Arrow Bowen Pipeline

ENVIRONMENTAL IMPACT ASSESSMENT

- Aquatic Ecology Assessment
- Revision 0
- 14 November 2011

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Sinclair Knight Merz
ABN 37 001 024 095
100 Christie Street
St Leonards NSW 2065 Australia
Postal Address
PO Box 164 St Leonards NSW 2065 Australia
Tel: +61 2 9928 2100
Fax: +61 2 9928 2500
Web: www.skmconsulting.com

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1. Executive Summary

Introduction

Sinclair Knight Merz (SKM) and Austral Research and Consulting were commissioned by Arrow Energy Pty Ltd to undertake an Aquatic Ecology Assessment for the proposed Arrow Bowen Pipeline project (the project).

The proposed pipeline is approximately 580 km in length and includes a mainline (AB) which is approximately 477 km long and three laterals (Dysart, Saraji and Elphinstone). The mainline runs from Red Hill, approximately 90 km north of Moranbah in central Queensland to a junction with the proposed Arrow Surat Pipeline at a proposed gas gathering station approximately 22 km southwest of Gladstone. The three laterals consist of the Elphinstone Lateral (EL) approximately 52 km in length, the Saraji Lateral (SL) approximately 25.8 km in length and the Dysart Lateral (DL) approximately 25.7 km in length.

Construction of the pipeline will require waterway crossings which may involve the clearing of riparian vegetation, trenching of stream bed and banks, soil placement and the construction of temporary access tracks. Following construction of the pipeline, the Right of Way (ROW) will be returned to its pre-construction profile with waterway crossing points rehabilitated where necessary.

Methodology

A variety of field survey techniques were employed to record the aquatic flora and fauna species and their habitats along the proposed pipeline route alignment.

The aquatic ecology survey consisted of 25 prioritised sites which were selected based on desktop review of relevant literature, habitat features and the likelihood of available water. Representative examples of stream types, habitats and ecological features were selected to enable a range of potential aquatic impacts to be assessed. Where feasible, water quality, aquatic habitat and fish were surveyed using a combination of seine nets, bait traps and fyke nets.

Environmental values

Fifteen species of fish and two species of aquatic reptiles were recorded along the pipeline route. None of these species were listed as threatened, however two sites, the Fitzroy River (Site AP8) and Isaac River (Site AP12) contained habitat for the Fitzroy River Turtle (*Rheodytes leukops*) which is listed as Vulnerable under the Commonwealth

Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and the *Nature Conservation Act 1992* (NC Act). This species has been previously recorded in the vicinity of both locations (DERM 2011a). Estuarine Crocodile (*Crocodylus porosus*) which is listed as Vulnerable under the NC Act was not observed during field surveys however, it is known to occur within the Fitzroy River at the proposed route crossing. Platypus (*Ornithorhynchus anatinus*) which is listed as Least Concern under the NC Act was observed at the Isaac River (Site AP12). Potential platypus habitat was also recorded at several locations including Limestone Creek (Site AP7), Fitzroy River (Site AP8) and Scrubby Creek (Site AP6). One noxious fish species *Gambusia holbrooki* and the aquatic weed Elodea/Egeria (*Eldodea Canadensis/Egeria densa*) were also recorded in the project area.

Potential impacts

The majority of waterways are ephemeral, however, the potential temporary impact to aquatic fauna from changes to water quality in streams with permanent flowing waters is likely to be the key impact associated with the project. Other potential temporary impacts include:

- Removal of riparian and aquatic habitat (such as woody snags and aquatic macrophytes);
- Disturbance to the Fitzroy River Turtle (and other turtles) breeding;
- Erosion and sedimentation from vegetation clearing, trench spoil, trenching activities and the construction of temporary access tracks;
- Spread of weeds and pest aquatic fauna; and
- Disruption of natural hydrology and associated impacts to fish passage.

Mitigation measures

A range of mitigation measures have been recommended to reduce the potential temporary impacts of the proposed pipeline on aquatic flora and fauna considered likely to occur along the pipeline route. Mitigation measures include strategies to minimise these temporary impacts to the Fitzroy River Turtle and the platypus, sediment and erosion control measures, and the monitoring of water quality prior to, during and post construction. Provided that the recommended mitigation measures are adopted along the proposed pipeline route, it is considered unlikely that the project will have an adverse long term impact on aquatic ecology.

2. Introduction

Arrow Energy Pty Ltd (Arrow) commissioned Sinclair Knight Merz and Austral Research and Consulting to conduct an assessment of aquatic ecology at waterway crossings for the Arrow Bowen Pipeline Project (the project), as part of the Environmental Impact Statement (EIS).

The proposed pipeline is approximately 580 km in length and includes a mainline (AB) which is approximately 477 km long and three laterals (Dysart, Saraji and Elphinstone). The mainline runs from Red Hill, approximately 90 km north of Moranbah in central Queensland to a junction with the proposed Arrow Surat Pipeline at a proposed gas gathering station approximately 22 km southwest of Gladstone. The three laterals consist of the Elphinstone Lateral (EL) approximately 52 km in length, the Saraji Lateral (SL) approximately 25.8 km in length and the Dysart Lateral (DL) approximately 25.7 km in length.

Construction of the pipeline will require watercourse crossings which may involve the clearing of riparian vegetation, trenching of stream bed and banks, soil placement and the construction of temporary access tracks. The pipe will be laid via trench with a minimum depth of cover of 750 mm. At watercourse crossings, the minimum depth of cover will be increased to at least 1,200 mm. Horizontal Directional Drilling (HDD) may also be considered depending on the geotechnical and ecological nature of key watercourse crossings. Following construction of the pipeline, the Right of Way (ROW) will be returned to its pre-construction profile with watercourse crossing points rehabilitated where necessary.

This assessment provides a description of existing ecological characteristics, the associated impacts from the proposed pipeline during construction and operation and mitigation measures to manage potential impacts on aquatic ecology values.

2.1. Scope of works

The scope of works for the aquatic ecology assessment is to:

- Describe and identify existing aquatic ecological characteristics of the proposed pipeline route through desktop and field investigations;
- Assess potential impacts on aquatic ecology features and values that may result from construction and operation of the proposed pipeline; and
- Identify appropriate measures to help avoid, minimise and mitigate potential impacts to aquatic ecology features and values.

2.2. Legislative context

2.2.1. Commonwealth Environment Protection and Biodiversity Conservation Act 1999

The Commonwealth *Environment Protection and Biodiversity Conservation Act* (EPBC Act) applies to those actions which are likely to have a significant impact on matters of national environmental significance (NES). The eight matters of NES protected under the EPBC Act are World heritage properties, National heritage places, Wetlands of international importance (listed under the RAMSAR Convention), listed threatened species and ecological communities, migratory species protected under international agreements, Commonwealth marine areas, the Great Barrier Reef Marine Park and nuclear actions (including uranium mines).

The EPBC Act has significant implications for the management of natural resources and the environment throughout Australia. The Act provides lists of vulnerable, endangered and extinct species, threatening processes and threatened ecological communities and migratory species. The EPBC Act makes it an offence for any person to take an action that is likely to have a significant impact on matters of NES protected by the Act, unless they have the approval of the Minister of Sustainability, Environment, Water, Population and Communities (DSEWPC).

2.2.2. Sustainable Planning Act 2009

Under the *Sustainable Planning Act 2009* (SP Act) the construction or raising of temporary or permanent waterway barriers and the disturbance of marine plants are classed as 'development'. The SP Act and the *Fisheries Act 1994* (Fisheries Act) provides the code for self-assessable development - Minor waterway barrier works. The self-assessable code is a technical guide to assist in undertaking minor waterway barrier works that meet legislative and policy requirements under the Fisheries Act. Where the development proposal does not comply with this code, an application for a development permit must be lodged.

Waterways include ephemeral streams, and waterway barrier works may include culvert crossings and bed level waterway crossings.

2.2.3. Water Act 2000

The *Water Act 2000* (Water Act) regulates the use, flow and control of water including water in a watercourse, lake or spring, underground water, overland flow water, water that has been collected from a dam and recycled and desalinated water. Such works may include pumps, diversion channels, weirs, dams or bores. The Department of Resource

Management (DERM) manages access to water under the Water Act and authorises water licences, water permits (for short-term use), water allocations and interim water allocations.

Under the Water Act, activities that will involve vegetation destruction, excavation and fill in a watercourse are exempt from assessment under section 49, 50 and 51 of the *Water Regulation 2002* as long as they are authorised under a licence, petroleum lease or authority to prospect under the *Petroleum and Gas (Production and Safety) Act 2004* (P&G Act). If works are undertaken outside the pipeline licence area, a riverine protection permit, which will require the written consent of adjacent land owners, will be required under the Water Act to remove vegetation, excavate and fill within the watercourses.

A permit is also required to source water from a watercourse, lake, spring or aquifer for an activity of a temporary nature under section 237 of this Act. Water may be temporarily required during construction of the proposed pipeline for horizontal direction drill (HDD), hydrotesting, dust suppression and for potable temporary workers accommodation camp water. This permit process is separate to the SP Act and is required regardless of the Petroleum Pipeline Licence (PPL) granted under the P&G Act.

2.2.4. Fisheries Act 1994

The *Fisheries Act 1994* (Fisheries Act) regulates the management, use, development and protection of fisheries resources and fish habitats and the management of aquaculture activities. The disturbance of marine plants and the construction and raising of waterway barrier works are administered under the Fisheries Act.

The construction and raising of waterway barrier works is self assessable where:

- They are intended to exist for no more than 21 calendar days (tidal waterways) or 42 calendar days (non-tidal waterways);
- They are no more than 20 m in length measured across the waterway; and
- They are no more than 10 m wide.

Where waterway barrier works are deemed self-assessable (in accordance with the criteria), the works must comply with the Code for self-assessable development, temporary waterway barrier works.

Non-indigenous and declared noxious fish species are listed under the *Fisheries Regulation 2008*. One noxious species of fish, *Gambusia Holbrooki* was recorded within the project area.

2.2.5. Nature Conservation Act 1992

The *Nature Conservation Act 1992* (NC Act) has a number of associated regulations, plans and orders. The objectives of the NC Act are based on principles to conserve biological diversity, ecologically sustainable use of wildlife and ecologically sustainable development. The NC Act and Regulations state that any person taking, using or interfering with protected fauna is required to have a Wildlife Rehabilitation Permit (spotter-catcher) and to posses the training and skills required to undertake this activity. Such a permit will allow a person to rescue and release a sick, injured or orphaned protected animal; or a protected animal whose habitat has been, or will be, destroyed by human activity or a natural disaster.

A clearing permit (protected plants) is also likely to apply to taking, using or interfering with protected flora under the NC Act. DERM administer the clearing permits.

2.2.6. Land Protection (Pest and Stock Route Management) Act 2002

The *Land Protection (Pest and Stock Route Management) Act 2002* (LP Act) and the *Land Protection (Pest and Stock Route Management) Regulation 2003* (LP Regulation) provide for pest and plant management in Queensland. The legislation aims to prevent declared pests impacts by:

- Preventing the introduction and establishment of new pest plants;
- Preventing the spread of established plants to new areas; and
- Reducing the extent of existing infestations.

There are three classes of declared pests that are enforced under the LP Act and the management intent varies between each class:

- Class 1 species are not generally established in Queensland but have potential to cause adverse economic, environmental or social impacts. The landowner is obliged to take reasonable steps to keep their land free of Class 1 pest species, unless the owner holds a declared pest permit allowing the pests to be kept on the land.
- Class 2 species are established in Queensland and can cause significant adverse economical, environmental or social impact. The landowner is obliged to take reasonable steps to keep their land free of Class 2 pest species, unless the owner holds a declared pest permit allowing the pests to be kept on the land.
- Class 3 species are established in Queensland and have or could have adverse economical, environmental or social impact. Legislative obligations relating to control these species are generally limited to specific conservation areas (AECOM, 2011).

2.3. Assumptions and limitations

The list of aquatic flora and fauna species recorded from this study should not be seen to be fully comprehensive, but an indication of the species present at the time of the surveys. A period of several seasons or years is often needed to identify all the species present in an area, especially as some species are only apparent at certain times of the year for short periods (e.g. migratory fish) or require specific weather conditions for optimum detection (e.g. reptiles). The conclusions of this report are based on available data and the early spring field surveys and are indicative of the environmental condition of the site at the time of the surveys. It should be recognised that site conditions, including the presence of threatened species, can change with time. As construction will be undertaken during dryer months, the ecological assessment is considered to be adequate for the Environmental Impact Statement.

3. Methodology

3.1. Desktop assessment

A review of relevant ecological literature and government maintained databases for the project area and locality was undertaken as part of the desktop assessment. A list of threatened aquatic flora and fauna species was compiled from the review and assessed to determine the potential presence of threatened biota in the project area. Available database records of aquatic species previously documented in the region, including watercourse dependent reptiles and fish are provided in **Appendix A**. The data sources used in this review are as follows:

- DERM WildNet – an internet based database that provides a list of all species threatened under State or National legislation for a search area defined by the user (DERM, 2011a);
- Directory of Important Wetlands;
- Department of Sustainability, Environment, Water, Populations and Communities (DSEWPC) Protected Matters Search Tool (http://www.environment.gov.au/erin/ert/epbc/index.html) – a Commonwealth internet-based database and search tool which enables the generation of a report that assists in determining whether matters of national significance or other matters protected by the EPBC Act are likely to occur in the area of interest;
- Biosecurity Queensland's Annual Pest Distribution Survey data and predictive maps to identify the possible presence of aquatic pest plants in the project area including Weeds of National Significance (WONS) (Queensland Government 2011a);
- DERM's Wetland Info site provides details on wetland habitat (Queensland Government 2011b);
- Records published in scientific journals (important data sources include Tucker et al. 2001); and
- Results of local environmental studies, including studies prepared by consultants, local government authorities, biological organisations, universities and other sources.

A literature review was conducted on all threatened species likely to occur in the project area including the Fitzroy River Turtle, the platypus and the Estuarine Crocodile to determine the likelihood of their presence along the proposed pipeline route, taking into consideration breeding requirements and the presence or absence of suitable habitat.

Suitable sampling sites were selected based upon desktop review of relevant database searches and existing data. Sampling sites were selected based upon site access, habitat

features, and the likelihood of available water. Representative examples of stream types, habitats and ecological features were selected to enable a range of potential aquatic impacts to be assessed. The selected sites were compared against the Watercourse Crossing Information for Arrow Bowen Gas Pipeline (AECOM, 2011) which visited the majority of watercourses within the project area to ensure representative sites were selected.

3.2. Project area

The proposed pipeline route will cross a number of perennial, seasonal and intermittent watercourses including rivers, streams, floodplains and wetlands. The nearest Ramsar Wetland is the Shoalwater and Corio Basin area located 60km North East of the proposed pipeline route. The proposed pipeline route transects 4 REs that are classified and mapped as wetlands according to the Queensland Wetland Mapping and Classification Methodology (EPA, 2005). The majority of the waterways and wetlands intersected by the pipeline are likely to be ephemeral and contain limited habitat for aquatic species.

3.3. Field survey methods

Suitable sampling sites were selected based upon desktop review of relevant database searches and existing data. Sampling sites were selected based upon site access, habitat features, and the likelihood of available water. Representative examples of stream types, habitats and ecological features were selected to enable a range of potential aquatic impacts to be assessed. The selected sites were compared against the Watercourse Crossing Information for Arrow Bowen Gas Pipeline (AECOM, 2011) which visited the majority of watercourses within the project area to ensure representative sites were selected.

3.3.1. Aquatic ecology field survey

Aquatic ecology field surveys associated with the project were undertaken from 12 to 24 September 2011. The survey comprised sampling at 25 watercourses (comprising two estuarine and 23 freshwater) in the project area with samples typically collected at the proposed pipeline watercourse crossings. The locations sampled are detailed in Table 3-1 and habitat descriptions are provided in **Appendix A**.

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- **Table 3-1 Summary of aquatic field survey**

Watercourse	KP	Site code	Map zone	Easting	Northing	Fish survey			Water quality	Aquatic Habitat
						Fyke nets	Bait trap	Seine nets		
Isaac River	AB50	AP22	55K	611484	7604086	No water				✓
Kenny's Creek	AB69	AP25	55K	614753	7587128				✓	✓
North Creek	AB105	AP24	55K	637727	7564113			✓	✓	✓
North Creek	AB109	AP23	55K	639399	7560879	No water				✓
Isaac River at alternative crossing	AB162	AP18 a	55K	675323	7520163			✓	✓	✓
Isaac River	AB165	AP17	55K	670062	7517147	No water				✓
Blackburn Creek	AB172	AP16	55K	673902	7512148			✓	✓	✓
Rolf Creek/Isaac River Anabranch Junction	AB213	AP15	55K	709651	7492976			✓	✓	✓
Isaac River Anabranch	AB216	AP14	55K	712614	7491111			✓	✓	✓
Bellarine Creek / Isaac River Anabranch Junction	AB217	AP13	55K	713735	7490466				✓	✓
Isaac River Anabranch	AB234	AP12	55K	727643	7482693			✓	✓	✓
Isaac River Anabranch	AB238	AP10	55K	731447	7481319	No water				✓
Stockyard Creek at pipeline	AB239	AP9	55K	732393	7481118	No water				✓
Stockyard Creek at aquatic survey location	AB239	AP9a	55K	736542	7485095	✓	✓	✓	✓	✓
Fitzroy River	AB319	AP8	55K	794117	7443094	Risk of crocodiles			✓	✓
Limestone Creek	AB371	AP7	56K	220877	7418080	✓	✓	✓	✓	✓
Scrubby Creek	AB391	AP6	56K	234850	7404747	✓	✓	✓	✓	✓
Inkerman Creek	AB426	AP5	56K	260370	7384683	✓	✓	✓	✓	✓
Oxbow lagoon off Inkerman Creek	AB429	AP5a	56K	262766	7384406	✓	✓	✓	✓	✓
Inkerman Creek*	AB430	AP4	56K	263610	7383801	Tidal, deep with strong current, no fish surveys			✓	✓
Twelve Mile	AB439	AP3	56K	270530	7379247	✓	✓	✓	✓	✓

Watercourse	KP	Site code	Map zone	Easting	Northing	Fish survey			Water quality	Aquatic Habitat
						Fyke nets	Bait trap	Seine nets		
Creek										
Raglan Creek*	AB447	AP2	56K	277329	7376501	Risk of crocodiles, too fast flowing and deep.				✓
Larcom Creek	AB476	AP1	56K	297665	7358398			✓	✓	✓
Isaac River at alternative Saraji Lateral crossing	SL14	AP19	55K	646609	7538593	No water				✓
Isaac River Saraji Lateral	SL19	AP26	55K	651437	7535917	✓	✓	✓	✓	✓

*Estuarine watercourses

3.3.2. Water quality

Water quality was measured in-situ at each of the freshwater sites using a YSI Pro Plus and a HACH 2100Q Turbidity Meter. A range of parameters were measured including dissolved oxygen (DO), pH, conductivity (µS/cm – mS/cm), turbidity (NTU) and temperature (°C). The water quality meter was calibrated prior to fieldwork being undertaken.

3.3.3. Fish sampling

Estuarine and freshwater fish communities were sampled at each site using a combination of bait traps and fyke nets. Electro-fishing was not conducted due to safety concerns such as electrocution. All nets were set to ensure a diversity of structural habitat available to fish was sampled in each watercourse (open water, amongst or against vegetation and woody material). The variety of these passive sampling methodologies increases the probability of sampling a wider range of species and size classes.

At feasible fish survey sites, 10 bait traps (unbaited) (45 × 25 × 25 cm) were set in shallow habitats for a minimum of two hours. Where possible, traps were set in stands of emergent vegetation, areas with submerged vegetation, or snag piles, as these areas are likely to have a greater diversity and abundance of small bodied fish. **Figure 3-1** shows a bait trap set in shallow water near submerged vegetation.

- **Figure 3-1 Bait trap**

Fyke nets were used to trap mobile, large bodied fish (**Figure 3-2**). Two to four fyke nets were set for a minimum of two hours. Large single-wing fyke nets with either a 4 m or 6 m leader were set with the cod-end on one bank and with the wing attached to the opposite bank. The cod-end of each fyke was always suspended out of the water to avoid the mortality of captured air breathing vertebrates. As fyke nets require entry into the body of the river, fyke nets were not deployed at sites with an identified risk of crocodiles or cattle.

- **Figure 3-2 Fyke net**

A 20 m seine net was used at sites where sections of the river or creek were at a wadeable depth (<1 m) and where the presence of instream habitat did not impede the passage of the net through the water. The net was deployed from the bank and dragged through the river/creek in a loop by two aquatic ecologists. The net was then dragged into the bank to record the catch. The seine net deployment was repeated 15 minutes after the first deployment at each of the sites. **Figure 3-3** shows an example of a seine net being deployed.

- **Figure 3-3 Seine net**

3.3.4. Platypus surveys

Fyke nets used for fish surveys also targeted Platypus (*Ornithorhynchus anatinus*). Fyke nets targeting platypus were installed adjacent to likely pond habitats for platypus. The physical characteristics of the riparian zone, upper banks and stream of each survey site were recorded on the Water Quality/ Habitat Assessment Proforma. The habitat assessments were used to identify the potential for platypus occurring at each site.

Fyke nets were always positioned such that they were never completely submerged, to ensure there was access to the water surface for air-breathing animals. Nets were checked regularly and by-catch immediately removed from the traps. All aquatic fauna handling was conducted by experienced ecologists employing techniques to minimise stress on captured animals (e.g. quiet and careful handling, careful observation at release).

3.3.5. Aquatic habitat and flora assessment

Submerged or emergent aquatic water plants encountered at each site were identified to assess and record threatened flora or noxious weed species. The description of aquatic macrophytes included submerged, floating and emergent macrophytes, macroscopic algae, as well as the presence of any introduced or pest plant species.

Aquatic flora was assessed along a 100 m reach at each site, with the presence of native and exotic macrophytes recorded. Photographs of the aquatic habitat were taken at each site and species were identified in the field, where practical.

4. Description of environmental values

4.1. Existing environment

The major watercourses within the pipeline corridor are the Fitzroy River and the Isaac River. The State of the Rivers (SoR) Report for the Fitzroy and Isaac Rivers and Capricorn Coastal Tributaries (SoR 2005) provides a detailed overview of the catchment's natural, physical and ecological values. It is important to note that the SoR report was written in 2005 and conditions may have changed in the region since the report was published.

The pipeline extends from Moranbah (in the Bowen Basin) to Gladstone in Central Queensland where the climate is described as tropical to subtropical with summer rainfall being dominant although variable. The inland regions of the catchments are generally drier and rainfall increases toward the east and ranges from 2000 – 500 mm per year. Extended dry periods are recognised as a regular feature of the weather patterns.

Land use is diverse and includes grazing, mining and recreational uses (national and state parks). Grazing is the dominant land use activity although coal mining activities are increasing. Dryland cropping and irrigation are also present on the alluvial flood plans adjacent to the major watercourses. Extensive clearing of native vegetation has occurred in the past to support pasture. Water quality in the Fitzroy and Isaac catchments is typically high in turbidity, nutrients and pesticides, particularly after rainfall events when overland flow has occurred.

The Reach Environs (land use adjacent to the riparian zone) was assessed during the field surveys as being good to very good (an excellent rating is applied to undisturbed natural vegetation) throughout much of the catchment and grazing impacts were the primary disturbance observed. River banks were mainly stable and the major cause of instability was reported to be river flows, wave action and uncontrolled stock access. Stream bed and bar formations were generally stable along most river reaches with bank instability and stock access recognised as the biggest threats to stability. Channel habitat diversity was low to very low with runs and pools the most common type of habitat recorded across the catchment.

Riparian vegetation condition was highly variable and ranged from very poor to very good. Very poor ratings were associated with narrow riparian corridors and exotic vegetation. The riparian community was dominated by *Melaleuca spp*., *Eucalyptus spp*., *Acacia ssp.*, *Lysiphyllum spp.* and *Callistemon spp*. A number of weed species were also observed throughout the riparian zone within the catchment including *Lantana spp.*, *Parthenium*

hysterophorus (Parthenium weed) and *Parkinsonia aculeate* (Parkinsonia). There was generally a lack of aquatic vegetation within the catchments. Aquatic habitat ratings were highly variable and ranged from very poor to very good. Twigs, leaf packs and large logs were the dominant habitat identified with overhangs and trailing back vegetation also recorded. Fauna passage was restricted due to the absence of flows for many reaches, however, fords, log jams, weirs and rapids were also identified as potential barriers.

4.1.1. Water crossing information (AECOM)

AECOM Australia Pty Ltd (AECOM) was engaged by Arrow to conduct a watercourse assessment for major watercourses in the project area. The study included recommendations for alternative nearby crossing points (micro re-alignments) that reduced potential impacts (e.g. existing clearing, less steep banks, smaller channel, less permanent water, waterhole avoidance, or fewer large trees).

A total of 54watercourses were assessed between 15 June to 4 July and 30 August to 10 September 2011. Watercourses surveyed during the aquatic ecology survey (this assessment) were selected in consultation with the watercourse crossing information provided by AECOM to ensure a selective representation of the watercourses in the project area. Additional watercourses not surveyed in the aquatic ecology report (due to time constraints) but with potentially good aquatic habitat include:

- Suttor Creek (AB12.3);
- Pluto Creek (AB275.6);
- Api's Creek (AB284.2);
- Endrick Creek (AB285.4);
- Eight Mile Creek Tributary (AB336);
- Two Mile Creek (AB349.3);
- Midgee Creek (AB410.4);
- Bob's Creek (AB413.6); and
- Horrigan Creek (AB445.5); and
- Unnamed wetland near Ripstone Creek (SL7.8, SL11.1).

Based upon available habitat and upstream catchment, it is likely that these watercourses may contain a similar fish and macrophyte community to those observed during the aquatic ecology surveys.

4.2. Database searches and desktop assessments

The desktop assessment included a review of the existing reports and data obtained via database searches. A search of the DERM Wildlife Online Atlas indicated that a number of native species and exotic species are known to occur within a 20 km radius of the proposed pipeline route (**Table 4-1**). The Fitzroy River Turtle (*Rheodytes leukops*) is the only protected species listed as vulnerable under the EPBC Act identified as potentially occurring within a 10 km radius of the proposed pipeline route. The Estuarine Crocodile (*Crocodylus porosus*) and the Fitzroy River Turtle (*Rheodytes leukops*), listed as vulnerable under the NC Act, may exist or have suitable habitat within the search area. The platypus (*Ornithorhynchus anatinus*) is listed as least concern under the NC Act.

- **Table 4-1 Aquatic species known to occur within the project area (~10 km search buffer)**

Scientific name	Common name	Source of record	Native/ introduced	Status NC Act	Status EPBC Act	Potential habitat
Ambassis agassizii	Agassiz's Glassfish	DERM	Native	-	-	Yes
Amniataba percoides	Barred Grunter	DERM	Native	-	-	Yes
Anguilla reinhardtii	Longfin Eel	DERM	Native	-	-	Yes
Arrhamphus sclerolepis	Snubnose Garfish	DERM	Native	-	-	Yes
Bidyanus bidyanus	Silver Perch	DERM	Native	-	-	Yes
Craterocephalus stercusmuscarum	Flyspecked Hardyhead	DERM	Native	-	-	Yes
Gambusia holbrooki	**Gambusia (Mosquitofish)**	DERM	**Introduced**	**-**	**-**	Yes
Glossamia aprion	Mouth Almighty	DERM	Native	-	-	Yes
Gobiomorphus australis	Striped Gudgeon	DERM	Native	-	-	Yes
Hypseleotris compressa	Empire Gudgeon	DERM	Native	-	-	Yes
Hypseleotris galii	Firetail Gudgeon	DERM	Native	-	-	Yes
Hypseleotris klunzingeri	Western Carp Gudgeon	DERM	Native	-	-	Yes
Hypseleotris species 1	Midgley's Carp Gudgeon	DERM	Native	-	-	Yes
Lates calcarifer	Barramundi	DERM	Native	-	-	-
Leiopotherapon unicolor	Spangled Perch	DERM	Native	-	-	Yes
Macquaria ambigua	Golden Perch	DERM	Native	-	-	Yes
Megalops cyprinoides	Oxeye Herring	DERM	Native	-	-	Yes
Melanotaenia splendida splendida	Eastern Rainbowfish	DERM	Native	-	-	Yes

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Scientific name	Common name	Source of record	Native/ introduced	Status NC Act	Status EPBC Act	Potential habitat
Mogurnda adspersa	Purplespotted Gudgeon	DERM	Native	-	-	Yes
Mugil cephalus	Sea Mullet	DERM	Native	-	-	Yes
Myxus petardi	Pinkeye Mullet	DERM	Native	-	-	Yes
Nematalosa erebi	Bony Bream	DERM	Native	-	-	Yes
Neoarius graeffei	Blue Catfish	DERM	Native	-	-	Yes
Neosilurus hyrtlii	Hyrtl's Catfish	DERM	Native	-	-	Yes
Notesthes robusta	Bullrout	DERM	Native	-	-	Yes
Oxyeleotris lineolata	Sleepy Cod	DERM	Native	-	-	Yes
Philypnodon grandiceps	Flathead Gudgeon	DERM	Native	-	-	Yes
Poecilia reticulata	Guppy	DERM	Introduced	-	-	Yes
Pseudomugil signifer	Pacific Blue Eye	DERM	Native	-	-	Yes
Scleropages leichardti	Southern Saratoga	DERM	Native	-	-	Yes
Scortum hillii	Leathery Grunter	DERM	Native	-	-	Yes
Strongylura krefftii	Freshwater Longtom	DERM	Native	-	-	Yes
Tandanus tandanus	Freshwater Catfish	DERM	Native	-	-	Yes
Chelodina expansa	Broad-shelled River Turtle	DERM	Native	-	-	Yes
Chelodina longicollis	Eastern Snake-necked Turtle	DERM	Native	-	-	Yes
Crocodylus porosus	Estuarine Crocodile	DERM, EPBC	Native	V	-	Yes
Elseya albagula	Southern Snapping Turtle	DERM	Native	-	-	Yes
Emydura macquarii krefftii	Krefft's River Turtle	DERM	Native	-	-	Yes
Rheodytes leukops	Fitzroy River Turtle	DERM, EPBC	Native	V	V	Yes
Wollumbinia latisternum	Saw-shelled Turtle	DERM	Native	-	-	Yes
Ornithorhynchus anatinus	Platypus	DERM	Native	C	-	Yes

Note: W = DERM Wildnet; EPBC = EPBC protected matters search; V= Vulnerable, C= Least Concern

The majority of the watercourses intersected by the pipeline route are ephemeral and contain limited habitat for aquatic species. The aquatic species listed in **Table 4-2** were recorded in the region by AECOM in the Environmental Assessment Report (Flora) for the Proposed Arrow Bowen Pipeline (AECOM, 2011) and reviewed prior to field surveys.

Table 4-2 Aquatic flora species

Scientific name	Family	Habitat	Recorded by Queensland Herbarium	Observed during the field survey
Abildgaardia ovata	Cyperaceae	Semi-aquatic	Y	N
Aponogeton queenslandicus	Aponogetonaceae	Freshwater	Y	N
Azolla pennata	Azollaceae	Freshwater	N	Y
Ceratophyllum demersum	Ceratophyllaceae	Freshwater	Y	N
Cyperus species	Cyperaceae	Freshwater, semi-aquatic	Y	Y
Eleocharis dietrichiana	Cyperaceae	Freshwater	Y	N
Eleocharis dulchus	Cyperaceae	Freshwater	N	Y
Fimbristylis species	Cyperaceae	Freshwater, semi-aquatic	Y	Y
Ischaemum australe	Poaceae	Semi-aquatic	Y	N
Juncus species	Juncaceae	Freshwater, semi-aquatic	Y	Y
Ludwigia octovalvis	Onagraceae	Semi-aquatic	Y	Y
Ludwigia peploides	Onagraceae	Freshwater	Y	N
Marsilea exarata	Marsileaceae	Freshwater	Y	N
*Marsilea mutica**	Marsileaceae	Freshwater	N	Y
Nymphaea gigantea	Nymphaeaceae	Freshwater	Y	N
Nymphaea violacea	Nymphaeaceae	Freshwater	N	Y
Ottelia alismoides	Hydrocharitaceae	Freshwater	Y	N
Ottelia ovalifolia	Hydrocharitaceae	Freshwater	N	Y
Paspalidium udum	Poaceae	Freshwater	Y	N
Persicaria attenuata	Polygonaceae	Freshwater	Y	N
*Persicaria decipens**	Polygonaceae	Freshwater	N	Y
Persicaria hydropiper	Polygonaceae	Freshwater	Y	N
Persicaria lapathifolia	Polygonaceae	Freshwater	Y	N
Persicaria orientalis	Polygonaceae	Freshwater	Y	N
Persicaria prostrata	Polygonaceae	Freshwater	Y	N
Phragmites australis	Poaceae	Freshwater	N	Y
Polygonum plebeium	Polygonaceae	Freshwater	Y	N
Potamogeton crispus	Potamogetonaceae	Freshwater	Y	Y
Potamogeton pectinatus	Potamogetonaceae	Freshwater	Y	N

Scientific name	Family	Habitat	Recorded by Queensland Herbarium	Observed during the field survey
Pseudoraphis paradoxa	Poaceae	Freshwater	Y	N
Pseudoraphis spinescens	Poaceae	Freshwater	Y	Y
Schoenoplectus litoralis	Cyperaceae	Freshwater	Y	N
Scleria mackaviensis	Cyperaceae	Semi-aquatic	Y	N
Scleria polycarpa	Cyperaceae	Semi-aquatic	Y	N
Utricularia sp.	Lentibulariaceae	Freshwater	N	Y

Biosecurity Queensland's Annual Pest Distribution Survey data suggests that there are a number of aquatic and semi-aquatic weeds whose distribution may extend to the project area. The species identified are listed in **Table 4-3** with their state classification under the LP Act, and whether the species is identify as weeds of national significance (WONS) at a national level. Data on the current distribution (2009/10) and potential distribution based on climate suitability has been presented (Queensland Government 2011a).

- **Table 4-3 Desktop assessment of aquatic weeds with potential distribution in the project area**

Species	Common name	WONS	State legislation		
			Class	Presence/ absence	Predictive mapping
Alternanthera philoxeroides	Alligator weed	Yes	Class 1	Absent	Suitable
Hymenachne amplexicaulis	Hymenachne or olive hymenachne	Yes	Class 2	Absent	Suitable
Gymnocoronis spilanthoides	Senegal tea plant	No	Class 1	Absent	Moderate suitability
Salvinia molesta	Salvinia	Yes	Class 1	Absent	Suitable
Cabomba spp.	Cabomba	Yes	Class 1 & 2	Absent	Highly suitable
Stratiotes aloides	Water soldiers	No	Class 1	Absent	Very low suitability
Lagarosiphon major	Lagarosiphon	No	Class 1	Absent	Low – moderate suitability
Pistia stratiotes	Water lettuce	No	Class 2	Absent	Highly suitable

Species	Common name	WONS	State legislation		
			Class	Presence/ absence	Predictive mapping
Eichhornia crassipes	Water hyacinth	No	Class 2	Absent	Highly suitable
Mimosa pigra	Mimosa pigra	Yes	Class 1	Absent	Marginally suitable
Neptunia oleracea	Water mimosa	No	Class 1	Absent	Not available
Ludwigia peruviana	Peruvian primrose bush	No	Class 1	Absent	Highly suitable
Myriophyllum spicatum	Eurasian water milfoil	No	Class 1	Absent	Highly suitable
Trapa natans	Floating water chestnut	No	Class 1	Absent	Very low suitability
Equisetum arvense	Horsetails	No	Class 1	Absent	Very low suitability
Equisetum hyemale	Horsetails	No	Class 1	Absent	Low suitability

Note: WON = Weeds of national significance.

4.2.1. Fitzroy River Turtle

Six species of freshwater turtle occur in the Fitzroy-Dawson drainage region of Queensland (Legler & Cann 1980). The Fitzroy River Turtle (*Rheodytes leukops*) is listed as vulnerable under the Queensland NC Act and vulnerable under the Commonwealth EPBC Act. It is also recognised internationally as vulnerable under the International Union for Conservation of Nature (IUCN) Red List of Threatened Species.

The species has been found in the Fitzroy, Connors, Dawson, Isaac and Mackenzie rivers and Windah and Develin creeks. The species was listed as vulnerable because its riffle habitat is threatened by dam and weir construction, as well as egg predation which have resulted in the population of the Fitzroy River Turtle consisting primarily of ageing individuals.

The Fitzroy River Turtle is commonly known as a 'bottom-breathing' turtle because it can obtain oxygen by cloacal ventilation. In well oxygenated water the turtle rarely needs to come to the surface to breathe, as the cloaca allows the turtle to extract oxygen from the water. Aquatic turtles that use cloaca respiration are vulnerable to fish poisons and other forms of water pollution.

The Fitzroy River Turtle is found in flowing streams and permanent waterbodies, it prefers fast flowing water and riffle characterised by well oxygenated water (Cann 1998, Tucker et

al. 2001). However in the dry season it may be found in large slow-flowing pools and non-flowing permanent water holes. They prefer clear water and are often associated with submerged logs and undercut banks (Cann 1998). Common riparian vegetation associated with the turtle includes Blue Gums (*Eucalyptus tereticornis*), River Oaks (*Casuarina cunninghamiana*), Weeping Bottle Brushes (*Callistemon viminalis*) and Paperbarks (*Meleleuca liniarifolia*) (Tucker et al. 2001). They are often associated with aquatic beds of Ribbonweed (*Vallisneria sp*.) (Cogger et al. 1993), however they have also been associated with logs in deeper water (Tucker et al. 2001).

During Spring (September and October), female Fitzroy River Turtles lay eggs in sand and gravel bars adjacent to the river or on sand banks adjacent to the river. Typically the banks consist of a deep layer of sand and a low vegetative cover. Juveniles spend much time sheltering on the flow of the watercourse beneath dead wood or buried sand. A key threat to the Fitzroy River Turtle includes the trampling of nests by stock and reduced access to nesting areas due to weed infestations such as Lantana (*Lantana camara*), Cat's Claw Creeper (*Macfadyena unguis-cati*), Heart Seed Vine (*Cardiospermum grandiflorum*), and Vegetable Sponge (*Luffa aegyptiaca*)..

Biological data on the movement pattern of the Fitzroy River Turtle are limited, however Tucker et al. 2001 observed that on average the turtles were observed to have a range span of 562 m, which suggests that viable populations are likely to be limited to waters in relatively close proximity to nesting habitat. The closest known locations to the proposed route are the Redbank and Glenroy crossings of the Fitzroy River (Inglis & Howell, 2009).

The *Action Plan for Australia Reptiles* (Cogger et al. 1993) outlines the actions for construction and operation of a gas pipeline to protect the Fitzroy River Turtle. This includes preventing pollution and silting of the Fitzroy River and its tributaries, reducing erosion, and retaining native vegetation along river edges.

It is important to maintain drainage patterns, and water quality in regions where the Fitzroy River turtle occurs, including areas adjacent to, or higher up the river bank of these areas. Care should be taken during construction of the pipeline to ensure that adjacent areas, and nearby uphill areas in the Fitzroy region are not accessed by construction crews, particularly during the Spring breeding season.

4.2.2. Estuarine Crocodile

Estuarine Crocodiles (*Crocodylus porosus*) (also known as saltwater crocodiles) are found across northern Australia in fresh and saltwater habitats. Typically the Estuarine Crocodile lives in the tidal reaches of rivers, however it can also occur in freshwater lagoons and

swamps, sometimes hundreds of kilometres inland from the coast. The Fitzroy River at Glenroy is the most southern known nesting point for Estuarine Crocodiles (Inglis & Howell 2009). Recent surveys have identified crocodiles at four locations in the lower Fitzroy River (Sullivan et al. 2010); however nesting crocodiles have also been recorded at Conroy Crossing (Iglis & Howell, 2009). The Estuarine Crocodile is listed as vulnerable under the NC Act.

4.2.3. Platypus

Platypus (*Ornithorhynchus anatinus*) are predominantly solitary animals with a distribution across Eastern Australia. Platypus are known to occur in freshwater creeks, slow moving rivers, lakes and even in farm dams (EPA 2004). Platypus spend part of their time out of the water, resting in burrows in the banks of watercourses (Serena et al. 1998). Previous studies have suggested that the placement of platypus burrows may be influenced by certain bank characteristics such as the presence of trees, bank undercutting, slope and the degree of soil impact (Serena et al. 1998).

Studies conducted by Serena et al. (1998) found that platypus tended to select burrow sites in banks that extended 1-2.5m above the water. No burrows were located in banks that measured less than 0.5m in height or sloping less than 20° (Serena et al. 1998; Woon 1995). Vegetation is thought to provide greater bank stability and help to hide burrow entrances from predators. Woon (1995) found that platypus burrows were positively associated with tree density, vegetation bank cover and vegetation overhanging the water. Overhanging banks are also thought to help hide burrows, with high densities of platypus observed along banks with overhanging ledges (Serena, 1994).

4.3. Aquatic survey results

The following sections provide a summary of the results of the water quality, aquatic fauna and flora surveys. A detailed description and photo of each survey location is provided in **Appendix A**.

4.3.1. Water quality

The majority of the watercourses in the vicinity of the project area are ephemeral or intermittent streams where the flow regime is dominated by extended periods of no flow. Rainfall and runoff are highly variable between years and water quality is also highly variable due to the nature of the flows regime. Exceptions include the Fitzroy River, which is a permanent watercourse at the route crossing, and sections of the Isaac River and Raglan Creek, which have isolated pools that are likely to retain water throughout the year.

The variable flow conditions within the region results in a highly specialised riverine ecology. During dry seasons, waterholes (including many within the Isaac River) become enclosed ecosystems and provide refuge for aquatic organisms. Persistence of waterholes with good water quality is important for sustaining aquatic life during the frequent and occasionally prolonged periods without flow. The major water quality issues for waterholes, and low flow watercourses are likely to be low dissolved oxygen, high temperatures, increasing salinity and algal blooms.

Table 4-4 provides a summary of in-situ data collected during the site surveys in September 2011. Generally the water quality in the project area was good with pH and dissolved oxygen concentrations relatively stable throughout the project area. Low dissolved oxygen concentration (4 mg/L) was observed at the Isaac River alternative crossing Site (AP18a), which may be due to low flows, high levels of organic matter and the presence of coal dust within the residual pool. Turbidity was highly variable throughout the project area, ranging from 1.96 NTU at Stockyard Creek (Site AP9a) to 696 NTU at Bellarine Creek/Isaac River Junction (AP13). Elevated turbidity was generally recorded at sites with limited riparian vegetation cover and stock access to the watercourses. Electrical conductivity levels were also highly variable. Aside from two estuarine sites (Inkerman Creek and Raglan Creek), conductivity within the freshwater sites fluctuated, which may be due to saline groundwater intrusions and/or salt concentration through the evaporation of ephemeral pools.

- **Table 4-4 Water quality data collected in September 2011 at the field survey locations**

Site	Temperature (°C)	Conductivity (µS/cm)	pH	Dissolved oxygen (mg/L)	Dissolved oxygen (%sat)	Turbidity (NTU)	Visual observations
AP1 - Larcom Creek	19.2	1315	8.6	7.2	77	5.5	Tannin stained from surrounding Teatrees. Isolated patches of oily films and foaming in backwater areas. Large quantities of floating debris on the water's surface.
AP2 - Raglan Creek	Not sampled due to safety concerns						Extremely turbid, fast flowing estuarine watercourse.
AP3 - Twelve Mile Creek	21.5	8552	8.7	8.2	95	8.3	Anoxic odour, no foaming or oily films, moderate algae on the substrate and within the water column.
AP4 - Inkerman Creek	19.2	43600	8.0	5.8	75	329	Turbid estuarine creek, no odour, foaming, oily films or algae observed.
AP5 - Inkerman Creek	24.7	1942	8.7	9.7	116	2.6	Anoxic odour, no foaming or oily films, moderate algae on the substrate and within the water column.
AP5a - Oxbow lagoon off Inkerman Creek	19.0	1440	9.7	9.0	100	35	Turbid pool, localised anoxic sediments, no oily films or foaming observed.
AP6 - Scrubby Creek	19.2	1971	8.7	8.3	90	16.2	No odour, foaming, oily films or algae observed.
AP7 - Limestone Creek	17.5	2666	8.1	7.6	79	6.1	No odour, foaming, oily films or algae observed.
AP8 - Fitzroy River	23.1	914	9.0	8.1	96	14	No odour, foaming, oily films or algae observed.
AP9 - Stockyard Creek at pipeline	No water						
AP9a - Stockyard Creek at aquatic survey location	20.4	694	8.9	8.8	98	2.0	Anoxic odour in some locations, moderate algae on substrate. No oily films or foaming on water surface.
AP10 - Isaac River Anabranch	No water						
AP12 - Isaac River Anabranch	19.8	567	8.0	6.3	70	18	No odour, foaming, oily films. Moderate algae on substrate.
AP13 - Bellarine Creek / Isaac	22.0	320	7.06	6.1	72	696	Film of Blue/green algae on surface. Very turbid pool.

Site	Temperature (°C)	Conductivity (µS/cm)	pH	Dissolved oxygen (mg/L)	Dissolved oxygen (%sat)	Turbidity (NTU)	Visual observations
River Anabranch Junction							
AP14 - Isaac River Anabranch	23.6	263	7.8	6.5	78	121	Turbid residual pool, with scum on the surface due to cattle access
AP15 - Rolf Creek/Isaac River Anabranch Junction	21.7	190.3	8.7	6.4	74	277	Turbid pool, largely due to clay substrate and cattle access.
AP16 - Blackburn Creek	17.8	528	8.4	7.7	81	21.9	Turbid pool, largely due to clay substrate and cattle access.
AP17 - Isaac River	No water						
AP18a - Isaac River at Alternative Crossing	19.9	624	7.3	4	50	6.3	Oily film and residual coal dust on surface. Lots of organic matter instream, resulting in anoxic odours.
AP23 - North Creek	No water						
AP24 - North Creek	20.8	360	8.0	7.6	88	17.3	Turbid isolated pool, with cattle faecal matter instream
AP25 - Kenny's Creek	19.5	696	8.3	7.5	85	27.7	No odour, foaming, oily films. Moderate algae on substrate.
AP22 - Isaac River	No water						
AP26 - Isaac River Saraji Lateral	19.3	373	8.1	8.0	87	45.4	Some foam on the surface of the pool.
AP19 - Isaac River at Alternative Saraji Lateral Crossing	No water						

4.3.2. Fauna surveys

A total of 1124 individuals from 17 species of fish and aquatic reptiles were collected from the 14 sites sampled. Eastern Rainbowfish (*Melanotaenia splendida*) was the most abundant fish recorded with over 256 individuals present at 11 sites. Agassiz's Glassfish (*Ambassis agassizii*) and Empire Gudgeon (*Hypseleotris compressa*) were also recorded in high abundances with 175 and 250 individuals recorded respectively. **Table 4-5** provides details of the aquatic fauna captured during field surveys.

None of the fish species recorded during field surveys have a State (QLD) or National conservation status. Platypus were not captured during the aquatic ecology surveys, however they were observed during the terrestrial fauna field survey (**Appendix A4.4, Volume 3**). Two introduced fish, Gambusia (*Gambusia Holbrooki*) and the Guppy (*Poecilia reticulata*) have been recorded in the project area, however, only Gambusia was observed during the aquatic field surveys.

- **Table 4-5 Aquatic fauna captured during field surveys**

Common name	AP1 - Larcom Creek	AP2 - Raglan Creek	AP3 - Twelve Mile Creek	AP4 - Inkerman Creek	AP5 - Inkerman Creek	AP5a - Oxbow lagoon off Inkerman	AP6 - Scrubby Creek	AP7 - Limestone Creek	AP8 - Fitzroy River	AP9 - Stockyard Creek at pipeline	AP9a - Stockyard Creek at aquatic	AP10 - Isaac River Anabranch	AP12 - Isaac River Anabranch	AP13 - Bellarine Creek / Isaac River	AP14 - Isaac River Anabranch	AP15 - Rolf Creek/Isaac River	AP16 - Blackburn Creek	AP17 - Isaac River	AP18a - Isaac River at Alternative	AP23 - North Creek	AP24 - North Creek	AP25 - Kenny's Creek	AP22 - Isaac River	AP26 - Isaac River Saraji Lateral	AP19 - Isaac River at alternative Saraji Lateral crossing
Agassiz's Glassfish		No fish surveys due to safety concerns and elevated crocodile risk		No fish surveys conducted due to site limitations	4	3	1		No fish surveys due to crocodile risk	No Water		No water		No fish surveys as completed upstream at AP14 and AP15	50	50	50	No water	8	Insufficient water		Insufficient water	No water	9	No water
Longfin Eel					1	1					2														
Flyspecked Hardyhead	8				1	2	50	3			15		15						30					2	
Gambusia (Mosquitofish)					2	30																			
Mouth Almighty			4		1	19					3														
Empire Gudgeon	50		50		50	50	50																		
Western Carp Gudgeon						1		14			2				3	5	30				50			2	
Spangled Perch					1		1								1	4	12		8		10			3	
Eastern Rainbowfish	3		*		50			9			30		11			2	50		>0		1			50	
Purple Spotted Gudgeon					6	2	2				6				2	8									
Freshwater Mullet					1																				

Common name	AP1 - Larcom Creek	AP2 - Raglan Creek	AP3 - Twelve Mile Creek	AP4 - Inkerman Creek	AP5 - Inkerman Creek	AP5a - Oxbow lagoon off Inkerman	AP6 - Scrubby Creek	AP7 - Limestone Creek	AP8 - Fitzroy River	AP9 - Stockyard Creek at pipeline	AP9a - Stockyard Creek at aquatic	AP10 - Isaac River Anabranch	AP12 - Isaac River Anabranch	AP13 - Bellarine Creek / Isaac River	AP14 - Isaac River Anabranch	AP15 - Rolf Creek/Isaac River	AP16 - Blackburn Creek	AP17 - Isaac River	AP18a - Isaac River at Alternative	AP23 - North Creek	AP24 - North Creek	AP25 - Kenny's Creek	AP22 - Isaac River	AP26 - Isaac River Saraji Lateral	AP19 - Isaac River at alternative Saraji Lateral crossing
Bony Bream							8									2	5							4	
Blue Catfish											2													1	
Hyrtl's Catfish						12	1									5								14	
Broad-shelled River Turtle						1																			
Krefft's River Turtle			4			2	5				14														

4.3.3. Aquatic flora

A total of 25 species of macrophytes were recorded during the surveys. None were rare or priority species (**Table 4-6**). Slender Knotweed (*Persicaria decipiens*) and Nardoo (*Marsilea mutica*) were the most abundant macrophytes, present at six of the 25 survey sites. No aquatic macrophytes were recorded at seven survey sites, which were generally dry intermittent streams within the northern extent of the project area. One aquatic weed, Elodea/Egeria was observed at two sites namely Inkerman Creek (Site AP5) and Stockyard Creek (AP9a).

- **Table 4-6 Aquatic macrophytes observed during field surveys**

Common name	Scientific name	AP1 - Larcom Creek	AP2 - Raglan Creek	AP3 - Twelve Mile Creek	AP4 - Inkerman Creek	AP5 - Inkerman Creek	AP5a - Oxbow lagoon	AP6 - Scrubby Creek	AP7 - Limestone Creek	AP8 - Fitzroy River	AP9 - Stockyard Creek	AP9a - Stockyard Creek	AP10 - Isaac River Anabranch	AP12 - Isaac River Anabranch	AP13 - Bellarine Creek / Isaac	AP14 - Isaac River Anabranch	AP15 - Rolf Creek/Isaac River	AP16 - Blackburn Creek	AP17 - Isaac River	AP18a - Isaac River at alternative	AP23 - North Creek	AP24 - North Creek	AP25 - Kenny's Creek	AP22 - Isaac River	AP26 - Isaac River Saraji Lateral	AP19 - Isaac River at alternative
Azolla	*Azolla spp.*					✓													No Macrophytes		No Macrophytes	No Macrophytes	No Macrophytes	No Macrophytes	No Macrophytes	No Macrophytes
Jointed Twigrush	*Baumea articulata*											✓														
Club-rush	*Bolboschoenus calwellii*			✓																						
Hornwort	*Ceratophyllum demersum*											✓														
Unknown Rush	*Elecharis spp.*											✓														
Tall Spikerush	*Eleocharis sphacelata*					✓																				
Elodea	*Elodea canadensis*					✓						✓														
Hydrilla	*Hydrilla verticillata*											✓														
Common Rush	*Juncus spp.*											✓			✓											
Water Primrose	*Ludwigia peploides*					✓																				
Nardoo	*Marsilea mutica*										✓		✓		✓	✓		✓		✓						

Common name	Scientific name	AP1 - Larcom Creek	AP2 - Raglan Creek	AP3 - Twelve Mile Creek	AP4 - Inkerman Creek	AP5 - Inkerman Creek	AP5a - Oxbow lagoon	AP6 - Scrubby Creek	AP7 - Limestone Creek	AP8 - Fitzroy River	AP9 - Stockyard Creek	AP9a - Stockayard Creek	AP10 - Isaac River Anabranch	AP12 - Isaac River Anabranch	AP13 - Bellarine Creek / Isaac	AP14 - Isaac River Anabranch	AP15 - Rolf Creek/Isaac River	AP16 - Blackburn Creek	AP17 - Isaac River	AP18a - Isaac River at alternative	AP23 - North Creek	AP24 - North Creek	AP25 - Kenny's Creek	AP22 - Isaac River	AP26 - Isaac River Saraji Lateral	AP19 - Isaac River at alternative
Water Milfoil	*Myriophyllum*					✓		✓				✓														
Stonewort	*Nitella sp. / Chara spp.*							✓				✓														
Native Waterlilly	*Nymphaea violacea*	✓		✓		✓						✓														
Water Snowflake	*Nymphoides indica*					✓																				
Swamp Lilly	*Ottelia ovalifolia*					✓						✓														
Slender Knotweed	*Persicaria decipiens*		✓					✓		✓	✓	✓					✓									
Common Reed	*Phragmites australis*											✓														
Curly Pondweed	*Potamogeton crispus*			✓				✓																		
Sago Pondweed	*Potamogeton pectinatus*			✓			✓																			
Floating Pondweed	*Potamogeton tricarinatus*					✓						✓														
Water Ribbons	*Triglochin procerum*							✓																		
Cumbungi	*Typha spp.*			✓					✓																	

5. Potential impacts and mitigation measures

5.1. Potential impacts

Pipeline watercourse crossing construction methods are typically open cut trenching or Horizontal Directional Drilling (HDD). Standard open cut (trenching) construction is used in dry or low flow conditions. During low flows (typically less than 1,000 L/s) water will either be concentrated through a flume pipe or pumped around the work area via standard flow diversion techniques or through the construction of barrier dykes/head walls above and below the trenched area. HDD involves the positioning of a drilling machine away from the bank and driving the pipe under the watercourse without creating physical disturbance of the bed and banks of the watercourse. This has a lower impact on aquatic ecology values compared with trenching techniques.

In most instances, an access track over the watercourse will also be required to provide access along the ROW for personnel, machinery and supplies to construction works. Access crossings include fords, causeways, flume crossings or temporary bridging.

The potential impacts of watercourse crossing on aquatic ecology values will depend on the type of watercourse crossing construction technique (ie trenching or HDD), the duration that the crossing is in place and the traffic that will use the watercourse crossing.

For the purposes of this assessment it has been assumed that any access tracks will remain in place until the pipeline has been tested and rehabilitation is completed.

5.1.1. Disturbance to aquatic fauna

Potential breeding habitat exists for the Fitzroy River Turtle at two crossing locations in the Fitzroy River (Site AP8) and the Isaac River (Site AP12). Platypus were observed at the Isaac River (Site AP12), and potential habitat exists at a number of other sites including Scrubby Creek (Site AP6), Limestone Creek (Site AP7), Fitzroy River (Site AP8) and the Isaac River at the Saraji Lateral (Site AP26).

Burrowing fauna such as platypus may be impacted or turtle nests may or unearthed at watercourses where trenching of the pipeline will occur. Construction activities and the provision of watercourse crossing access tracks (such as causeways and fords) also have the potential to injure or disrupt the normal behaviour of some aquatic fauna (such as platypus and turtles). Trenching will occur over several days at each watercourse and any potential disturbances to aquatic fauna will be temporary in nature.

For significant watercourse crossings (e.g. Fitzroy River, Isaac River and Raglan Creek), HDD will be used (subject to geotechnical verification) and no impacts to the Fitzroy River Turtle or Platypus are expected at these sites from drilling activities.

5.1.2. Disruption of natural hydrology and fish passage

Most Australian native fish migrate along watercourses as a component of their life cycle. Watercourse barriers that slow or prevent fish movement have the potential to impact on the health, distribution and populations of native fish. Access track watercourse crossings (including bed level watercourse crossings), are considered to be watercourse barriers under the SP Act and the Fisheries Act.

The potential impacts at watercourse crossings where trenching is used will be minimised due to the short timeframes associated with the activity, however short term disruptions to hydrology and fish passage are expected.

Disruption to natural hydrology and fish passage will be minimised at trenching sites through the provision of adequate stream/flow diversions and trenching activities occurring over the shortest possible period. Flows will be reinstated at each site as soon as trenching is completed and access tracks removed.

Where HDD is to be used, there will not be any disruptions to fish passage from drilling activities.

5.1.3. Water quality

Construction activities have the potential to cause water pollution through mobilisation of sediments, nutrient enrichment and accidental release of other pollutants. The greatest risk to water quality and aquatic ecology is the mobilisation of sediments during in-stream construction works where flowing water is present. There is also a risk to water quality and ecology from the disturbance of potential acid sulfate soils (PASS), as the proposed pipeline route passes through some land at or below 5 m Australian Height Datum (AHD).

As construction of watercourse crossings is planned for periods of low flow, the potential impacts to water quality are expected to be minimal and temporary in nature. There will be no impacts to water quality from HDD activities.

Construction of access tracks where flowing water is present may result in temporary minor impacts to water quality from mobilisation of sediments.

5.1.4. Erosion and sedimentation

Construction and operational activities (such as vegetation clearing, stockpiles, trenching and construction of temporary access tracks) have the potential to cause erosion which could impact water quality and bank stability. Increased turbidity and suspended solids in flowing watercourses can impact on local biota as well has have the potential to impact on sensitive downstream environments. It is recognised that many of the watercourses in the project area already experience some erosion and turbidity from existing adjacent land uses including livestock grazing.

5.1.5. Weeds and introduced species

There is a risk that construction activities could potentially promote the spread of weed species found in riparian areas along the pipeline route. Numerous terrestrial weeds were recorded within the riparian zone of the survey sites including Parkinsonia (*Parkinsonia aculeata*), Parthenium (*Parthenium hyserorus*), Prickly Pear and Mexican Poppy. Section 4.8 of the EIS identifies appropriate weed management procedures that will be implemented as part of the construction and ongoing operation of the proposed pipeline.

One aquatic weed, Elodea/Egeria, was observed at two sites, Inkerman Creek (Site AP5) and Stockyard Creek (AP9a). Whilst the current proposed pipeline route does not cross either pool where the Elodea/Egeria was observed, there is the potential for this weed to be present within other watercourses in the region, especially following a significant rainfall event. The risk of spread of Elodea/Egeria due to construction activities is low, as the weed does not persist in intermittently flowing streams (were trenching activities would occur), whilst the permanent pools which provide ideal conditions for Egeria/Elodea are likely to be underbored via HDD, minimising the risk of further weed spread.

One noxious fish, Gambusia (*Gambusia Holbrooki*) was observed at two sites in the Inkerman Creek region (Sites AP5 and AP5a). Gambusia is commonly found in lakes or still, slow flowing streams and tolerates a wide range of water temperatures, oxygen levels, salinity and turbidity. Given this tolerance and its ability to breed rapidly, the Gambusia fish often reaches plague proportions in many habitats. Gambusia prey on the eggs of native fish, frogs and larval fish and have been implicated in the decline of more than 30 fish species worldwide (Lintermans, 2007). Construction activities are not likely to result in the spread of Gambusia, however potential impacts to water quality as a result of construction activities may create a more favourable environment for existing Gambusia populations.

5.2. Mitigation measures

The proposed pipeline route has been developed with an aim to minimise potential impacts on aquatic ecology. Creek crossings have been sited to minimise the number of crossings and the amount of riparian vegetation clearing required. To minimise the period of construction and subsequent environmental disturbance, watercourse trenching activities will be undertaken within the shortest period practicable, usually occurring over a few days. It is anticipated that construction will occur during the drier periods when there is less rainfall and watercourses are usually at their lowest flow level.

Pipeline watercourse crossing construction methods (open cut trenching or HDD) are selected based on both environmental and geotechnical specifications as described in **Table 5-1**.

Table 5-1 Water crossing construction methods

Sensitivity	Sensitivity criteria	Technique
Low	■ Ephemeral stream (or no flow at time of construction); ■ No threatened species habitat; ■ In-stream habitat highly modified / disturbed; and ■ Poor riparian vegetation, high percentage of introduced and / or weed species.	Open trench
Moderate	■ Flow at time of construction; ■ Some good quality in-stream habitat; ■ Moderate riparian vegetation, with some native species present; and ■ Downstream water users that can tolerate temporary increased sediment load.	Open trench with flow diversion
High	■ High flow at time of construction; ■ Threatened species habitat present; ■ Known presence of threatened species; ■ Near natural / excellent in-stream habitat; ■ Good intact native riparian vegetation; and ■ Highly sensitive downstream water users.	HDD or flow diversion with site specific mitigation measures

A summary of mitigation measures for aquatic ecology is provided in **Table 5-2** below.

Table 5-2 Aquatic ecology mitigation measures

Impact	Mitigation measures
Disturbance to aquatic fauna	■ A preconstruction survey should be conducted to identify potential turtle nests and platypus borrows in the sandy areas of the lower Fitzroy catchment and the Isaac River; ■ Subject to geotechnical investigation, HDD construction methods will be employed at the Isaac River (Site AP12), the Fitzroy River (AP8) and

Impact	Mitigation measures
	Raglan Creek (AP2) crossings; ▪ In watercourses that are potential Fitzroy River Turtle habitat, disturbance to the sandy substrate areas of these watercourse basins and banks should not occur during the breeding season (September and October); ▪ Temporary access tracks across the sandy areas of the stream bed and banks of the Isaac River (AP12) and the Fitzroy River (Site AP8) should be avoided unless a prior turtle survey has been undertaken. Should access crossing be required, a temporary bridge or other mechanism to avoid disturbance to these sandy banks and sandy stream beds (particularly in the vicinity of the landholder crossing of the Fitzroy River) or use of alternative road crossings such as the Glenroy Road Crossing south of the alignment at the Fitzroy River should be used.
Disruption of natural hydrology and fish passage	▪ Relevant permits (including waterway barrier permits) will be obtained in accordance with the SP Act and the Fisheries Act; ▪ Provision of adequate stream/flow diversions; ▪ Flows will be reinstated at each site as soon as trenching is completed and access tracks removed. ▪ Access tracks across watercourse crossings will be designed to meet best management practice guidelines and will consider fish passage.
Water quality	▪ Regional weather conditions and river flow levels should be monitored during construction to assist in the scheduling of key activities; ▪ Watercourse crossings will be completed promptly and with due regard to the weather (i.e. construction will be scheduled for the dry season and postponed during significant rainfall/flood events); ▪ No turbid water generated from the construction corridor or construction area is to be discharged to any watercourse; and ▪ Water Quality Monitoring will be implemented to monitor potential water quality impacts in accordance with the Environmental Protection (Water) Policy 2009 (EPP Water) and the Water quality guidelines for the protection of the freshwater aquatic ecosystems in the Fitzroy Basin (Jones & Moss 2011) during the construction and reinstatement process at waterways which contain flowing water. Water quality monitoring of the watercourses should occur before, during and post construction process and should continue for a minimum of at least four weeks after the rehabilitation works are completed to ensure that the rehabilitation works and the stability of the watercourse is comparable to pre-construction conditions.
Erosion and sedimentation	▪ Watercourse crossings (including temporary vehicle tracks) will generally

Impact	Mitigation measures
	be constructed at right angles to the direction of water flow to minimise scour potential; ▪ Where it is necessary to pump water around the watercourse crossing, the outlet water should not be directed onto the bed or bank of the drainage line; ▪ During restoration, the creek or gully walls should be re-established to a stable profile consistent with the natural profile; ▪ Stormwater diversion banks/drains are to be placed near the top banks for each watercourse to prevent stormwater flowing across disturbed areas and exacerbating erosion; ▪ Sediment fences shall be installed between the watercourse and the construction area and any soil or sediment stockpiles at all watercourse crossings regardless of whether any water is present; ▪ If the watercourse contains a sandy substrate, consideration should be given to the use of rock stabilisation of the channel and embankments to prevent scour; ▪ Where the natural stream bed has a surface layer of cobbles and coarse gravels care shall be taken to ensure that the material is replaced or that weed-free imported rock of comparable structure is spread over the disturbed area; ▪ Should Acid Sulfate Soils (ASS) be encountered in the vicinity of watercourses, appropriate procedures and measures will be put in place for the notification, mitigation, investigation and remediation of ASS material to prevent water quality and aquatic ecology impacts.
Weeds and introduced species	▪ A weed management plan will be developed and implemented to prevent weed incursion in to riparian areas at watercourse crossings, and the potential spread of aquatic weeds. ▪ Should construction activities occur within watercourses with Egeria/Elodea present, machinery and equipment which has come into contact with weed to should be cleaned and allowed to thoroughly dry out prior to accessing the next watercourse
Aquatic habitat	▪ The disturbance corridor for the bed, banks and approaches to watercourses will be the narrowest practicable for safe construction and existing access tracks will be utilised wherever possible; ▪ Where practicable large trees and root stock will be retained for bank stabilisation; ▪ Where practical the removal of mature riparian trees will be avoided; ▪ Watercourse banks will be reinstated as near as possible to their former

Impact	Mitigation measures
	profile, stabilised and re-vegetated as necessary to prevent scouring; ▪ Pre-stripping and stockpiling of topsoil and bed material is to be undertaken. Material shall be stored separately in an area above the top of the bank where it will not be buried or damaged; ▪ Consideration to be given to seeding watercourse embankments with a fast growing native grass seed or the use of hydromulching to aid in rehabilitation; and ▪ Where practical, aquatic habitat such as woody snags should be reinstated in the watercourse post construction as appropriate.

5.3. Impact assessment

The potential temporary impacts of the proposed pipeline construction will depend on the construction process employed. HDD will have the least impact on aquatic ecology values. Trenching through flowing watercourses will have the highest potential impact on aquatic ecology values. The construction of the pipeline access track adjacent to the pipeline at the associated watercourse crossing will also have potential temporary impacts on aquatic values.

This section describes the potential nature, extent and likelihood of impacts that may affect aquatic ecology values. The assessment of impacts associated with the and consequences of actions associated with the construction of the pipeline project on aquatic ecology is based on the key threats of:

- Impacts to the protect species;
- Impacts on aquatic values (i.e. fauna);
- Water quality impacts; and
- Changed habitat values post construction.

The consequence criteria (**Table 5-3**)**,** likelihood descriptors (**Table 5-4**) and risk matrix (**Table 5-5**) have been adopted for the risk assessment. The risk assessment is presented in **Table 5-5**. The specific impacts are discussed in more detail in the following sections.

- **Table 5-3 Consequence criteria adopted for the risk assessment**

Overall impact assessment				
Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Minimal, if any, impact which has an overall negligible net affect	Localised, reversible short term reversible event with minor affects which are contained to an onsite level	Localised long term but reversible event with moderate impacts on a local level	Extensive, long term, but reversible event with high impacts on a regional level	Long term, extensive, irreversible with high level impacts at potential state wide levels
1	2	3	4	5
Species specific (state or nationally listed species)				
No detectable permanent impacts on population of a listed species; AND/OR short term removal of >1% of the site population but <1% of the local, regional or state population of a listed species	Permanent removal of >1% of the site population but <1% of the local, regional or state population of a listed species; AND/OR short term removal of >1% of the local population but <1% of the regional or state population of a listed species	Permanent removal of >1% of the local population but <1% of the regional or state population of a listed species; AND/OR short term removal of >1% of the regional population but <1% of the state population of a listed species	Permanent removal of >1% of the regional population but <1% of the state population of a listed species; AND/OR short term removal of >1% of the state or national population of a listed species	Permanent removal of >1% of the state or national population of a listed species
General aquatic ecology				
No measurable permanent impacts on aquatic ecology values	Minor short term impacts, life cycle may be disrupted but for less than a year. Annual recruitment should still occur. Short and long term viability of individual species not impacted	Medium term (1-2 year) impacts, life cycle disrupted and resulting in no recruitment for a year. Short term viability of individual species impacted recovery within 1 - 5 years. Long term viability of species not impacted	Long term (2-5 year) impacts, life cycle significantly disrupted no recruitment for successive years. Short term and long term viability individual species impacted recovery time frame (5-10 years)	Loss of species and population. Minimal possibility of recovery
Surface water - water quality				

No measurable change to surface water quality or quality changes are not measurable	Changes to surface water quality during the activity, no further changes noted once activity is finished	Changes to surface water quality due to activity, recovery up to 1 year	Changes to surface water quality due to activity, recovery 1-2 years	Changes to surface water quality, where water becomes toxic, or permanent changes to quality, recovery is greater than 2 years
Changes in habitat values				
No measurable change in habitat values	Minor changes to habitat values within the immediate vicinity crossing	Major changes to local habitat within the immediate vicinity of the crossing	Minor changes to local and downstream habitat values	Major changes to local and downstream habitat values

- **Table 5-4 Likelihood descriptors adopted for the risk assessment**

Likelihood				
Rare	**Unlikely**	**Moderate**	**Likely**	**Almost certain**
A	B	C	D	E
The consequence is highly unlikely to occur within the time scope of the assessment	The consequence is unlikely to occur within the time scope of the assessment	The consequence may occur within the time scope of the assessment	The consequence will probably occur within the time scope of the assessment	The consequence is expected to occur within the time scope of the assessment

- **Table 5-5 Risk matrix adopted for the risk assessment**

Risk ranking matrix			**Likelihood**				
			Rare	**Unlikely**	**Moderate**	**Likely**	**Almost certain**
Consequence			**A**	**B**	**C**	**D**	**E**
Impact	Catastrophic	**5**	**M**	**S**	**H**	**H**	**H**
	Major	**4**	**M**	**M**	**S**	**H**	**H**
	Moderate	**3**	**L**	**M**	**M**	**S**	**H**
	Minor	**2**	**L**	**M**	**M**	**M**	**S**
	Insignificant	**1**	**L**	**L**	**L**	**M**	**M**

- **Table 5-6 Aquatic ecology risk assessment for the project**

Risk issue- What can happen and how can it happen	Existing control measures (planned controls)	C	L	R	Comments
Species specific (state or nationally listed species)					
Construction disrupts Fitzroy River Turtle and turtle breeding (Isaac River AP12 and Fitzroy River AP8).	HDD Isaac River (AP12) and Fitzroy River (AP8). Avoid disturbance to sandy watercourse beds and banks during breeding season (September/October). No temporary access track through sandy stream bed or banks (temporary bridge access or use alternative access route).	1	C	L	Location of Fitzroy River Turtle populations not confirmed and targeted surveys for route alignment not conducted.
Construction (trenching and/or access tracks) impact on platypus and their burrows.	Preconstruction surveys HDD Isaac River (AP12) where platypus sighted.	1	C	L	Location of platypus populations not confirmed and targeted surveys not conducted for entire route.
Construction activities and potential changes to water quality impact on Estuarine Crocodiles.	HDD of the Fitzroy River (AP8). No temporary access track through the sandy stream bed or banks (temporary bridge access or alternative route only).	1	B	L	Estuarine Crocodile unlikely to be impacted by construction activities.
General aquatic ecology					
Trenching and reinstatement impacts on aquatic fauna	Preconstruction survey. Trenchfall mitigation measures. Sediment and erosion control as per the EMP.	1	C	L	Impacts will vary depending upon the duration of construction, in addition to whether the watercourse is flowing.
Construction, use and reinstatement of access tracks disrupts aquatic flora and fauna	Appropriately sized and designed crossings in respect to duration access track will be required. Fauna passage to be considered in design (particularly turtles and platypus).	2	D	M	Duration of crossing will govern likelihood of impacts in addition to whether the watercourse is flowing. The longer the temporary access track is in place the higher the likelihood of potential impacts.
Surface water - water quality					
Discharge of turbid water from construction corridor to the water way during	Sediment and erosion control.	2	D	M	No water quality monitoring plan has been developed as part of this assessment, however monitoring is proposed for the

Risk issue- What can happen and how can it happen	Existing control measures (planned controls)	C	L	R	Comments
construction or post construction.					construction period..
Construction, use and removal of access tracks could impact on water quality.	Sediment and erosion controls and rehabilitation.	2	D	M	Turbidity unlikely to be generated during construction and rehabilitation for dry watercourses. Turbidity likely to occur when watercourse is flowing.
Changes in habitat values					
Changes in stream bed, banks and habitat values due to trench crossings.	Appropriately designed temporary watercourse crossings and remediation procedures.	2	C	M	Risk is increased the longer the crossing is in place.
Changes in stream bed, banks and habitat values due to access track crossings.	Appropriately constructed temporary watercourse crossings and remediation procedures	2	C	M	Risk is increased the longer the crossing is in place. No certainty that 'dry' watercourses will remain dry for the duration that the access track is in place. Access track construction method to be refined during detailed design

6. Conclusion

6.1. Assessment outcomes

Sinclair Knight Merz and Austral Research Consulting were commissioned by Arrow Energy Pty Ltd to undertake an aquatic ecology assessment for the proposed Arrow Bowen Pipeline project. A range of aquatic survey methods were utilised during surveys and were combined with habitat assessment along the proposed route.

No threatened aquatic flora or fauna species were recorded along the pipeline route, however two sites, the Fitzroy River (Site AP8) and Isaac River (Site AP12) contained habitat for the threatened Fitzroy River Turtle (*Rheodytes leukops*). This species has been previously recorded in the vicinity of both locations (DERM 2011). Potential platypus (*Ornithorhynchus anatinus*) habitat was also recorded at several locations including Limestone Creek, the Fitzroy River, Scrubby Creek and was observed at the Isaac River (Site AP12) during terrestrial surveys.

Potential temporary impacts to water quality, including increased turbidity and mobilisation of suspended solids in flowing waterways, are likely to be the key impacts to aquatic ecology associated with the proposed pipeline project. Other potential impacts during construction include the temporary disruption to breeding habitat of the Fitzroy River Turtle, erosion of bed and banks, and the spread of weeds.

Management measures have been recommended to reduce the potential impacts of the proposed pipeline on aquatic flora and fauna considered likely to occur along the route. These include the timing of construction to occur during the dry season/periods and outside key species breeding periods, the use of HDD for major watercourse crossings (such as the Isaac and Fitzroy Rivers) and the implementation of water quality monitoring during construction at watercourse crossings subject to flowing water.

Providing that the recommended mitigation measures are adopted along the proposed pipeline route it is considered unlikely that the project will have an adverse long term impact on aquatic ecology.

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Appendix A Sampling locations

Site	Description	Photo
AP1 - Larcom Creek	Freshwater, tannin stained pool, with isolated patches of oily films and foam in backwater areas. Deep pool with steep instream banks. Good aquatic habitat with woody snags and rocky substrate. Evidence of flows greater than 1.5m in height. Site is located approximately 3.3 km upstream from proposed pipeline route crossing due to property access constraints. Riparian habitat consists primarily of Bottlebrushes (*Callistemon*), and Teatrees (*Leptospermum*).	

Site	Description	Photo
AP2 - Raglan Creek	Estuarine site, with steep clay banks. Good riparian habitat consisting of mangroves, and saltmarsh. Fast flowing, very turbid water. No aquatic surveys or water quality assessment conducted due to site safety concerns including flow velocity, depth and elevated risk of crocodiles. Site is likely to be underbored via HDD. Upstream Raglan Creek provides known habitat for the Southern Snapping Turtle (*Elysea albagula*) (Inglis & Howell 2009) which is listed as Least Concern under the NC Act.	

Site	Description	Photo
AP3 - Twelve Mile Creek	Deep, potentially channelised watercourse with clay/silt substrate. Channel is 18 m wide at proposed pipeline route crossing. Banks highly eroded in places due to cattle access. Minimal riparian habitat consisting of scattered Poplar Box Gums and *Acacia spp*. Extensive aquatic macrophytes throughout the site.	

Site	Description	Photo
AP4 - Inkerman Creek	Turbid, estuarine Creek, with clay substrate. Good riparian habitat consisting of Salt Couch, (*Sarcicirnua quinqueflora*) and mangroves. Moderate bank and catchment erosion occurring in the region. Grazing occurring on left bank, which has exacerbated erosion throughout the site. No aquatic surveys conducted due elevated crocodile risk, and tidal habitat making the use of fyke and bait traps unfeasible.	

Site	Description	Photo
AP5 - Inkerman Creek	Moderately deep pool/ wetland area with dense aquatic macrophytes throughout the site. Clay/sand substrate with minimal bank erosion. Sparse riparian vegetation consisting primarily of Poplar Box Gums. Proposed pipeline route currently does not intersect pool, however the alignment comes into close proximity to this watercourse.	

Site	Description	Photo
AP5a - Oxbow lagoon off Inkerman Creek	Shallow lagoon with banks degraded by regular cattle access. Clay substrate with limited aquatic habitat. Sparse riparian vegetation consists primarily of scattered Poplar Box Gums. Proposed pipeline route currently does not intersect this oxbow lagoon, however the site was surveyed as a substitute for the estuarine extent of Inkerman Creek.	

Site	Description	Photo
AP6 - Scrubby Creek	Turbid slow, flowing creek with silt, sand and gravel substrate. Wetted channel width averages 22 m, with top of bank 44 m wide. Site is situated in the road reserve due to property access restrictions immediately adjacent to the sampling site. Riparian vegetation is limited and consists primarily of Casuarinas, Leptospermum, Acacias and Lantana.	

Site	Description	Photo
AP7 - Limestone Creek	Clear flowing creek with excellent aquatic habitat with sand gravel bed and banks, and plenty of submerged woody snags and overhanging vegetation, potential platypus habitat. Riparian vegetation is dominated by Callistemon and Casuarinas.	

Site	Description	Photo
AP8 - Fitzroy River	Ideal habitat for Fitzroy River Turtle with sand gravel banks. Some localised bank erosion due to cattle and wild pig access. Well vegetated right bank consisting of River Red Gums and Melalucas. Left bank consists primarily of dead Melalucas, Mexican Poppy and various thistle species. Channel is very sandy, on average 110 m wide, and 130 m from top of bank. No aquatic surveys were conducted due to depth and very high risk of crocodiles, with crocodiles regularly sighted in the Fitzroy River at this location.	

Site	Description	Photo
AP9 - Stockyard Creek at pipeline	Dry ephmeral watercourse, encroached with vegetation. Macrophytes present include Nardoo and Slender Knotweed. Channel is 28 m wide and 50 m from top of bank. Riparian habitat consists of Eucalypts, Melalueuca, and Leptospermum. Sand, silt and gravel substrate, with moderate bank erosion occurring throughout the site. Unlikely platypus habitat. No water at site, so aquatic surveys conducted upstream at road crossing.	

Site	Description	Photo
AP9a - Stockyard Creek at Aquatic survey location	Located approximately 7.3 km upstream of proposed pipeline route crossing. Sand/silt substrate with a wetted width of 38 m, channel width is 42 m from top of banks. Moderately vegetated riparian corridor including Eucalypts, Casuarinas and Melalucas. Excellent aquatic habitat with submerged woody snags and diverse range of aquatic macrophytes including Water Milfoil (*Myriophyllum spp*.) Stoneworts (*Nitella/ Chara spp*.), Swamp Lilly (*Ottellia ovalfolia*), Native Waterlilly (*Nymphaea violacea*), Common Reed (*Phragmities australis*) and Hydrilla (*Hydrilla verticillata*).	

Site	Description	Photo
AP10 - Isaac River Anabranch	Broad ephemeral sand/silt channel which was dry at the time of sampling. Channel rarely flows and as such is encroached with vegetation including Eucalypts, Brigalow and Melalueca. Channel is 55 m wide, and 75 m from top of banks. Macrophytes, Nado and Lomandra occurs throughout the channel.	

Site	Description	Photo
AP12 - Isaac River Anabranch	Broad channel which is 38 m wide and 65 m wide from top of bank. Excellent aquatic habitat with sand gravel substrate and submerged woody snags. Aquatic macrophytes consist of Nardoo. Riparian vegetation consists of Eucalypts Melaluca, and Lomandra. Large densities of the noxious weed, Parkensonia occur within the catchment. Sand gravel bed providing potential habitat for the Fitzroy River Turtle. Excellent platypus habitat, with platypus observed during terrestrial flora and fauna surveys at the site.	

Site	Description	Photo
AP13 - Bellarine Creek / Issac River Anabranch Junction	Very turbid ephemeral pool, with a clay substrate. Pool averages 3.5 m wide. A film of blue/green algae present on the surface of the pool. Banks degraded by cattle access. Riparian vegetation consists of Lignum, Leptospermum, and the noxious weeds Parthenium and Parkensonia.	

Site	Description	Photo
AP14 - Isaac River Anabranch	Ephemeral residual pool, heavily degraded by cattle access. Clay /sand substrate, with oily film on surface likely to be due to cattle access. Riparain habitat consists of Lignum, Water Couch and Melalueca.	

Site	Description	Photo
AP15 - Rolf Creek/Isaac River Anabranch Junction	Turbid, semi-permanent watercourse which has been heavily degraded by cattle access. Wetted width ranges from1 to 4 m, with the channel extending to 50 m from top of bank. Sparse riparian vegetation which includes Brigalow and Eucalyptus. Only seine nets were deployed at this site due to the potential for cattle to become tangled in the fyke nets. Yabbies, freshwater prawns and shrimp were also collected at the site.	

Site	Description	Photo
AP16 - Blackburn Creek	Residual pool, likely to be dry in a few weeks provided no rain falls within the catchment. Degraded aquatic habitat due to extensive cattle access degraded the clay/silt substrate and banks. Banks are steep (approximately 17 m high), and have localised erosion due to cattle access. Channel width is approximately 52 m from top of bank, reducing to a wetted width of approximately 1.5 m. Riparian vegetation consists of scattered Eucalypts, Casuarinas, Lomandra, and the noxious weed Parkensonia.	

Site	Description	Photo
AP17 - Isaac River	Dry channel ranging from 24m wide to 51 m from top of bank. Mobile sand bed, with steep sandy banks. Good aquatic habitat when water is present with overhanging riparian vegetation and woody snags. No aquatic surveys or water quality assessment due to lack of water.	

Site	Description	Photo
AP18a - Isaac River at Alternative Crossing	Residual pool in a channel with highly mobile sand beds. Wetted width is 24m increasing to 38m from top of bank. Moderate aquatic habitat with many woody snags, but limited macrophyte cover. Large quantity of organic matter instream. Riparian habitat consisting of Melaluca, Casuarinas, Eucalypts and Lomandra. Water quality and fish surveys consisting of two seine nets were conducted at this site. This site was assessed due to its potential to be an alternative crossing point for the proposed pipeline route. It is located approximately 7 km downstream of the current proposed pipeline route crossing.	

Site	Description	Photo
AP23 - North Creek	Dry sandy channel ranging from 10 m wide to 18 m from top of bank. Mobile sand beds with isolated residual pools which are likely to be dry in the coming weeks. Riparian vegetation includes Casuarinas and Eucalypts. No aquatic survey or water quality due to lack of water.	

Site	Description	Photo
AP24 - North Creek	Sandy clay channel with moderate erosion due to cattle access. Wetted width is 14 m wide, increasing to 17 m from top of bank. Riparian habitat consists primarily of Eucalypts, and Casuarinas.	

Site	Description	Photo
AP25 - Kenny's Creek	Small residual pool of water, unsuitable for fish surveys. Silt, sand and gravel bed, with steep sandy banks. Extensive erosion is occurring on the left bank. Evidence of high velocity flows at times when sufficient rain has fallen in the catchment. Riparian habitat consists of Casuarinas and various eucalyptus species. Terrestrial weed Mexican Poppy (*Argemone ochroleuca*) occurs throughout the riparian corridor.	

Site	Description	Photo
AP22 - Isaac River	Steep banked intermittent river with mobile sand beds which were dry at the time of sampling. Instream channel was approximately 39 m, increasing to 66 m from top of bank. Dense riparian corridor consisting of Casuarinas and various eucalypt species (including Poplar Box Gum) and the declared Class 1 Pest Prickly Pear (*Opuntia spp*.)	

Site	Description	Photo
AP26 - Isaac River Saraji Lateral	Sand clay bed and banks with large residual pool on left bank meander. Woody snags throughout the residual pool. Instream channel 50 m wide increasing to 94 m from top of bank. Moderate bank erosion due to cattle access. Riparian vegetation includes Eucalypts, Casuarinas and the weed Mexican Poppy (*Argemone ochroleuca*).	

Site	Description	Photo
AP19 - Isaac River at alternative Saraji Lateral crossing	Broad intermittent flowing river which was dry at the time of sampling. Channel ranges from 73 m up to 106 m at the top of bank. Riparian habitat includes River Red Gums, and Casuarinas. Woody snags present throughout the channel. No water quality or fish surveys due to the lack of water.	

Appendix B Fish species information

(Source: Pusey et al, 2004)

	Life history requirements	Fish spawning periods-movement/ other requirements, tolerances	Cope with translocation?	Distribution and description of the habitat	Sensitivity to flow regimes
Agassiz's Glassfish *Ambassis agassizii*	Entirely freshwater. Microphagic carnivore (predominantly aquatic insects and microcrustaceans). Sensitive to stream bed disturbance and resulting disruption of growth of aquatic vegetation.	Move upstream Extended breeding season from spring through to autumn with spawning concentrated in spring and early summer. Spawning stimulus is unknown but corresponds with increasing water temperature and photoperiod in later winter/early spring. Unlikely to be associated with rising water levels or flooding though have been observed to take advantage of ponds after water level rise. Peak spawning generally coincides with pre-flood period of low and relatively stable discharges (south-east Qld) but may continue through elevated discharge/start of wet season (Mary River). Repeat spawning. Spawning in aquatic	No quantitative data on environmental tolerances but is likely to be tolerant of a wide range of physicochemical conditions.	Still or slow flowing parts of large lowland rivers, upland rivers and streams and small coastal streams. Also dune systems (on islands), lakes ponds, swamps & dams/weirs. Majority of length of rivers from 10 to 311km from river mouth to elevations of 250m (above sea level). Most common in mid-upper catchment around 90masl. More common in larger streams with low to moderate riparian cover. Fine substrate with abundant and extensive submerged macrophytes, filamentous algae and submerged bankside vegetation. Leaf litter,	Have been found in shallow fast flowing riffle but presumably in process of moving upstream. Prefers pools (0.5m deep) with low water velocity. Small fish have difficulty negotiating high velocities, particularly in fishways.

	Life history requirements	Fish spawning periods- movement/ other requirements, tolerances	Cope with translocation?	Distribution and description of the habitat	Sensitivity to flow regimes
		macrophytes, eggs observed attached to rocks on the stream bed, and aquatic plants. Observed mass upstream dispersal, possibly cued or facilitated by elevated discharge. Occurs through much of the year, concentrated during late autumn and spring. Observed to navigate a modified vertical slot fishway on Fitzroy River. Recorded in brackish estuarine areas but unknown whether this is an intentional dispersal to fulfil an unknown ecological process or whether they have been displaced by elevated flows.		undercut banks and root masses not as important.	
Bony Bream *Nematalosa erebi*	Live up to 5 years and life history appears to be relatively flexible. Gender discernible at 115mm SL males & 127mm SL females (poss about 12 months old based on Alligator River (Northern Territory). Has been found as the second most	Depressed abundance levels following a Cyclone had recovered substantially within 12 months. Reductions in abundance over winter may be related to susceptibility and frequency of infection as body condition deteriorates. Lack of physico-chemical	Most widespread of Australia's freshwater fishes. In most major basins of Queensland as far south as the Albert River. It's also an abundant species. Translocated populations do well at much higher	Wide range of habitats from salt lakes, lowland rivers, floodplain billabongs and lagoons, impoundments and rainforest streams. Only habitat not utilised are higher, cooler, faster flowing, clear upper reaches, possibly because their	May be affected by flow regulation. Drops in water temperature (6 degrees lower than expected) caused by hypolimnetic releases from large dams can cause decline in

	Life history requirements	Fish spawning periods- movement/ other requirements, tolerances	Cope with translocation?	Distribution and description of the habitat	Sensitivity to flow regimes
	abundant fish moving through a fishway with juveniles most commonly recorded in Burnett River fishway. Small and intermediate sized fish make substantial movements not associated with reproduction.	tolerance information but water quality parameters of sites where they are collected are reported (Burdekin River information deemed most relevant to this project). Water temp- 15-31 deg., DO (mg/L) 4.0-12.0, pH 6.66-8.46, Conductivity (µS/cm) 50-780, Turbidity 0.3-20. They've been found in water much more turbid in the Fitzroy and Alligator Rivers (160 and 360 NTU respectively). They've also been found in water as cold as 12deg in the Murray River but appear susceptible to fungus, bacterium and protozoan parasites at lower temperatures and appear to have been affected by hypolimnetic releases from large dams that lowered summer temperatures by 6deg, resulting in a decline in abundances for several hundred kilometres downstream. Preferentially avoids very warm water (31+degs).	elevations than found naturally as they're possibly only limited by access and minimum water temps.	preferred food sources are not present (macrophytes and detritus). Abundances vary spatially, corresponding to variation in mesohabitat. In Burdekin River, there's a negative association with moderate to fast water velocity and possibly substrate composition (possibly correlated to water velocity), but in the Wet Tropics they occur in fast flowing boulder strewn habitats. Therefore, water velocity/ abundance relationship appears variable from location to location. Little information on microhabitat useage or preference. High numbers in moderate depths and fish below 250mm are most common in open shallow areas. Primarily	abundance downstream. Spawning unrelated to flooding but coincidental flooding may be beneficial in recruitment. Needs more research to identify effect of river regulation on potential spawning migration.

	Life history requirements	Fish spawning periods-movement/ other requirements, tolerances	Cope with translocation?	Distribution and description of the habitat	Sensitivity to flow regimes
		Has a very wide salinity tolerance. Presence in turbid water is more likely due to preferred habitat of slow flowing lowland rivers rather than a preference for turbid water. Peak spawning Oct-March possibly induced by interaction btw temp and daylength. Observation in Burnett River found reproductively active fish year round except for June to August. Spawning migration is inferred. Oviposition and spawning in shallow sandy embayments and muddy lagoons (shallow still-water habitats). Distinctions have been made in the Murray and Alligator Rivers regarding adult and juvenile habitats suggesting adults make spawning associated migrations but it needs more research that identifies the impact of river regulation on this.		detritivore/algivore.	
Carp Gudgeon spp.	Entirely freshwater. Diverse diet but may	Sexual maturity at around 12 months. Relatively	*Hypseleotris galii* has been	Common and widespread within	Rising water levels or flooding

	Life history requirements	Fish spawning periods- movement/ other requirements, tolerances	Cope with translocation?	Distribution and description of the habitat	Sensitivity to flow regimes
Hypseleotris spp.	be under threat from exotic fish such as *Gambusia holbrooki* as they have similar habitat and dietary requirements.	hardy and tolerant of poor water quality and often common in heavily degraded habitats. Water temp btw 8.4-31.2, but may have wider range than this. DO btw 0.3-19.5, pH 4.4-8.9, Conductivity 51-4123, Turbidity 0.1-331. Reproductively active from late winter to early autumn but spawning concentrated between Aug/Sept and January. Spawning stimulus is unknown but reproduction corresponds with increasing water temp and photoperiod and is unlikely to be associated with rising water levels or flooding. Able to spawn repeatedly. Little information on movement biology. Small numbers reported to use fishways. Observations suggest upstream dispersal movements may occur when flow conditions allow (ie, through culverts when water levels high	translocated to Bolgu Island in Torres Strait for mosquito control and other undocumented translocation via contamination of fish hatchery stock in north eastern Australia.	river basins of South-eastern Qld. Broad habitat requirements, appearing in small coastal streams, throughout large rivers and floodplains, coastal wetlands, dune lakes and stream systems and river impoundments in lowland areas and headwaters. Between 4-335km from river mouth and up to 460m elevation. Most common in mid to lower reaches at elevations ~80m. Wide range of substrates but most common with fine to intermediate substrates (sand, fine gravel and coarse gravel) and where submerged aquatic macrophytes, leaf litter beds, undercut banks and root masses. Low water velocity over a wide range of depths but in lower half of water column,	unlikely to be a spawning cue.

	Life history requirements	Fish spawning periods-movement/ other requirements, tolerances	Cope with translocation?	Distribution and description of the habitat	Sensitivity to flow regimes
		enough).		most commonly in contact with substrate.	
Eastern Rainbowfish *Melanotaenia splendida splendida*	Member of a widespread and important family in Australia and elsewhere. Largest component of diet is algae. Prefer low flow environments especially for reproduction and development. Reproductive biology varies from region to region in relation to regional variation in hydrology. Flooding may expand habitat available to juveniles and allow them to move into floodplain habitats. Persist and thrive in impoundments.	Tolerance experiments have found LD50 temperatures of 34.4°C and 31.4°C (adults and juveniles respectively). Fish in the Burdekin River have been found in temperatures between 15-32.5°C, DO btw 1.1-10.8 with a preference for well oxygenated water, pH btw 6.87-8.47, conductivity btw 49-790, and turbidity btw 0.6 and 16.0. Peak spawning in Johnstone River strongly focused between August and November. There is little evidence of environmental cues to induce spawning. Spawning is continuous when temperatures are above 20°C. Upstream migration at the start of wet season in Black-Alice River. Lateral migration in floodplain on the Normanby River. Upstream movement of low numbers through a fishway on the Fitzroy	Juvenile fish don't survive (dying within 12 hours) an abrupt transfer to salinities of $9^0/_{00}$ and adult fish unable to survive a transfer to salinities of $15^0/_{00}$. Gradual acclimatisation only improves survivorship marginally.	Restricted to rivers draining to the east of the Great Dividing Range. Very widely distributed along the east coast of Queensland with the southern limit possibly the Burnett River or Elliott River but these may be *M. duboulayi* and the actual southern limit is the Boyne River near Gladstone or slightly further south in Baffle Creek drainage basin. The northern limit is uncertain. Abundant wherever it occurs but actual figures may be bias due to collection methods with single pass electrofishing underestimating abundance. Tolerant of environmental degradation, particularly loss of riparian vegetation and changed habitat due to impoundment. Preferred habitat is	Reproductive biology varies from region to region in relation to regional variation in hydrology. Changes in seasonality of flows are likely to negatively impact on larvae and juveniles.

	Life history requirements	Fish spawning periods- movement/ other requirements, tolerances	Cope with translocation?	Distribution and description of the habitat	Sensitivity to flow regimes
		River commonly btw Nov to April. Little information for seasonal rivers or ability to navigate fishways.		sluggish currents within a range of stream sizes from small to large lowland rivers including floodplain billabongs and wetlands. Generally considered to prefer larger streams with low water velocities. Found in a range of habitats and therefore a range of substrates and doesn't appear dependant on one type of substrate or cover type. One of the few species that tolerates and perhaps benefits from change from lotic to lentic habitat caused by impoundment.	
Fly Specked Hardyhead *Craterocephalus stercusmuscarum*	Despite being collected in tidal areas, access to estuarine water is not necessary. Microphagic carnivore, primarily aquatic insects and microcrustaceans. Interactions with alien	Collected over a wide range of water qualities. In south-east Queensland, they've been collected from temperatures between 12.4 and 33.6 although tolerances may be geographically variable, DO between 2.9 and	Ensure temperature variation isn't outside the range of the original river. Likely able to undertake local dispersal and/or recolonisation.	Very widespread occurring in coastal and inland drainages of eastern and northern Australia but patchy in north-eastern Queensland. It is present in most major drainages from the Barron River south	Changes to natural discharge regime and releases of unnaturally cold water from large dams may interrupt possible cues for movement or

	Life history requirements	Fish spawning periods-movement/ other requirements, tolerances	Cope with translocation?	Distribution and description of the habitat	Sensitivity to flow regimes
	fish species is a potential threat, as is siltation from erosion as it may threaten spawning habitats.	19.5, pH between 6.1 and 9.1, Conductivity between 19.5-5380 but most frequently in very dilute freshwaters, and turbidity between 0.2 and 62.3. Spawns and completes entire lifecycle in freshwater. Sexually mature at <12months. Peak spawning late winter through to summer for *C. s. fulvus* and Sept to Nov in Wet Tropics region for *C.s.stercusmuscarum.* Spawning stimulus unknown but corresponds with increasing water temperatures (19-23°C) and photoperiod (11 to 11.5 day length). Debate as to whether flooding is of assistance by transporting larvae to nursery areas (floodplain wetlands), or that low flow periods facilitate successful recruitment as for other small bodied fish in south-eastern Queensland streams. Spawning probably in aquatic macrophytes and		to the NSW border but absent from short coastal streams near Cardwell, Prosperpine, Tin Can Bay and the Sunshine Coast. Some debate as to whether the southern extent is only to the Nerang River in south-eastern Qld or extends to just over the NSW border. Common in central Queensland drainages. Widely distributed in both upland and lowland sections of the Burdekin River. In a variety of habitats including large floodplain rivers and billabongs, small rainforest streams, volcanic crater lakes, dune lakes, dams and weirs and brackish estuaries. Found across a wide range of substrate types and instream cover is abundant where the species occurs. Lower	critical spawning, larval movement and development. Unseasonal releases during low flow periods (Sept/Oct) may disrupt peak spawning activity and larval development through changes to availability of macrophyte beds.

	Life history requirements	Fish spawning periods- movement/ other requirements, tolerances	Cope with translocation?	Distribution and description of the habitat	Sensitivity to flow regimes
		submerged marginal vegetation. Have been recorded using fishways on weirs and tidal barrages. Reports of small numbers moving upstream and have been observations of downstream movement through fishways. Low numbers move almost year round but possibly a peak upstream migration in early summer.		numbers where para grass is present. Preference for low velocities, mid water column in depths between 10-60cm.	
Hyrtl's Tandan Neosilurus hyrtlii	Average diet is dominated by aquatic invertebrates, supplemented by detritus and microcrustacea.	Upstream spawning migrations recorded on tributary of Ross River. Downstream and lateral movements have also been reported. In the Burdekin River, fish have been observed in the following water conditions. Temp between 21 and 33°C, dissolved oxygen between 2.6 and 11.0, pH between 6.76 and 8.46, conductivity between 56 and 790 (although it's considered a freshwater species), and turbidity between 0.25 and 16.0.	Differences in cold water tolerance should be taken into account.	Extremely widely distributed, especially in the Northern Territory and can have high levels of abundance. Occurs in the Black-Alice, Ross, and Burdekin rivers. It's widespread in this system, found in the mainstem, turbid tributaries, and floodplain lagoons. It has also been recorded in more southern rivers but it's not as common. Despite being	Development of infrastructure that limits upstream movement or reduces high flow events (and therefore probable spawning stimulus) should be avoided.

	Life history requirements	Fish spawning periods- movement/ other requirements, tolerances	Cope with translocation?	Distribution and description of the habitat	Sensitivity to flow regimes
		The temperature range is much broader in the Mary River (12.8-32.2°C) reflecting the colder temperature of the river and may indicate the lower temperature limit of the species. DO levels indicate that the species is tolerant of hypoxic conditions but has also been found as part of a large fish kill attributed to hypoxia. Sexually mature at about 12 months old and the peak spawning activity is at the start of the wet season, induced by rising water levels. Appears that upstream spawning migration into tributaries occurs. Some movement has been recorded through fishways. Movement on the Burnett River was recorded in spring and early summer, over a temp range of 15-25°C whereas movement in the Fitzroy River hasn't been recorded <22°C. Juveniles don't appear to disperse widely during		previously recorded from Brisbane River it hasn't been recorded in recent surveys, therefore the southern limit appears to be the Mary River. Distribution is most likely limited by low tolerance to low water temperatures. Wide variety of macrohabitats ranging from small permanent or intermittent tribs, large lowland seasonal rivers, high gradient perennial rivers and floodplain lagoons and wetlands, basically everything except for estuarine reaches. Benthic species in a wide range of water depths most frequently on the substrate. Adults in deeper water (>2m) during the day unless abundant cover when will be in shallower water. Small juveniles common in sandy glides as shallow as	

	Life history requirements	Fish spawning periods- movement/ other requirements, tolerances	Cope with translocation?	Distribution and description of the habitat	Sensitivity to flow regimes
		flooding.		5cm in Burdekin River. Most frequently collected from muddy or sandy substrate reaches. Prefers still water but can ascend reaches with high water velocities, using woody debris or root masses as resting spots.	
Purple Spotted Gudgeon *Mogurnda adspersa*	Spawn and complete entire lifecycle in freshwater. Microphagic carnivore with aquatic insects the largest proportion. Potential threats may be from alien fish species (*Gambusia* and redfin), loss of aquatic plants, flow regulation, and degradation of water quality. Translocation of sleepy cod may pose a predator threat as has already occurred in the Burdekin River.	This species has a wide water quality tolerance. In south-eastern Queensland, it has been found in water with temperatures between 11.9 and 31.7°C (lower water temperatures, <16°C, make them susceptible to fungus), dissolved oxygen between 0.6 and 12.8, pH between 5.6 and 8.8, conductivity between 72.0 and 2495 (likely to tolerate higher salinities as has been found in estuaries, although increasing salinities appear to be detrimental to populations in some lakes) and turbidity	May cope with lower temperatures if given opportunity to acclimatise.	Widespread occurring in coastal drainages of the east coast (from central Cape York Peninsula possibly to Clarence River in Northern NSW) and the Murray Darling system. Fifth most abundant species collected in Wet Tropics, north Qld and is often very abundant in headwater streams in distribution area. It's moderately common and widespread on the central Qld coast and relatively common but patchily distributed in south-eastern Qld. Usually in freshwater	Rapid fluctuations in water levels may impact on reproduction and recruitment by exposing fish eggs. This has already been observed in a tributary of Burnett River (SE Qld). Short term water releases and subsequent extraction for irrigation lead to poor recruitment in comparison to nearby unregulated sites. Fish

	Life history requirements	Fish spawning periods- movement/ other requirements, tolerances	Cope with translocation?	Distribution and description of the habitat	Sensitivity to flow regimes
		between 0.2 and 200NTU although it prefers less turbid water (mean 5.8NTU). Sexually mature at 6 months and whilst breeding in south east Qld occurs from spring through to late summer, peak spawning activity is in November and February. Spawning coincides with increasing water temperature (>20-22°C from August to April/May), more importantly relating to stable low flows and a reduced flooding frequency. An abundance of food and availability of spawning sites may also be a factor. There may be a mass dispersal of juveniles and sub adults although there are few reports. They're also rarely reported in fishways which could indicate that they're sensitive to weirs and impoundments. Breeding information is scarce and from Alligator		but has been found in estuaries. Prefers slow flowing weedy areas in pools and slow moving or still waters in rivers, creeks and billabongs. They're also found in small shallow riffles. More commonly associated with fine substrates (a product of the lower velocities) and most common in reaches with abundant cover, particularly submerged marginal vegetation, root masses and undercut banks. Found between 18 and 303km of larger rivers to elevations up to 400masl, most commonly in the mid-range.	subject to regulation also have poorer condition.

	Life history requirements	Fish spawning periods- movement/ other requirements, tolerances	Cope with translocation?	Distribution and description of the habitat	Sensitivity to flow regimes
		Rivers region. Breeding season is limited to the early wet season and spawning was in muddy lowland lagoons. Little is known about movement except for migration into lowland lagoons for breeding.			
Spangled Perch *Leiopotherapon unicolor*	Spawning migration and freshwater migration but all freshwater.	Tolerances have been experimentally determined for parameters such as temperature where survival decreased below 7.3°C and above 37.5°C and no fish survived below 4.1°C or above 40°C. Upper LD50 values are estimated as 35.5 and 41.8°C for juveniles and adults respectively. Other experiments have concluded that acclimation history is important for determining temperature tolerances. Upper salinity tolerance has been experimentally determined to be that of seawater ($35.5^0/_{00}$) and they've been found in low salinity springs ($0.2^0/_{00}$).	Likely to have been translocated into the Brisbane River in late 1930's.	One of the most widely distributed Australian freshwater fishes, with the distribution probably limited by the July minimum temperature of 4.4°C. Whilst distribution may extend outside these areas, it's likely that all eastern coastal populations south of the Mary River are introduced. Often very abundant but levels vary in space and time and decreases in rivers further south. Most common in sandy river reaches with low flows with highest numbers	Abundance is reduced in regulated reaches, most likely due to the need for high water temperatures to stimulate gonad development and spawning which may be affected by hypolimnetic releases. Barriers (such as weirs etc) are likely to impact their movement and increases in velocity and/or sediment coarseness are also likely to be a disadvantage.

	Life history requirements	Fish spawning periods- movement/ other requirements, tolerances	Cope with translocation?	Distribution and description of the habitat	Sensitivity to flow regimes
		Inferences from distributions have been used to determine oxygen, pH and turbidity tolerances. Fish have been found in springs, billabongs and pools with dissolved oxygen concentrations as low as 0.4, 0.8 and 1 mg/L. They have been found in water with a pH as low as 4.0 and as high at 8.6 and the turbidity ranging from 1.52 to 5.44NTU although it has been collected from highly turbid (260NTU) floodwaters in the Burdekin River. Reach sexual maturity at the young age of 3-6 months. Peak spawning activity in Burdekin River is the wet season and in Oct/Nov in the Burnett River. The critical temperature for spawning is 22°C in the Burnett River. Rising water temperatures are an inducement to spawning and whilst rising water levels were thought to be an inducement, and it		recorded after wet season floods. Found in desert springs and bores, billabongs, impoundments, rivers and streams. Frequently the dominant species in isolated pools of intermittent rivers. Rarely found in estuarine conditions.	Natural flood regime is required for connectivity to off-channel habitats.

	Life history requirements	Fish spawning periods- movement/ other requirements, tolerances	Cope with translocation?	Distribution and description of the habitat	Sensitivity to flow regimes
		enhances recruitment in the Burdekin River, they will spawn in impoundments. Seasonal migrations during the wet season have been recorded in the Alligator River, they move upstream at the start of flooding to spawn in tributary creeks in the Black-Alice River, and they move laterally into the floodplain lagoons on the Normanby River. They have been observed trying to use fishways. The species move up or downstream for reproduction at the start of the wet season and they also disperse from dry season refuges which may be a move to floodplain habitats or other riverine habitats. Diverse diet with almost half made up of aquatic invertebrates.			