were considered to be potential drivers of variable macroinvertebrate diversity in a study conducted on the nearby Dawson River (Duivenvoorden et al. 2000). Importantly, this study noted the presence of a greater diversity of these sensitive taxa, albeit at lower abundances, within all weir sites assessed (Duivenvoorden et al. 2000).

7.3.6.6 Mitigation measures

The following mitigation measures are proposed to avoid and/or minimise changes in water quality and subsequent impacts on aquatic fauna:

- An operations Water Quality Management Plan will be developed and implemented in accordance with the Project EMP (Chapter 23). Specific management actions will include:
  - Including multi-level off-takes in weir design
  - Using selective withdrawal outlets to select water of most appropriate quality for downstream release

– Manipulating flows to prevent the build-up of blue-green algae or to disperse blooms.

- A Weed Management Plan will be developed and implemented for the Project. The management plan will detail the control and treatment of introduced aquatic weeds that may negatively impact water quality
- A Feral Animal Control Program will be developed and implemented for the Project or in collaboration with local council, community groups and landholders. Specific measures may include the control of pigs which cause degradation to aquatic habitat and water quality
- A Drainage, Erosion and Sediment Control Plan will be developed and implemented to minimise degradation of water quality. Management actions will be in accordance with the Best Practice Erosion and Sediment Control Guidelines (IECA 2008).

7.3.7 Changes in downstream flow regime during operations

7.3.7.1 Potential impact

The operation of weirs is predicted to result in a change to the flow regime between the weir and upper inundation limit of the downstream impoundment. Based on the aquatic habitat segment analysis, aquatic habitats downstream of Rookwood Weir that will potentially be impacted by operations of the proposed weir comprise 38.2 km of pool habitat, 12.1 km of run habitat and 3.7 km of riffle habitat. Further to this, six named creeks join the Fitzroy River between the proposed Rookwood Weir site and the upper limit of the Eden Bann Weir Project footprint, while eight off-stream water bodies were identified within 1 km of the Fitzroy River between the proposed Rookwood Weir site and the upper limit of the Eden Bann Weir Project footprint. Aquatic habitats downstream of Eden Bann Weir that are currently subject to downstream impacts, and which will continue to be impacted post-raising of the weir, comprise 25.5 km of pool habitat, 8.9 km of run habitat and 3.7 km of riffle habitat. Further to this, 13 named creeks join the Fitzroy River between Eden Bann Weir and the Fitzroy Barrage, while 32 off-stream water bodies were identified within 1 km of the Fitzroy River between Eden Bann Weir and Fitzroy Barrage.

The operation strategy for the impoundments will be dictated by environmental flow objectives dictated by the Fitzroy WRP and implemented through the Fitzroy ROP. As described in Chapter 9 Surface water resources, preliminary modelling indicates that all mandatory environmental flow objectives are achieved for the Project, except for the upper limit development (both Eden Bann Stage 3 and Rookwood Weir Stage 2) in relation to the 20 year daily flow volume. Further modelling to be conducted for detailed design will refine this. The timing and quantity of releases downstream is likely to vary between seasons with the dry winter period expected to trigger the highest demand for water resources downstream. As a result, water flows downstream will increase during the dry season and the frequency and duration of no flow periods will decrease (Chapter 9 Surface water resources). The increase in flows during the dry season has the potential to improve the quality of aquatic habitat downstream by reducing the duration and severity of pool isolation and prolonging the presence of flowing riffles zones and runs. The increase in habitat availability during the dry season will provide additional resources for aquatic fauna during times when conditions would be limiting under pre-development conditions. The diversity and abundance of macrophytes and macroinvertebrates, is likely to change with a potential increase in species that prefer flowing conditions and a reduction in species that prefer slow flowing and ephemeral habitats (DERM 2010).

The operation of the proposed weirs is also likely to result in a reduction in the frequency and magnitude of small to medium downstream flood flows. Flood flows entering the impoundment are likely to be captured and stored until the weir reaches its full supply level. This will result in the reduction of flows downstream (or at least a lag in the flow downstream) and is most likely to occur at the start of summer when the storage is predicted to be at a minimum in most years. It is noted that this lag is expected to be of short duration; in the order of a week to a month. Once the weir reaches its full supply level, downstream flows will increase however the magnitude of the events will be reduced compared to existing conditions. Large flood flows, > 9,000 m^3/s (weir drown-out) will, however, not be affected by the proposed infrastructure.

A reduction in the magnitude of flood events may affect fish movement. The greatest number of fish move within the river system during large flow events which often take place during summer (Marsden and Power 2007). For catadromous fish (e.g. barramundi and eels), high flows and floods are especially important for downstream migration as high flow events can allow fish to move over weirs in order to enter estuarine and marine waters for spawning (DERM 2010). Barramundi have shown increased recruitment and strong year-class associations with high flows when fish migrate laterally into connected floodplains (Staunton-Smith et al. 2004). As such, catadromous fish have evolved a migration strategy that corresponds to and takes advantage of flooding events.

Fitzroy River turtle nesting habitats located downstream of the Project footprints may become degraded due to these changes in water flows. Conversely improvements to downstream habitat through more regulated flow may improve habitat. Nesting banks naturally change over time with substrates being eroded and redeposited under different flow conditions. The overall reduction in water flows that are expected to occur as a result of the impoundments may disrupt the natural rejuvenation of downstream banks potentially reducing their suitability for nesting. Changes to downstream water flows may also lead to an increase in macrophytes along stream margins which may prevent access to nesting areas (Tucker 2000; Hamann et al. 2007). Large flood flows, > 9000 m^3/s (weir drown-out) will, however, not be affected by the proposed infrastructure, and as such, sufficient sediment transport past the weir structure is expected to occur to maintain downstream nesting habitats and the high flows will remove macrophytes that may have become established.

Operational water releases that result in increased water levels during the turtle nesting periods could also lead to the inundation of nests downstream (Cann 1998). Based on the predicted demand triggers, there is expected to be an increase in downstream flows during the dry season with peak water releases occurring immediately prior to the pre-summer floods. An increase in water flows during early September is unlikely to affect nests of the Fitzroy River turtle, as the releases are likely to have commenced prior to the peak laying period and therefore eggs will be laid above the water line and not drowned. Early nesting of these species during August may be affected by inundation. Controlled releases during operations have the potential to regulate the flows downstream at this time which will prevent the inundation of nests established early in the breeding season. Nests of the white-throated snapping turtle are at most risk of inundation as these species lay but not hatch, prior to the predicted increase in water release. As for the Fitzroy River turtle controlled releases during operations have the potential to regulate the flows downstream during his period to prevent inundation. Nesting habitats that remain within the impoundments (Section 7.3.4) may also be impacted by fluctuations in water level (i.e. associated with seasonal flooding and management of the storage). A rapid increase in water storage level may inundate turtle nests if flooding occurs following nesting, while periods of low water level will result in the disconnection of nesting banks from the water’s edge (Cann 1998).

As large flood flows, > 9,000 m^3/s (weir drown-out) will not be affected by the proposed infrastructure, impacts to off-stream water bodies located downstream of the Project footprint are not expected. Additional information on changes in the downstream flow regime is provided in Chapter 9 Surface water resources.

7.3.7.2 Mitigation measures

The following mitigation measures are proposed to minimise the potential impact of the Project as a result to changes to the downstream flow regime:

- The operation strategy of the weirs will be dictated by the environmental flow objectives defined in the Fitzroy WRP and implemented through the Fitzroy ROP (as amended). These objectives will aim to minimise environmental impacts as a results of the water infrastructure and will mimic natural flow conditions as much as possible. Where required, yield adjustments and operating rules will be amended to comply with the Fitzroy WRP and Fitzroy ROP. Achievement of the WRP objectives regarding environmental flows is expected to effectively mitigate impacts to related to flow regimes
- Subject to compliance with the Fitzroy WRP and Fitzroy ROP, water release volumes and timing will be controlled to minimise the inundation of turtle nests downstream of the weir during nesting season. Further modelling will be undertaken during detailed design to facilitate this implementation
- As part of the operational phase Turtle Monitoring Program (Section 7.3.12), important nesting habitats downstream of the Project footprint (Alligator Creek) will be monitored for signs of degradation as a result of changes in the downstream flow regime.

7.3.8 Fauna injury and mortality

7.3.8.1 Potential impacts

Aquatic fauna residing within the construction footprints may experience direct injury and/or mortality. Similarly, aquatic fauna moving upstream or downstream within these areas are at risk of being trapped or injured in the active construction zones. Construction activities may also foster greater utilisation of the area by introduced animals. The incorrect disposal of rubbish and other refuse may encourage introduced species (including pigs, dogs, foxes, and cats) to the area, which in turn may increase predation pressure on aquatic fauna species.

The increase in vehicular activity associated with construction has the potential to increase the incidence of turtle mortality via collision with motor vehicles. This is particularly relevant for the eastern long-necked turtle and broad-shelled river turtle which make long-distance overland migrations in response to habitat degradation (e.g. drying of ephemeral pools) and nesting.

During operation, injury and mortality can occur when aquatic fauna (in particular freshwater turtles and fish species) are swept over the spillway during periods of high flow, when they contact hard structures in the turbulence of downstream pools and when high velocity water is released during regulated flow discharges. Injury and mortality can also occur when fauna are trapped against trash screens or within fish transfer devices (Larinier 2000; Limpus et al. 2011a).

Fish species are particularly susceptible to shearing and abrasion injuries from contact with hard structures in the downstream pool and contact with the spillway during flooding events. Fish are also vulnerable to gill, eye and internal organ damage from the sudden changes in velocity and pressure that occur as the fish are swept over the spillway (Larinier 2000). Fish larvae are also known to suffer high levels of mortality (e.g. 95 per cent in golden perch) as a result of undershot gates (Baumgartner et al. 2006). Freshwater turtle injury and mortality is commonly associated with entrapment on trash screens, contact with hard surfaces and aggregations of turtles within areas of intermittent flow velocity. Particularly high levels of turtle injury and mortality are associated with their interaction with stepped weir designs (Limpus et al. 2011a).

A detailed design process has been undertaken for the Project to minimise risk of fish and turtle injury and mortality at Eden Bann Weir and Rookwood Weir. The key design features responsible for high levels of fauna injury and mortality described above (stepped spillway, dissipater teeth, high turbulence, insufficient pool length and depth, high velocity trash screens) have been completely avoided in Project design thereby substantially reducing the risk of injury and mortality to fish and turtles.

Fishing practices can cause injury and mortality to aquatic fauna within impoundments from entrapment in traps, boat/propeller strikes and interaction with and ingestion of fishing hooks (Tucker 2000; Hamann et al. 2007; Limpus et al. 2011a). The Project will not promote or facilitate recreational activities and combined with the remote locations and limited access opportunities to each weir, impacts on aquatic fauna as a result are not expected in this regard.

7.3.8.2 Mitigation measures

The following measures would be implemented to avoid/minimise injury and mortality to aquatic fauna during construction:

- Prior to initial construction works, all river banks within the construction areas will be surveyed by a suitably trained and qualified ecologist, during the peak Fitzroy River turtle nesting (to November) and hatching (November to March) season. Pre-clearance surveys will occur during and immediately following rainfall events and will involve systematically searching banks for direct and indirect evidence of turtle nesting and hatchlings. Surveys will be repeated throughout the construction period for any new disturbance scheduled to occur during the nesting and hatching season. If construction works are scheduled to commence prior to the end of the hatching period (November to March), a suitably trained and qualified fauna spotter/catcher will relocate the eggs to a suitable area. Nest protection mesh will be secured over relocated nests to provide predator protection. Exclusion fencing will be erected along the nesting bank/s to prevent further nesting within the construction areas. A detailed Fitzroy River turtle species management program is included at Appendix M
- Prior to any initial or new disturbance to aquatic habitat within the construction areas, all impact areas will be inspected by a fauna spotter/catcher for the presence of aquatic fauna. Pre-clearance surveys will be undertaken immediately prior to disturbance works. Aquatic fauna captured will be relocated and relevant measures implemented to exclude fauna access to active constructions areas (e.g. erection of exclusion fencing/netting, bund walls)
- A fauna spotter/catcher will be located on site during all works that have the potential to cause injury or mortality to aquatic fauna located in the area. The fauna spotter/catcher will identify, capture and relocate aquatic fauna and/or nests as required to avoid impact.
- If injury occurs, injured fauna will be immediately removed and taken to a qualified veterinary or wildlife carer for treatment. Suitable veterinarians and wildlife carers in nearby areas and Rockhampton will be identified and commercial arrangements established to guarantee the financial costs of treatment and rehabilitation

- All construction personnel will be informed of their environmental responsibility with respect to minimising the risk of fauna injury or mortality. Site inductions will include information on the identification of the Fitzroy River turtle, white-throated snapping turtle and estuarine crocodile, location of any confirmed nesting habitat areas within or adjacent to the construction areas and associated access tracks and relevant management actions
- Resource extraction will not occur in Fitzroy River turtle important habitat areas or from historical, confirmed or high potential turtle nesting habitat
- A Feral Animal Control Program will be developed and implemented. Management actions will be in accordance with the Project EMP may include culling, baiting and trapping of pigs, foxes, wild dogs and feral cats.

The following measures would be implemented to avoid/minimise the risk of injury and mortality of aquatic fauna during operation:

- The structural components of the weirs and associated works are designed (concept/preliminary design level) to avoid/minimise risks of aquatic fauna injury and mortality. Specific design features of Eden Bann Weir and Rookwood Weir include:
  – A roller compacted concrete ogee spillway to provide a smooth formed surface finish at the crest of the weir in the spillway section
  – A smooth downstream face of the spillway section
  – Stilling basin that extends the full length of the spillway to prevent fish and turtles being projected against hard concrete during spilling events
  – Spillway gates have been designed such that, when they close, the shape mirrors that of the ogee crest. This limits fauna entrapment at the edge or under gates
  – Energy dissipater and stilling basin/plunge pool design to minimise injury and mortality to fish and turtles
  – Features that may become downstream barriers to fish movement under low flow regimes to be modified to facilitate passage
  – Outlet works and fishway gates that close to prevent turtles aggregating in areas of intermittent high velocity water flow
  – Outlet works and fishway gates that prevent turtles from being crushed when closing
  – Sloped (45 degree) ramp to allow turtles to exit the environmental flow outlet area
  – Channel downstream of the environmental flow area to build tailwater and prevent turtles landing on hard concrete when exiting this area
  – A sloped entrance to the environmental flow gates lined with slippery substrate to prevent turtles accessing the area immediately in front of the gates during no flow periods
  – Smooth stainless steel plates to discourage turtles from climbing into unsafe locations
  – Slot in environmental flow area baffle wall to allow turtles to exit the area
  – Trash screens to prevent turtles and fish entering the outlet works from the impoundment or being trapped by high water pressures on the upstream side of the outlet works
  – Trash screens have been designed so that the water pressure on the face of the screen will not trap fish and turtles(20 mm screens, 0.3 m/s velocity)
  – Trash screens that allow for turtles to grip and climb

- Discussions with DAF (Queensland Fisheries) and DEHP will be held during the detailed design phase to further refine the design features and identify any additional options for minimising the potential for injury and mortality
- The weir operating strategy will avoid/minimise risk of aquatic fauna injury and mortality. Specific operational actions will include:
  - Controlling the flow of water through release values to provide gradual increments in water release volume
  - During planned releases, increase water release during dawn and dusk periods when turtles are more likely to be away from weir infrastructure
  - Operate the flood gate next to the fishway independently and initiate the gate opening sequence with this gate to build tailwater in the stilling basin.
- Recreational activities within the impoundment will not be encouraged or facilitated.

7.3.9 Restriction of movement

7.3.9.1 Overview

At the Rookwood Weir construction site, water flow within the construction areas has the potential to be impacted during the construction period and, as a consequence, upstream and downstream movement of aquatic fauna may be temporarily restricted. Weir construction will be primarily undertaken during two consecutive dry seasons when flows are reduced and the river is likely to exist as a series of isolated pools. Movement of aquatic fauna during this period is likely to be low. An in-stream flow diversion strategy (Chapter 2 Project description) will maintain flows at the Rookwood Weir site during construction and provide safe aquatic fauna passage during the construction phase flow events

The existing fish lock at Eden Bann Weir will remain in operation during construction on the right bank to maintain flows and provide fish passage. During this time, the turtle passage facility will be constructed. The turtle passage facility on the right bank will provide safe turtle movement past the Eden Bann Weir construction area when construction works move to the left bank.

Existing low level causeways at river crossings will remain in situ during bridge construction to facilitate water flow and maintain fauna passage. The existing low level causeways will be decommissioned once bridge construction is complete. Construction at river crossings will primarily be undertaken during the dry season when flows are reduced and the river is likely to exist in isolated pools. Flow diversion will be put in place during construction to maintain flows and provide safe aquatic fauna passage where required. Movement of aquatic fauna is not expected to be impacted at river crossing construction areas.

During operation, in-stream structures such as weirs represent an impediment to the movement of aquatic fauna. This disruption to connectivity along the continuum of the river not only has the potential to fragment populations and habitats, but also potentially impedes the life-history behaviour of aquatic fauna occurring within the system. The upgraded weir at Eden Bann and the proposed Rookwood Weir have the potential to impede or prevent aquatic fauna movement upstream and downstream. Without suitably designed aquatic fauna passages that facilitate movement, these barriers to movement may adversely affect the viability of local and regional populations, through disruption to critical behaviours (e.g. breeding, dispersal). At a taxon level, potential impacts of inhibited up- and downstream aquatic fauna passage are described in the following sections.

7.3.9.2 Potential impacts to freshwater turtles

Little information is known about the movement requirements of freshwater turtles in Australia. The home range size of the Fitzroy River turtle and white-throated snapping turtle are generally relatively small with the movement of individuals occurring between riffle zones and adjacent pools within a local area (Tucker et al. 2001; Hamann et al. 2007). The requirement for the these turtle species to undertake long distance migrations has not been thoroughly investigated, however, initial observations suggest upstream and downstream movement may occur for the purposes of nesting and courtship migrations, repositioning following flood displacement, and dispersal.

Monitoring of turtle nesting at Alligator Creek has observed large numbers of females returning to the same nesting habitat every year (Dr Col Limpus pers comm.). It is unknown how far females may migrate to this traditional area, however, survey of the population indicates an immigration of females into the immediate area is occurring for the purpose of nesting (Dr Col Limpus pers com.). Initial research on the movement behaviour of freshwaters turtles in the Burnett catchment has discovered that male turtles may undertake upstream and/or downstream movements to attend breeding aggregations (Dr Col Limpus, pers. com). Restriction of turtle movement as a result of the Project therefore has the potential to disrupt the breeding cycle of the species and may inhibit nesting in traditional areas.

Upstream and downstream movements may also be undertaken in association with flooding events. Upstream movement of turtles into refuge habitat (e.g. creeks and backwaters) is thought to occur as the river rises (Dr Col Limpus pers comm.). Some individuals are, however, inevitably carried downstream. Approximately 40 freshwater turtles from a variety of species were observed below the Fitzroy River Barrage following a spilling event in 2008. At this time a Fitzroy River turtle was recorded attempting to move upstream through the vertical slot fishway at the barrage. Similar attempts at upstream movement following flood displacement have been observed in a number of other catchments including the Burnett and Mary catchments (Dr Col Limpus pers comm.).

The movement behaviour of hatching and juvenile turtles is unknown, however, dispersal is a requirement in any population in order to maintain genetic diversity. A long-term decrease in dispersal migrations within the catchment may cause a reduction in gene flow resulting in the formation of genetically isolated populations. A restriction of dispersal migrations may also result in physically isolated populations becoming threatened with localised extinction due to a lack of immigration from neighbouring areas (Tucker 2000; Bunn and Arthington 2002).). Existing fishways, such as vertical slots and mechanical locks, have not been designed to accommodate freshwater turtles and as a result, have relatively low, to no, success at facilitating turtle passage (Hamann et al. 2007; Limpus et al. 2011a). Anecdotal observations of turtle behaviour at dams and weirs have revealed that turtles attempt to move upstream by climbing in-stream structures such as the spillway face and abutments during rainfall and small flow events (Limpus et al. 2011a; Limpus et al. 2011b). A recent study by Limpus et al. 2011, recorded evidence of the Fitzroy River turtle attempting to move upstream by climbing the concrete structures of Tartrus Weir at night. During higher flow conditions, the turtle was observed attempting to climb past the wall via the river bank (Limpus et al. 2011b).

A specifically designed turtle passage facility (turtle ramp) will be constructed at Eden Bann Weir and Rookwood Weir to mitigate the potential impacts discussed above. As turtle movement is currently restricted at Eden Bann as result of the existing weir, provision of the turtle ramp will improve the movement of turtles past this structure and restore the connectivity of the population in this region. A turtle ramp has been selected as the turtle passage design based on expert knowledge of turtle movement capabilities and evidence of turtle behaviour at existing structures.

The existing low level causeways at Glenroy, Riverslea and Foleyvale crossings are low, dark structures not conducive to turtle passage. New bridges will better facilitate the movement of turtles at these locations.

7.3.9.3 Potential impacts to estuarine crocodiles

The estuarine crocodile is known to undertake long-distance migrations within and between river systems. These movements occur in response to a number of environmental and biological cues, including changes to habitat resources, habitat degradation, disturbances and for the purpose of dispersal and reproduction (Walsh and Whitehead 1993). It is not expected that construction activities at either Eden Bann Weir or the proposed Rookwood Weir site will impact negatively ion the species.

As is evidenced with the existing Eden Bann Weir impoundment, once inundated, the impoundment upstream of the Rookwood Weir may represent suitable foraging and sheltering habitat due to the presence of deep, permanent water and will provide opportunity for colonisation. It is not expected that operation of the Project will negatively impact the crocodile population on the Fitzroy River.

7.3.9.4 Potential impacts to fish

Tropical freshwater fish regularly move among spawning, feeding and refuge habitats (Lowe-McConnell 1987; Lucas and Baras 2001) and free movement of fish within the river system is thought to be crucial in order to maintain viable populations (Marsden and Power 2007). Obstacles to fish migration can impact native species in a number of ways including declines in abundance, species distribution truncation, localised extinction events and a reduction in species diversity (Marsden and Power 2007).

Although the majority of fish species known to occur upstream of Eden Bann Weir are potamodromous, movement within a variety of freshwater environments remains a critical aspect of the life-history of many species. Barriers such as weirs have the potential to significantly compromise the ability of fish to freely move downstream and upstream within the freshwater environment (potamodromous species) or between the freshwater and estuarine/marine environment (catadromous and amphidromous species). The Fitzroy Basin catchment is a highly regulated system and much of the natural aquatic habitat has been inundated as a result of weir/dam operations.

Fish movement within the catchment is generally initiated by changes in river flow and/or water temperature (Marsden and Power 2007). Rainfall (and associated changes in river flow/river height) at the beginning of the wet season is thought to be a major cue for movement for species including the golden perch, leathery grunter, blue catfish, Hyrtl's tandan, black catfish and Rendahl's catfish (Marsden and Power 2007). Low and moderate flow periods also represent a significant period for fish movement in the area for some small species (empire gudgeon) and juveniles of larger species (for example sea mullet).

When a migrating fish approaches a dam or weir there is often a short interruption or delay before the individual can negotiate the fishway. Such short delays are not expected to have negative consequences. However, if fish passage is not accessible throughout a range of water depths then fish may experience prolonged delays until fish passage infrastructure becomes accessible. As a result of delayed migration, small-bodied fish may experience an increase in mortality below weirs from terrestrial and/or aquatic predators.

Amphidromous and some potamodromous fish might be able to tolerate short delays (e.g. hours) while delays of days or weeks may be more directly detrimental to catadromous fish species. For potamodromous fish, there might also be a reduction in spawning success with "flood ready" males and females unable to reach their preferred spawning habitat at the appropriate time. Within the upper Fitzroy Basin catchment, there are a specific set of conditions that contribute to successful spawning and recruitment (rising flow in late spring or early summer) (Roberts et al. 2009). Fish caught below dams will either resorb their eggs or spawn in secondary habitats downstream of the dam.

No EPBC Act or NC act listed threatened fish species occur in the study area. However, two endemic species (southern saratoga and leathery grunter), one endemic sub-species (Fitzroy River golden perch) and a number of other fish species are likely to be negatively impacted by delays to migration in the absence of mitigation measures proposed below. These include golden perch, barramundi, sea mullet, blue catfish, long-finned eels, ox-eye herring, bony herring, leathery grunter, spangled perch, Hyrtl's tandan, Rendahl's catfish, eastern rainbowfish and empire gudgeon, all of which undertake spawning migrations during flow events (Reynolds 1983; Stuart 1997; Stuart 1999; Pusey et al. 2004; DERM 2010). Unmitigated, habitat fragmentation and loss of connectivity as a result of restricting movement upstream and downstream may impact the ability of these species to migrate within the freshwater environment, particularly during breeding migrations.

7.3.9.5 Potential impacts to macroinvertebrates

Downstream dispersal and colonisation by aquatic macroinvertebrates is facilitated by a process known as macroinvertebrate drift ("drift"). Passive drift results from the dislodgement and downstream transport of macroinvertebrates due to the force of flowing water. Conversely, active drift results from a behavioural response to factors such as competition or poor water quality (Koetsier and Bryan 1995). While adult insects may move upstream and downstream during their winged phase, strictly aquatic, less mobile macroinvertebrates (including larvae of winged insects) may be more reliant on drift for dispersal.

In-stream structures such as dams and weirs impede downstream drift of macroinvertebrates. A study of macroinvertebrate assemblages directly downstream from 19 dams in New South Wales and Victoria found relatively lower macroinvertebrate family diversity in downstream areas (40 per cent lower than expected) (Marchant and Hehir 2002). This result was attributed to in-stream structures limiting drift (Marchant and Hehir 2002). The existing structure at Eden Bann Weir has likely limited downstream drift, with additional development likely to further exacerbate drift restrictions (in the absence of mitigation measures). The proposed Rookwood Weir is also likely in the absence of mitigation measures restrict and impede macroinvertebrate drift with a resultant decline in downstream diversity.

7.3.9.6 Mitigation measures

The following mitigation measures are proposed to minimise impacts on aquatic fauna due to inhibited up and downstream passage:

- A fishway design process has been undertaken in accordance with Queensland Fisheries Design Process criteria. This process involved the selection and refinement of fishway design specifications and success criteria and the development of fishway designs for both Eden Bann Weir and Rookwood Weir. State fish biologists and technical specialists (suitably qualified and experienced in fish passage biology and fish way design) participated in the fishway design process and provided key technical input and review (Appendix X). The fishway design options were assessed against an agreed design specification and success criteria (Section 7.1.2.5) to demonstrate that fishway design provides adequate fish passage. Fishway design will be informed by physical model studies to be undertaken during the detailed design phase and will be progressed in consultation with DAF (Queensland Fisheries) and technical specialists.
- Eden Bann Weir fish passage infrastructure for the Project has been designed to concept/preliminary design level. It comprises an upgrade to the existing fish lock on the left bank and a new fish lock located on the right bank at Eden Bann Weir to cater for high and low reservoir levels (flows from about 500 m^3/s to 2700 m^3/s). This provides for normal operating conditions as well as low spillway flow conditions at the weir. Flood flow analysis has indicated that the river typically exceeds 500 m^3/s in flow between one and three times per year (a total of 117 times over a 95 year history based on analysis of flows presented in the Integrated Quantity Quality Model developed for the Fitzroy system (Appendix P). This occurrence is less than the life cycle of fish (average one to five years) and coupled with the known fish migration on flows greater than 500 m^3/s, it is considered important in the movement of fish for spawning. Sixteen fish species have been recorded migrating on flows between 500 m^3/s and 1600 m^3/s. Four fish species, including the endemic leathery grunter, have been recorded moving on flows of 2265 m^3/s (Pers com, Queensland Fisheries, Fishway Design Team Workshops).

  The proposed lock arrangement at Eden Bann Weir proposed is considered suitable for the purpose of fish passage as:

  - It is in a configuration known to work (although physical model studies are required to assist with refinement of entry/exit conditions and sedimentation management)
  - The addition of a right bank fish lock will improve on current passage efficiency above spilling flows. Currently fish are attracted to the right bank spillway section of the weir, and as there is no passage, become stranded as tailwater levels drop
  - It covers between 96.6 per cent and 100 per cent of the seasonal flow range as shown in Table 7-10. Table 7-10 also shows that the increase in coverage across the seasons is generally improved)'
  - It reduces average wait days per occurrence from an approximate 11 days under the existing situation to seven days. This is particularly beneficial and important as it is considered possible that some species will wait up to 7 days for passage
  - It caters for small and large-bodied fish
  - It provides upstream and downstream passage
  - It can be shut down in large floods to maximize operation following flood.
- Rookwood Weir fish passage infrastructure has been designed to concept/preliminary design level. In order to cater for flows from a minimum operating level up to 500 m^3/s, it comprises a right bank fish lock to cover low and high reservoir levels. The lock arrangement proposed is considered suitable for the purpose of fish passage at Rookwood Weir as:

  - It is a standard provision of infrastructure for fish passage at the current time and is in a configuration known to work (although physical model studies are required to assist with refinement of entry/exit conditions)
  - It provides for between 89.4 per cent and 99.8 per cent of flows across the seasons as shown in Table 7-10
  - The average number of waiting days per event is estimated at 10
  - It caters for small and large-bodied fish
  - It provides upstream and downstream passage
  - It can be shut down in floods to maximize operation following flood.
- A Fish Monitoring Program will be designed and implemented to monitor the effectiveness of fish passage infrastructure during both the construction and operation phases, as applicable. This Fish Monitoring Program will include at least the following:
  - Records on the diversity of the fish population above and below the construction footprint
  - The relative abundance of the fish population above and below the construction footprint
  - Health of the fish population (injury/mortality rates) above and below the construction footprint
  - Diversity of the fish population above and below the weir post construction
  - Relative abundance of the fish population above and below the weir post construction
  - Health of the fish population above and below the weir (injury/mortality rates) post construction
  - Attraction to fishway entrance (assessment of fish diversity and abundance within the tailwater pool)
  - Effectiveness of fishway transfer (assessment of fish within the entrance channel, holding chamber and exit channel)
  - Relative health and behaviour of fish surveyed
  - Hydrological monitoring – monitoring of storage water level, tailwater level, fishway discharge, outlet works discharge and spill discharge will facilitate interpretation of monitoring data.

  The monitoring program will be undertaken biannually for a period of five years pre and post wet season to capture seasonal variation and will include areas upstream of the inundation area, within the impoundment and downstream of the weirs.

  The monitoring program will be developed in consultation with DAF (Queensland Fisheries) during the detailed design phase.
- A species specific and Project specific turtle passage facility (turtle ramp) has been designed to concept level for each weir. Discussions with DEHP will be held during the detailed design phase to further refine the design of the turtle ramp at each weir from concept through to detailed design. Operability of the turtle ramps will be maintained through the life of the Project. A detailed description of the turtle ramp design features is provided in Appendix L
- Environmental flow releases and overtopping will facilitate downstream movement of macroinvertebrates

- A monitoring program will be developed and implemented to evaluate the performance of the turtle ramps at each weir. The monitoring program will be developed in consultation with DEHP and will include a procedure for corrective action
- Culverts at Hanrahan crossing have been designed at various sizes to facilitate movement under a range of flow conditions.

Table 7-10 Seasonal flow range covered by the provision of fishlocks

Season	Eden Bann Weir		Rookwood Weir	
	Seasonal flow range covered (%)			
	Pre-mitigation	Post-mitigation	Pre-mitigation	Post-mitigation
Spring	99.8	100	0	99.8
Summer	88.8	96.6	0	89.4
Autumn	95.8	99.0	0	95.8
Winter	98.3	99.9	0	98.4

7.3.10 Increased pest and weed species

7.3.10.1 Potential impact

Vegetation clearing, excavation within the bed and banks and vehicle transport around sites have the potential to result in the introduction and spread of introduced weed and pest species. Riparian habitat throughout the catchment is currently impacted by a high level of disturbance from weed and pest species and nest predation is identified as the key threatening process to the Fitzroy River turtle and white-throated snapping turtle. The mitigation measures proposed, in the form of a Weed Management Plan and Animal Control Program, are considered sufficient such that no additional impact to aquatic and riparian habitat is expected.

During operation, the Project is likely to result in an increase in the abundance of predators within the Eden Bann Weir and Rookwood Weir impoundments, potentially resulting in an increase in predation of the turtles and nests. The creation of impounded pool habitat is expected to increase the availability of suitable habitat for large predatory fish (such as long-finned eels and golden perch) and the estuarine crocodile. An increase in abundance of these species within the impoundments, either through natural immigration or stocking for recreational purposes (fish species only), may result in a direct increase in the predation of turtles (Tucker 2000; Hamann et al. 2007; Limpus et al. 2011a). As discussed in Section 7.3.6.2, the Fitzroy River turtle and white-throated snapping turtle may also be more susceptible to predation within the impoundments as a result of changes to water quality and the associated impact on turtle physiology and behaviour.

The greatest threat to the survival of the Fitzroy River turtle and white-throated snapping turtle is the lack of hatchling recruitment in the population as a result of nest predation. This is currently a major issue in the Fitzroy Basin irrespective of the presence of weir infrastructure and impoundments (Appendix L). In the absence of mitigation measures, the increase in permanent water resource availability associated with the weir impoundments may increase the abundance of terrestrial predators such as feral pigs, water rats and goannas, thereby sustaining the existing predation pressure on nesting habitat within the Project footprints.

7.3.10.2 Mitigation measures

The following mitigation measures are proposed to avoid/minimise the potential impact of pest and weed species on aquatic fauna:

- A Weed Management Plan (Chapter 23 Environmental management plan) will be developed and implemented and will include the following control techniques specific to the protection of aquatic habitat:
  - Existing aquatic weeds within the construction footprints will be removed prior to construction activities
  - Vehicles, plant and equipment will be cleaned prior to entering site to prevent the introduction of weeds to potential nesting areas
  - Key personnel on site will be capable of identifying terrestrial and aquatic weed species and preventing their spread and translocation. During an initial site inspection, weeds will be identified and flagged and recorded in the site register. Weeds will be treated to prevent spread.
- A Feral Animal Control Program will be developed and implemented for the Project (Chapter 23 Environmental management plan).

Project impacts on the Fitzroy River turtle, while mitigated as far as is practicable, will also be offset (Chapter 22 Offsets).

7.3.11 Impacts to downstream estuarine/marine habitat and species

The Fitzroy delta system supports a number of sensitive environmental areas and conservation significant species. The flow regime in this region is currently regulated by releases from the Fitzroy Barrage and habitats have been modified as a result of existing human land use. Analysis of flow data revealed that there will be no statistical differences between current flow regimes and the flow regimes projected with any additional infrastructure associated with the Project in place. Impacts to the sensitive environmental areas and conservation significant species are therefore not predicted. Additional information on the predicted downstream flow regime is provided in Chapter 9 Surface Water Resources and discussed in Volume 2, Chapter 8 General impacts.

7.3.12 Impacts on conservation significant aquatic fauna

7.3.12.1 Fitzroy River turtle

As discussed above, the Fitzroy River turtle is endemic to the Fitzroy Basin catchment and important habitat for the species is present within both the Eden Bann Weir and Rookwood Weir Project footprints and the largest known nesting aggregation for the species occurs downstream. Due to the proportion of the species' habitat in which the Project is located and the significance of habitats within and downstream, the Project footprint is considered to support an important population of the Fitzroy River turtle.

The Project has the potential to lead to a long-term decrease in the size of this important population of Fitzroy River turtle through the inundation of 114.5 km of natural river habitat. The Project will inundate pool-riffle-run sequences. Although considered preferred habitat, pool-riffle-run sequences are not critical to the survival of the species. The shallow margins and upstream reaches of the impoundment are expected to contain suitable habitat for the Fitzroy River turtle and the presence of this species within existing impoundments substantiates this expectation.

The Project is expected to create new and enlarged deep water areas (areas > 5 m depth). Due to reduced oxygen levels, little or no light penetration and colder temperatures within these deep water areas, it is expected that these areas will largely be avoided by the species. The open water pelagic zones are likely to provide transient habitat, however, the low abundance of micro-habitats and food resources within these areas will generally limit permanent habitat availability and suitability. Due to the overall decrease in habitat resources within the impoundments, the carrying capacity of these habitats is expected to be reduced. Impacts to the availability and quality of habitats downstream of the Project footprints are not expected to be adversely impacted and will be maintained through operational releases in accordance with the Fitzroy ROP.

The Project has the potential (in the absence of mitigation measures) to fragment the existing population of Fitzroy River turtles within the catchment by physically inhibiting upstream and downstream movement of turtles past the weir infrastructure. The home range extent of the Fitzroy River turtle is generally relatively small, however, individuals are thought to make long distance migrations for nesting and courtship, dispersal and reposition following flood displacement. Turtle movement is currently restricted at Eden Bann Weir and at other impoundments throughout the catchment. Turtle passage facilities (turtle ramps) will be constructed at both Eden Bann Weir and Rookwood Weir to maintain turtle movement and prevent fragmentation of populations.

The population of Fitzroy River turtle is currently impacted by a number of existing threatening processes, the key factor being extremely high nest predation rates. At the current rate of recruitment, the population of Fitzroy River turtles within the catchment is not considered sustainable. A total of 5.71 ha of Fitzroy River turtle nesting habitat (historical, confirmed and high potential) will be inundated during Project commissioning. While only isolated nesting has been recorded in these areas (that is there are no aggregated nest sites) and the Fitzroy River turtle has demonstrated an ability to adapt to new nesting conditions, the loss of this habitat is considered important to the survival of the species. Loss of nesting habitat has the potential to disrupt the breeding cycle of the species by restricting nesting to sub-optimal habitats and reducing reproductive success. Impacts on nesting habitats (in the absence of suitable mitigation measures) have the potential to contribute to the sustained reduction in population recruitment, noting that current pressures, mainly from predation by feral species (not related to weirs or impoundments), results in near 100 per cent nest predation.

The management actions proposed for the Project, particularly the implementation of a predator control program and provision of turtle ramps, will minimise impacts and promote the recovery of the species. Nevertheless it is considered that the Project is likely to have a residual impact on the Fitzroy River turtle during operations and, as such, offsets are proposed under the EPBC Act Environmental Offset Policy and EO Act. The protection and management of turtle nests has been selected as the proposed offset for the Project. The protection and management of nests will target Project specific impacts as well as address the key processes currently threatening the survival of the species. These actions will reduce nest predation, increase population recruitment and promote the recovery of the species. Details of the proposed offset for the Fitzroy River turtle is provided in the Project Offset Strategy (Chapter 22).

Additional information on the potential impacts of the Project on the Fitzroy River turtle is provided in Appendix L. A Species Management Program for the Fitzroy River turtle (Appendix M) describes measures to be implemented to avoid, and if this is not possible, minimise the potential impacts of the Project on the species and provides a framework for the management of the species throughout the life of the Project.

7.3.12.2 Estuarine crocodile

The Fitzroy River represents marginal habitat for the estuarine crocodile, and is at the southern extreme of the species' range in eastern Queensland. While present in low numbers, survey results indicate that the existing Eden Bann Weir impoundment supports a greater density of estuarine crocodiles than upstream and downstream reaches of the Fitzroy River (Britton 2007b). The availability of permanent, deep water and shelter and foraging resources has been cited as the basis for the observed higher density of crocodiles upstream of Eden Bann Weir (Britton 2007b).

Poor nesting success has been identified as the primary factor limiting population growth in the Fitzroy River estuarine crocodile population (Britton 2007b). This is as a result of limited suitable nesting habitat, flooding of nest sites and nest predation. The inundation of vegetated islands and riparian fringes upstream of Eden Bann Weir and Rookwood Weir may further reduce nesting habitat resources in the short-term. However, inundation of terrestrial environments is likely to create new islands which are likely to support crocodile nesting when suitable habitat establishes. In particular, permanent inundation of depressions in the riparian zone and adjacent to creeks may represent suitable crocodile nesting habitat with the establishment of dense vegetation within 10 m to 20 m of the water body. Due to the longevity of estuarine crocodiles, it is not anticipated that a short-term loss of some potential nesting habitat will detrimentally impact the viability of the population upstream of Eden Bann Weir, with several years of little or no recruitment unlikely to result in a notable decline in the population.

While habitat modification as a result of the Project is likely to have short-term impacts on the species, it is unlikely to result in long-term negative impacts to the population, and in fact may serve to benefit the population through the provision of more deep water habitat and linear shoreline (Britton 2007b). The existing Eden Bann Weir impoundment is a highly productive system in that it provides a forage resource that supports the most notable estuarine crocodile population in the Fitzroy Basin. The provision of similar habitat upstream of the existing Eden Bann Weir impoundment may allow for a higher carrying capacity for the species in the area. Construction of Rookwood Weir and the associated impoundment of river behind the weir may encourage inhabitation of these upstream areas by the species.

7.4 Summary

Approach and methodology

Aquatic fauna conservation values are bound by Commonwealth and State legislation, including the EPBC Act, NC Act, EP Act, Fisheries Act, Water Act and the environmental offsets policies. To document the known aquatic fauna values within the Eden Bann Weir Project footprint and Rookwood Weir Project footprint, a desktop assessment was undertaken, including studies and reports previously conducted for the Project. Field surveys were also undertaken to verify the likely occurrence of EPBC Act and NC Act listed aquatic fauna species, and important habitats expected to occur based on the literature review. Survey timing and design considered seasonal variations and the ecology of targeted threatened species.

Aquatic habitats

Aquatic habitats in the Dawson, Mackenzie and Fitzroy rivers are highly dynamic. The temporal distribution and spatial extent of the aquatic habitat types are related to fluctuating water levels driven by factors such as seasonal rainfall, river flow regime (both in natural and impounded sections), water storage management, water extraction and evaporation and ground seepage.

Past and present land use practices throughout the catchment have also had a significant influence on aquatic ecological values within the Project footprints. Such impacts include degradation of riparian habitats by livestock, changes to water quality (agriculture and mining) and disruption to natural flow regimes and connectivity of aquatic systems. Climate, hydrological regime and land use practices have all influenced the diversity and abundance of aquatic species within the Eden Bann Weir and Rookwood Weir Project footprints.

Six main aquatic habitats occur within the Project footprints. The impoundment created as a result of the existing Eden Bann Weir is the dominant aquatic habitat type within the Eden Bann Weir Project footprint. Upstream of the impoundment, the Fitzroy River exists as a series of pool-riffle-run sequences. These sequences represent the natural hydrological and geomorphologic regime of the rivers in the study area. Seasonal variability markedly alters the characteristics and linear extent of these habitats – a natural regime to which the aquatic species of the Fitzroy Basin catchment are adapted. A number of creeks and off-stream water bodies provide further aquatic habitat beyond the main channel of the rivers. Four Great Barrier Reef wetland protection areas are located adjacent to or near the Eden Bann Weir and Rookwood Weir Project footprints.

Aquatic species

Thirty-seven fish species have been previously recorded in the study area, with all species relatively common. No EPBC Act or NC Act listed-threatened fish species have been previously recorded or are predicted to occur. Three fish species, southern saratoga, leathery grunter and golden perch, are considered to have a local conservation value due to their restricted geographic range. Fish species in the Fitzroy Basin catchment have adapted to the highly dynamic and variable nature of this system as this is evident in their habitat utilisation and movement behaviour.

Six turtle species have been previously recorded within the study area. The Fitzroy River turtle is endemic to the Fitzroy Basin catchment and is listed as vulnerable under the EPBC Act and the NC Act. The white-throated snapping turtle is endemic to the Fitzroy, Burnett and Mary River catchments and is listed as least concern under the NC Act and critically endangered under the EPBC Act (listing occurring after the release of ToR for the Project).. The Project footprints support an important population of Fitzroy River turtle and important habitat for the species occurs at Glenroy Crossing, Redbank Crossing, Marlborough Creek and upstream of Boolburra rail crossing. Suitable nesting habitat for the Fitzroy River turtle and white-throated snapping turtle occurs within both the Eden Bann Weir and Rookwood Weir Project footprints. Important aggregated nesting habitat occurs at Alligator Creek (adjacent to the Fitzroy Barrage impoundment) located approximately 40 km downstream of Eden Bann Weir.

The estuarine crocodile is listed as marine and migratory under the EPBC Act and vulnerable under the NC Act. The Fitzroy River represents marginal habitat for the estuarine crocodile, and is at the southern extent of the species' range in Queensland. Field studies confirmed the presence of the estuarine crocodile within the Eden Bann Weir Project footprint. Platypus is listed as special least concern common wildlife under the NC Act. Platypus is known to occur in the Fitzroy Basin. A single record for platypus was recorded (Wildlife Online, March 2000) on the Dawson River near Boolburra, coinciding with the upstream extent of impoundment associated with the Proposed Rookwood Weir Stage 2. Platypus were not observed during wet and dry season field surveys. It is considered that platypus are limited or absent from the Project footprint based on lack of burrowing habitat present along the main river channels within the Project areas.

Studies of macroinvertebrate diversity recorded a total of 4,270 individuals from 59 families of macroinvertebrates during the wet season and 233 individuals from 28 families during the dry season. A total of one hundred and five species of macrophytes have been previously recorded in the Fitzroy Basin catchment, however, macrophytes abundance and diversity was relatively low within the Project footprints at the time of survey. Aquatic weeds recorded within the catchment include Salvinia and *Hymenachne amplexicaulis.*

Potential impacts and mitigation measures

It is anticipated that a number of construction activities may have short-term (over the two dry season construction period) impacts upon aquatic ecological values, specifically clearing of vegetation and excavation within the bed and banks, vehicle and plant movement, storage and possible spillage of potentially hazardous materials, construction within the waterway and resource extraction. Following construction, direct impacts will occur during filling of the impoundments (commissioning). Operations phase activities that have potential to impact aquatic ecological values include: water capture and storage, releases of water captured and stored behind the weir to downstream reaches and in-stream barrier operation.

Direct impacts associated within Project construction include the permanent loss of aquatic habitat within the construction footprints. The area of habitat in this footprint to be impacted is relatively small in size in relation to that available within the immediate area and as such the loss of habitat is not considered significant. Additional impacts to aquatic ecological values that may occur as a result of Project construction activities include: the degradation of habitat, increased injury and mortality, and the restriction of fauna movement. These impacts will be localised, restricted to the duration of the construction period and primarily managed through the Project construction Environmental Management Plan. Key mitigation measures to be implemented will include: pre-clearance surveys for Fitzroy River turtle nesting habitat, fauna capture and relocation, and flow diversion/maintenance.

Raising the Eden Bann Weir and constructing the Rookwood Weir is expected to result in the inundation of an additional 114.5 km of natural riverine habitat, increasing the area of impacted habitat within the sub-catchment by 10 per cent. Alteration of natural riverine habitats within the Eden Bann Weir and Rookwood Weir Project footprints will reduce the heterogeneity of the river system and therefore the diversity of habitats available to aquatic fauna. Aquatic species are expected to persist, particularly within the shallow littoral habitats along the perimeter of the inundated areas and within the upper reaches. An increase in deep water habitat and linear shoreline is likely to benefit the population of estuarine crocodile within the existing Eden Bann Weir. Alteration in the seasonality, duration, frequency and volume of water entering and leaving the off-stream water bodies has the potential to impact the specific habitat characteristics of the water bodies and their value for aquatic flora and fauna. Those habitats replenished by large flood flows are not expected to be affected by the proposed infrastructure and flood modelling indicates that the Great Barrier Reef wetland protection areas located adjacent to the Eden Bann Weir and Rookwood Weir Project footprints will not be impacted by the Project.

The Project will result in the inundation of known and potential Fitzroy River turtle nesting habitat within the Project footprints during commissioning. The loss of nesting habitat within the Project footprints has the potential to disrupt the breeding cycle of the species by restricting nesting to sub-optimal habitats and reducing reproductive success. Suitable nesting habitat for the Fitzroy River turtle is expected to persist in the upper reaches of the impoundments with potential nesting habitat remaining above the full supply level within the Rookwood Weir Project footprint. Suitable nesting habitat is also expected to be naturally created in flood deposition areas over time. Due to the specific nesting requirements of the species' and the extremely high nest predation rates throughout the catchment, the loss of Fitzroy River turtle and white-throated snapping turtle nesting habitat within the Project footprint is considered significant. The implementation of a Weed Management Plan and Feral Animal Control Program will assist in increasing the quality of potential nesting habitat for turtle nesting and the potential for successful recruitment of hatchlings within the Project footprints.

During operation, Eden Bann and Rookwood Weirs will be an impediment to the movement of aquatic fauna. This disruption to connectivity along the continuum of the river will (in the absence of specific management and mitigation measures) not only serves to fragment populations and habitats, but also potentially impedes the life-history behaviour of aquatic fauna occurring within the system. Maintaining upstream and downstream fauna movement and minimising the potential risk of fauna injury and mortality associated with the in-stream infrastructure have been key management objectives through the Project design phase. A detailed fishway design process has been undertaken in accordance with Queensland Design Process criteria. Fish passage infrastructure at Eden Bann will comprise an upgraded fish lock on the left bank and two new fish locks located on the right bank for high and low reservoir levels. Fish passage infrastructure at Rookwood Weir will include two right bank fish locks. A specifically designed turtle passage facility (turtle ramp) will also be constructed at Eden Bann Weir and Rookwood Weir to mitigate the potential impacts of the Project on turtle movement and population fragmentation. As fauna movement is currently restricted at Eden Bann Weir as result of the existing weir, a proposed reconfiguration of the existing left bank lock, addition of the two right bank locks and provision of the turtle ramp will improve the movement of fish and turtles past this structure and improve the connectivity of the populations in this region.

Aquatic habitats within the lower Dawson, Mackenzie and Fitzroy Rivers are highly dynamic, and influenced by complex interactions between a range of local to basin-wide anthropogenic and environmental drivers. Construction and operation of the Project (in the absence of mitigation measures) have the potential to exacerbate existing threatening processes including water quality issues and weed and pest species. Various management plans will be implemented to improve the quality of aquatic and riparian habitat remaining within the Project footprints. Engagement with landholders, community groups and local councils will promote more holistic control of feral animals and weeds to better manage impacts on aquatic ecological values including turtle nesting habitat.

The operation of weirs is predicted to result in a change to the downstream flow regime between the Eden Bann Weir and the Fitzroy Barrage. Water flows are predicted to increase during the dry season resulting in a decrease in the frequency and duration of no flow periods. The operation of the weirs is also likely to result in a reduction in the frequency and magnitude of small – medium downstream flood flows. The increase in flows during the dry season has the potential to improve the quality of aquatic habitat downstream by reducing the duration and severity of pool isolation and prolonging the presence of flowing riffles zones and runs. An alteration in the magnitude and timing of downstream flows does, however, have the potential to impact fish movement and turtle nesting. The operation strategy of the weirs will be dictated by the objectives set in the Fitzroy WRP and subordinate Fitzroy ROP, inclusive of environmental flow objectives. The operational strategy will aim to minimise environmental impacts as a result of the water infrastructure and will mimic natural flow conditions as much as possible. Flow analysis indicates that flows downstream of the Fitzroy Barrage will not be significantly impacted by the Project. Impacts to the downstream sensitive environmental areas and conservation significant species are therefore expected to be minimal.

The Project footprints are considered to support important habitat for the Fitzroy River turtle. Assessment of Project impacts and proposed management and mitigation strategies has identified that the Project is likely to have a residual impact on the Fitzroy River turtle during operations. Offsets are thus required under the EPBC Act Environmental Offset Policy. The protection and management of turtle nests has been selected as the proposed offset for the Project. The protection and management of nests will target Project specific impacts as well as address the key processes currently threatening the survival of the species. These actions will reduce nest predation, increase population recruitment and promote the recovery of the species. The management actions proposed for the Project, particularly the implementation of a predator control program, provision of turtle ramps, and protection and management of Fitzroy River turtle nests will also directly benefit the white-throated snapping turtle. Residual impacts on aquatic habitat are proposed to be offset in accordance with the provisions of the EO Act (Chapter 22 Offsets).