18. FRESHWATER ECOLOGY

This chapter describes the freshwater ecology values within the study area, assesses the potential impacts of the project on these values and describes the measures Arrow Energy will implement through project design, construction, operations and decommissioning to manage impacts on these freshwater ecology values.

This chapter is based upon the findings in the freshwater aquatic ecology impact assessment for the Arrow LNG Plant undertaken by Aquateco Consulting Pty Ltd (Appendix 11, Freshwater Ecology and Water Quality Impact Assessment).

This chapter provides details of freshwater aquatic ecosystem values of the study area (including aquatic habitat, macrophytes and aquatic fauna species). Marine and estuarine ecology is addressed in Chapter 19, Marine and Estuarine Ecology, and covers those areas dominated by marine and estuarine species. Riparian flora and fauna is discussed in Chapter 17, Terrestrial Ecology.

The objectives for freshwater ecology have been developed based on the relevant legislative context with the aim of protecting the existing values. The objectives for freshwater ecology are set out in Box 18.1.

Box 18.1 Objectives: Freshwater ecology

- To avoid or reduce the adverse effects on freshwater aquatic ecology values during project construction, operation and decommissioning.
- To protect freshwater ecology and associated biodiversity of state and national conservation significance.
- To avoid or reduce the loss of aquatic habitat.
- To avoid or reduce the potential for adverse effects from sedimentation or contamination from construction, operation and decommissioning activities on watercourses.
- To prevent the introduction or spread of new or existing aquatic weeds or plant and animal pathogens.
- To avoid or reduce disruption to flow regime as far as practicable and to maintain, as far as practicable, fish passage through watercourses.
- To avoid abstraction of freshwater for project uses, where practical.

18.1 Legislative Context and Standards

This section outlines the specific legislation and policies that are enforced to protect the values of the freshwater aquatic environment within and surrounding the study area.

18.1.1 Commonwealth and State Legislation

The following legislation and guidelines are relevant to managing impacts to freshwater ecology through all project phases:

- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act). The act provides for the protection of matters of national environmental significance, including listed threatened species and ecosystems and protected areas. The development proposal has been declared a controlled action under the EPBC Act, and will be assessed as a bilateral agreement between the Commonwealth and state governments.

The freshwater aquatic ecology study has utilised the EPBC database and approvals documentation for other projects within the region to identify likely matters of national environmental significance within the study area.

- *State Development and Public Works Organisation Act 1971* (Qld). The act provides for state planning and development through a system of public works and environmental consultation. The Gladstone State Development Area was created under the act, with the aim to guide development while protecting environmental values.
- *Nature Conservation Act 1992* (Qld). The principal legislation that supports biological diversity, ecologically sustainable use of wildlife and ecologically sustainable development, and the conservation of nature that may be impacted by the project, the act places requirements on any person taking, using or interfering with protected fauna. Subordinate to the act are:
  - Nature Conservation (Protected Areas) Regulation 1994 identifies national parks, conservation parks, resource reserves and nature refuges that are of particular importance in and adjacent to the study area.
  - Nature Conservation (Wildlife) Regulation 2006 defines the conservation status of native wildlife species in Queensland and non-native species with a declared management intent for each class.
- *Land Protection (Pest and Stock Route Management) Act 2002* (Qld). Regulates the use of the stock-route network in Queensland and provides a framework for the management of pest flora and fauna. The act designates exotic species that threaten natural resources, conservation of biodiversity and remnant vegetation, reduce agricultural production and interfere with human health, including aquatic species. The declaration of a pest places a legal obligation on landholders to control or eradicate the species.
- *Environmental Protection Act 1994* (Qld). Provides for the protection of Queensland's environment while allowing for ecologically sustainable development. The subordinate policy, Environmental Protection (Water) Policy 2009 (EPP (Water)), provides for the management of surface water quality in Queensland, while allowing for ecologically sustainable development. This purpose is achieved within a framework that includes:
  - Identifying environmental values for aquatic ecosystems and for human uses of those ecosystems.
  - Determining water quality guidelines and water quality objectives to enhance or protect the environmental values identified, through monitoring and reporting on the condition of Queensland waters.

No specific environmental values and water quality guidelines/objectives have been set for the Port Curtis region although values are scheduled for adoption for the Curtis Island basin and coastal waters by December 2013. The Queensland water quality guidelines (DERM, 2009b) prepared under the EPP (Water) set a framework for assessing water quality in the state and provide water quality guidelines for the Central Coast Queensland region.

The applicable guidelines for physico-chemical indicators for the project are those described for lowland streams of the Central Coast Queensland region. These streams are considered to be slightly to moderately disturbed waters.

Relevant guidelines for toxicant indicators are the freshwater trigger values described in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000) for slightly to moderately disturbed systems.

- *Water Act 2000* (Qld). This act provides the basis for planning and allocation of Queensland water resources and sets out licensing requirements to take or interfere with water, to ensure the improved security of water resources. The project lies within the region covered by the Water Resource (Calliope River Basin) Plan 2006, which provides for water from the basin to be allocated and sustainably managed. The Calliope River Basin Resource Operations Plan 2008 (DNRW, 2008) implements the Water Resource (Calliope River Basin) Plan 2006.
- State Planning Policy 4/10: Healthy Waters (Qld). Ensures development is planned, designed, constructed and operated to manage stormwater and wastewater, while protecting water environmental values specified in the EPP (Water).
- *Fisheries Act 1994* (Qld). Provides for the management, use and protection of fisheries resources and fish habitats in a way that is ecologically sustainable. There are no commercial or recreational freshwater fisheries within the study area. Activities within freshwater areas could impact on adjacent marine fisheries and fish habitat.

18.1.2 Plans, Policies and Environmental Management

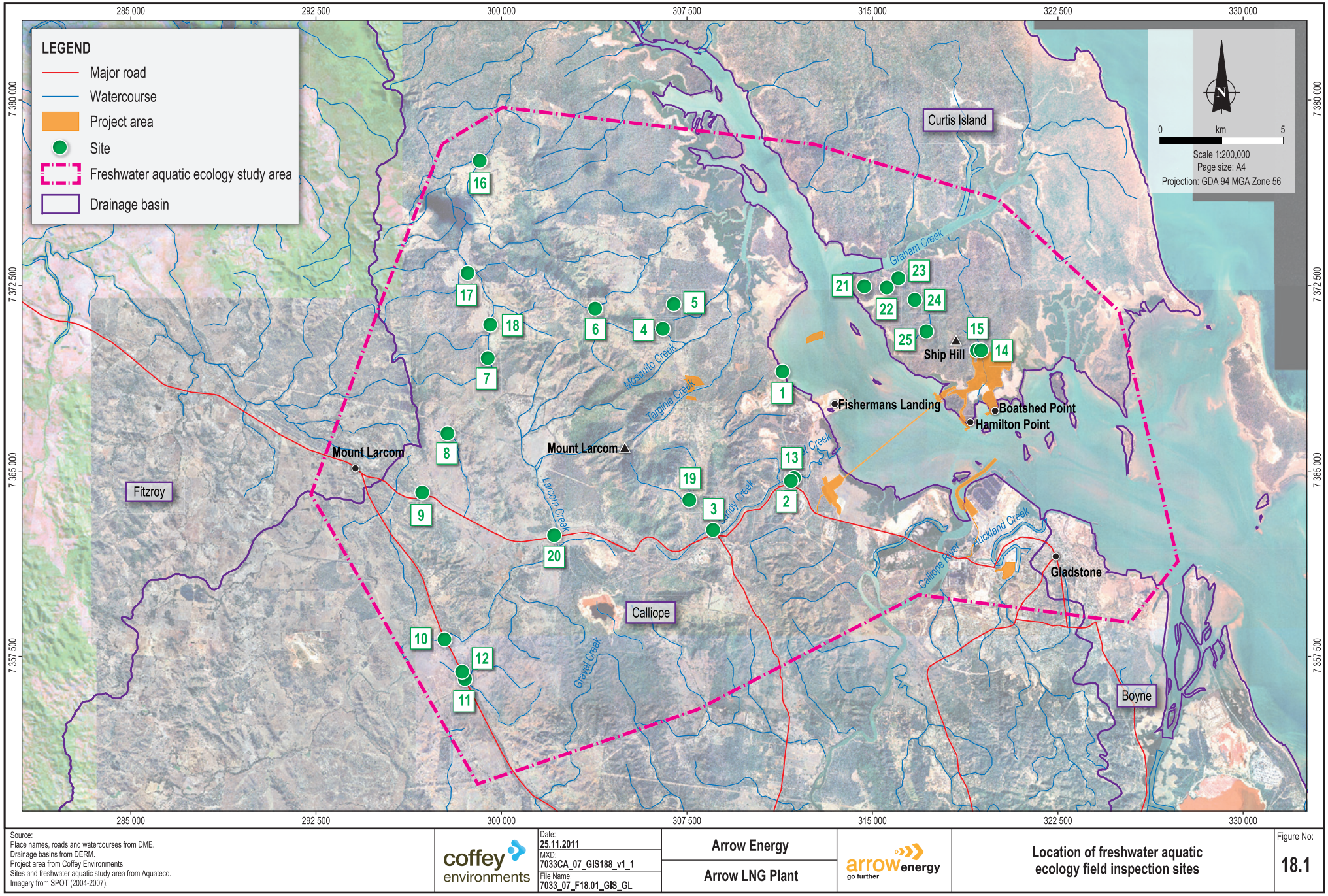
The following non-statutory mechanisms apply to freshwater aquatic ecology and the project:

- Australian Pipeline Industry Association Code of Environmental Practice – Onshore Pipelines 2009 (APIA, 2009). Includes industry standard management measures to alleviate the environmental impact of pipeline projects in construction and operation.
- Draft Policy Statement 2007: Use of environmental offsets under the *Environment Protection and Biodiversity Conservation Act 1999*. (DEWR, 2007) Outlines the position of the Commonwealth government on environmental offsets under the EPBC Act and ensures the consistent application of offsets to projects under the act.
- Environmental Offsets Policy 2008. (EPA, 2008b). Aims to address impacts to biodiversity values that may be lost as a result of development or other activities and sets out the Queensland government‘s offsets policy.

18.2 Assessment Method

The freshwater ecology impact assessment was carried out through literature review, field survey and assessments (see Appendix 11, Freshwater Ecology and Water Quality Impact Assessment). The study method has adopted the significance (sensitivity and magnitude) approach.

The study area for the freshwater aquatic ecology impact assessment was established to provide a regional context for assessing freshwater aquatic ecology values. The area includes waterways away from the area of disturbance (reference sites) and any watercourses that may be impacted by project activities (even if downstream of the area of disturbance). An additional area of 20 km was researched beyond this area when undertaking database searches and the literature review. This was defined as the extended freshwater aquatic ecology study area so that any potentially present, legislatively significant species in the local area were included as part of the study. The study areas for the freshwater aquatic ecology assessment are shown in Figure 18.1.



Source:
Place names, roads and watercourses from DME.
Drainage basins from DERM.
Project area from Coffey Environments.
Sites and freshwater aquatic study area from Aquateco.
Imagery from SPOT (2004-2007).

coffey environments

Date: 25.11.2011
MXD: 7033CA_07_GIS188_v1_1
File Name: 7033_07_F18.01_GIS_GL

Arrow Energy

Arrow LNG Plant

arrow energy go further

Location of freshwater aquatic ecology field inspection sites

Figure No: 18.1

18.2.1 Baseline Assessment

The freshwater aquatic ecology study was undertaken through a combination of desktop study and field survey.

Desktop Study

A desktop review of available literature identified freshwater aquatic flora and fauna species present in the study area.

The search of databases covered the extended freshwater aquatic ecology study area and included:

- An EPBC protected matters report to identify matters of national environmental significance (DSEWPC, 2011c).
- A Queensland state (Wildnet - Wildlife Online) report to include species listed under state legislation (Nature Conservation Act) in the assessment (DERM, 2010).
- The Queensland wetland mapping database (Wetland*Info*) for records of wetlands within or adjacent to the study area (DERM, 2011c).

Literature from the following projects and planning instruments were reviewed to assist the baseline assessment of aquatic ecosystem values. This literature included:

- EIS documents from other projects (LNG plants and feed gas pipelines) within the study area.
- Other resource and infrastructure development projects within the Gladstone State Development Area and Common Infrastructure Corridor including water, nickel, aluminium, coal, steel and oil facilities.
- Relevant planning instruments, including the Development Scheme for the Gladstone State Development Area (DIP, 2010c), the Gladstone Planning Scheme (SKM, 2006) and the Curtis Coast Regional Coastal Management Plan (EPA, 2003).
- The EIS and supplementary EIS for the Gladstone–Fitzroy Pipeline Project (GAWB, 2008; 2009b).

Published scientific papers, technical reports, field guides, primary texts as well as the DERM biodiversity planning assessments (EPA, 2002) were also reviewed. Aerial photography interpretation allowed sites within the study area to be identified as requiring field assessment. This review indicated that watercourses within the study area were largely first and second order ephemeral streams.

Stream order is a number assigned to waterways based on the number and size of tributaries associated with the waterway using the Strahler stream classification system. This system provides a measure of system complexity and therefore the potential for fish habitat to be present. Generally, third order streams and above are recognised as likely to contain valuable fish habitat, and support viable fish populations.

These databases and data sets were used to identify significant aquatic flora and fauna species potentially occurring within the study area, to be targeted in the field surveys and taken forward into the impact assessment.

Field Survey

Two survey events were completed in December 2009 (early wet season) and mid June 2010 (post wet season). Access to areas in December was limited to public roads on the mainland and to existing tracks on Curtis Island.

Both surveys comprised field observations and photographs taken at all points within the study area at which public roads (mainland) and existing tracks on the LNG plant site on Curtis Island crossed waterways or drainage lines. Observations of aquatic flora and fauna or areas of high value aquatic habitat were noted and marked using GPS.

The study area is crossed by numerous small drainage lines that are assumed to contain water during the wetter months. While these were observed in the field, they are of negligible consequence in terms of aquatic habitat, due to limited connectivity with more permanent waterbodies, and were not included in this assessment.

The location of aquatic field inspection sites is shown in Table 18.1. The locations of these sites are shown in Figure 18.1.

Table 18.1 Arrow LNG Plant freshwater aquatic ecology field inspection sites

Site	Waterway	Description
1	UC1	Unnamed creek north of Fishermans Landing
2	Boat Creek	Boat Creek at Landing Road
3	Boat Creek	Boat Creek at Targinie Road
4	Mosquito Creek	Mosquito Creek at Targinie Road
5	UC2	Unnamed Creek at Chernin Road
6	Scrubby Mountain Creek	Scrubby Mountain Creek at Nichols Road
7	UC3	Unnamed creek at The Narrows Road
8	UC4	Unnamed creek at The Narrows Road
9	UC5	Unnamed creek at Gladstone-Mount Larcom Road
10	Larcom Creek	Larcom Creek at Bruce Highway
11	UC6	Unnamed creek at Bruce Highway
12	UC7	Unnamed creek at Bruce Highway
13	Boat Creek	Boat Creek from public reserve
14	UC8	Unnamed creek on Curtis Island at LNG site
15	UC8	Unnamed creek on Curtis Island at LNG site
16	Munduran Creek	Munduran Creek at Narrows Road
17	Munduran Creek	Munduran Creek at Mattson Road
18	Munduran Creek	Munduran Creek at Nichols Road
19	Spring Creek	Spring Creek at Targinie Road
20	Larcom Creek	Larcom Creek at Gladstone–Mount Larcom Road
21	UC8	Unnamed creek, Curtis Island pipeline envelope
22	UC8	Unnamed creek, Curtis Island pipeline envelope
23	UC8	Unnamed creek, Curtis Island pipeline envelope
24	UC8	Unnamed creek, Curtis Island pipeline envelope
25	UC8	Unnamed creek, Curtis Island pipeline envelope

Notes: UC = Unnamed creek.

Survey Limitations

There was limited opportunity for sampling of fish and macroinvertebrates in the field surveys. In the early wet season survey, almost all watercourses within the study area were dry and high quality habitat (permanent or semi-permanent waterholes and pools or structural woody or rocky habitat) was absent. The ephemeral nature of the streams also reduced the value of collecting water samples to describe baseline stream water quality conditions. The quality of water is highly variable depending on the flow phase or the period of evapoconcentration, in addition to other factors such as catchment land use, condition and soil types.

The fieldwork and baseline assessment present an accurate representation of the aquatic flora and fauna of the study area and provide a robust basis for the impact assessment. The literature review enabled field surveys to be targeted to habitats and areas likely to hold species of conservation concern. Where there was any doubt as to whether a species could occur within the study area, the precautionary approach was adopted in the desktop assessment, and species considered likely to occur in the study area were carried forward for consideration in the impact assessment, whether they were recorded by field survey or not (see Appendix 11, Freshwater Ecology and Water Quality Impact Assessment).

18.2.2 Impact Assessment

The freshwater ecology impact assessment considered a range of direct and indirect impacts on freshwater aquatic ecosystems, with the potential impacts quantified as a function of the sensitivity of the freshwater aquatic value and the magnitude of the impact. The sensitivity of each ecological value and magnitude of impacts on each ecological value was developed using the criteria defined in Chapter 9, Impact Assessment Method.

Table 18.2 shows the criteria developed to assign sensitivity rankings to freshwater aquatic ecosystem values, and evaluate the magnitude of impacts expected on aquatic ecosystems as a result of the project. Once an ecosystem had been assessed on the basis of each attribute, it was assigned the sensitivity ranking of the most sensitive of the attributes.

Table 18.2 Definition of freshwater ecology sensitivity and magnitude

Sensitivity			
Descriptor	**High**	**Moderate**	**Low**
Conservation status	• Wild river status (declared by DERM). • World heritage status. • Ramsar status. • EPBC/Nature Conservation Act listed flora/fauna/communities. • High value fishery. • International ecotourism destination.	• Local government management. • Species of conservation interest (currently unlisted). • Moderate/marginal fishery values. • State or local ecotourism destination.	• No formal conservation status. • No species, habitat or communities of special conservation significance. • No fisheries value. • Local or no ecotourism value.
Intactness	• Undisturbed, pristine aquatic system. • High-quality aquatic habitat. • Important movement corridor for aquatic species. • Nursery/spawning area for aquatic fauna.	• Moderately disturbed aquatic system. • Moderate to good quality habitat. • Limited passage of aquatic fauna. • Limited spawning/nursery opportunities.	• Highly disturbed aquatic system. • Poor quality aquatic. habitat. • Minimal value as movement corridor for fauna. • Minimal value for spawning/nursery.

Table 18.2 Definition of freshwater ecology sensitivity and magnitude (cont'd)

Sensitivity			
Uniqueness or rarity	Unique on a national or international scale in terms of biota, communities or processes.	Unique on a regional scale in terms of biota, communities or processes.	Unique on a local scale in terms of biota, communities or processes.
Resilience to change	Poor tolerance to disturbance events, minor impacts have catastrophic effect.	Moderately tolerant or adaptive communities.	Highly tolerant or adaptive communities able to survive significant disturbance impacts.
Replacement potential	Disturbance likely to cause irreparable damage or permanent loss of values.	Communities likely to exhibit moderate to good recovery following disturbance.	Communities capable of rapidly recovering or regenerating after disturbance events.
Magnitude			
Descriptor	**High**	**Moderate**	**Low**
Geographical extent	Impact has potential to affect aquatic ecosystems over a wide spatial range (over 20 km).	Impact has potential to affect aquatic ecosystems within a range of 0.5 km to 20 km radius.	Impact has potential for localised effects on aquatic ecosystems up to 0.5 km away.
Duration	Impact period is from two years to perpetuity.	Impacts affect aquatic ecosystems for three months to two years.	Impact is short term (less than three months).
Severity	Potential for complete loss of aquatic communities.	Potential for temporary or partial loss of aquatic communities.	Potential for minor, short-term impairment of aquatic communities.

The sensitivity of ecological values and the magnitude of each impact were assessed to determine the significance of an impact on the freshwater ecology of the study area (Table 18.3).

Table 18.3 Matrix of significance – freshwater ecology

	Sensitivity of Environmental Value		
Magnitude of Impact	**High**	**Medium**	**Low**
High	Major	High	Moderate
Medium	High	Moderate	Low
Low	Moderate	Low	Negligible

The levels of significance of an impact determined using the matrix can be defined as:

- Major significance. An impact that is irreversible, widespread and has the potential to completely eradicate aquatic communities. The values are of international or national importance, have low tolerance to disturbance and, if lost, cannot be replaced.
- High significance. An impact that is important at a regional or district scale and will require the application of specific environmental controls to be managed.
- Moderate significance. An impact that is important at a local scale with potential for partial loss of aquatic communities and impacts lasting up to two years.
- Low significance. An impact that has potential for local effects, although impacts are typically short term in nature. These impacts are typically on low-value aquatic communities, capable of recovery after disturbance events.

- Negligible significance. An impact that will not result in any noticeable environmental change or effects, and that will not influence the decision-making process.

18.3 Existing Environment and Environmental Values

This section describes the existing environmental values in the study area to establish baseline conditions against which to assess the impacts of the project. These existing environmental values incorporate both the physical habitat and existing flora and fauna.

Aquatic freshwater ecosystems within the study area include the Calliope River, Larcom Creek, Boat Creek and numerous minor tributaries of these waterways. There are also numerous first and second order ephemeral streams throughout the study area, which are so small as to be unnamed and which do not appear on topographical maps. There are also a limited number of small farm dams. There are no permanent freshwater wetlands within the project area and very few permanent pools.

18.3.1 Aquatic Habitat

There are no perennial systems on Curtis Island within the vicinity of the LNG plant site. There are a number of drainage channels of an ephemeral nature, which flow intermittently during rainfall events. One such channel flows from south of Graham Creek through the Arrow LNG plant site (Plate 18.1). During the post wet season survey, this was devoid of any remnant pools.

DERM has advised that the drainage features in the project area on Curtis Island are not watercourses as defined by the *Water Act 2000* (see Chapter 13, Surface Water Hydrology and Water Quality).

Field surveys found permanent water at only two sites (both on the mainland) during the early wet season survey: Mosquito Creek (approximately 1 km northwest of TWAF 8) and at Site 13 on Boat Creek. Both these sites contained remnant, standing water at the time of the early wet season site survey, but were flowing during the post wet season survey. Boat Creek is likely to be non-tidal as far upstream as Site 13, which is approximately 2 km from the mouth of the creek. An absence of water a further 3 km upstream at Site 3 during the early wet season survey suggests that the remnant pool system is confined to the lower reaches of the Boat Creek system immediately upstream of tidal influence (Plate 18.2).

The paucity of permanent pools within streams in the study area resulted in very poor abundance and diversity of macroinvertebrates, with the possible exception of Larcom Creek. All other watercourses during the early wet season survey were dry and devoid of remnant waterholes or wetlands.

The Arrow LNG Plant survey was limited to road crossings. The relatively uniform topography and geography indicated that watercourses on private land were very similar to those observed at the roadsides.

During the post wet season survey, the majority of the ephemeral watercourses were still flowing as a result of an above average intensity wet season. Within the lower order waterways, flow was minimal and likely to have ceased within a few weeks of the survey. Some small remnant pools may have been retained although these were likely to be dry by the end of the dry season (as observed in the early wet season survey).

Source: Aquateco

Plate 18.1
UC8 on Curtis Island at LNG Plant site

Source: Aquateco

Plate 18.2
Boat Creek west of Landing Road

Source: Aquateco

Plate 18.3
Targinie Creek east of Yarwun - Targinie Road at TWAF 8

Ephemeral waterways, such as Targinie Creek at TWAF 8 (Plate 18.3) play a significant role in local and regional aquatic ecosystems, providing seasonal refuge, foraging and spawning habitat for many fish species, macroinvertebrates and waterfowl. They may play a significant role in the flux of nutrients and organic material to downstream environments and can facilitate the connectivity of waterways to enable the migration of aquatic species to upstream pools, waterholes or wetlands. Habitat within the ephemeral streams was of relatively poor quality. Substrates were often mud or silt, although some rocky areas were observed. Structural woody habitat was generally sparse, although exposed tree roots (resulting from erosion) were occasionally present.

Larger waterways, such as Larcom Creek are present within the study area. Larcom Creek at the Bruce Highway (Site 10) still contained significant flows during the post wet season survey. Systems such as this contain a variety of habitats, which are likely to act as temporary refugia during the dry season and a corridor for movement of aquatic species from further upstream.

No freshwater wetlands or spring-fed streams were observed during surveys for the freshwater aquatic ecology or terrestrial ecology studies, and local geology and topography is unsuitable for such systems. Aquatic communities maintained by groundwater influx are unlikely to be present.

18.3.2 Aquatic Flora Species

The desktop study did not identify any EPBC Act listed nationally significant aquatic flora or any aquatic flora species of state significance listed under the Nature Conservation Act. No aquatic plant species listed as matters of national environmental significance or matters protected by the EPBC Act occur within the study area.

The Wildlife Online database search (DERM, 2010) found a total of 75 native aquatic, semi-aquatic or riparian plant species within the extended freshwater aquatic ecology study area. None of these species were listed under the EPBC Act or the Nature Conservation Act.

Field surveys for the Queensland Curtis Liquefied Natural Gas Project (QCLNG Project) (QGC, 2009) found three listed aquatic flora species as potentially being within the study area for this project. The study area for these surveys covered areas in the Surat Basin far to the west of the project area. The three species identified, Queensland lace plant (*Aponogeton queenslandicus*), Blake's spikerush (*Eleocharis blakeana*) and *Fimbristylis vagans,* are all restricted to these areas and are highly unlikely to be within the Arrow LNG Plant study area.

Arrow LNG Plant field surveys for the project did not identify any EPBC Act-listed nationally significant aquatic flora or any aquatic flora species of state significance listed under the Nature Conservation Act. The following 14 species of aquatic flora were observed during the two surveys at sites within the study area:

- Cumbungi (*Typha latifola*).
- Common reed (*Phragmites australis*).
- Pacific azolla (*Azolla pinnata*).
- Native water lily (*Nymphaea violacea*).
- Water snowflake (*Nymphoides indica*).
- Slender knotweed (*Persicaria decipiens*).
- Water primrose (*Ludwigia peploides*).
- Umbrella sedge (*Cyperus eragrostris*).
- Para grass (*Urochloa mutica*).
- Curly pondweed (*Potamogeton crispus*).
- Curled dock (*Rumex crispus*).

- Watershield (*Brasenia schreberi*).
- Water millfoil (c.f. *Myriophyllum* spp).
- Pondslime (Filamentous algae).

Only three sites recorded species; Site 13 at Boat Creek recorded all 14 species, cumbungi and common reed were found at Site 1 and common reed was found at Site 2.

The species observed included four introduced aquatic flora species. None are listed under the Land Protection (Pest and Stock Route Management) Act.

Introduced species present were:

- Umbrella sedge. A native of South America, it is a tufted perennial sedge. Although it is introduced, the species assists in stabilising earth banks and provides habitat for aquatic biota.
- Curled dock. A native of Europe and a noxious weed in agricultural areas, it is a prolific plant that thrives in seasonal wetlands.
- Para grass. A perennial grass and common weed in cane growing areas, it is an aggressive invader. It displaces native plants, with the potential to alter the flow characteristics of streams, resulting in localised flooding. It is commonly found in wetland areas (DPIF, 2007a).
- Cumbungi. There are three species of bullrush in Australia; two of which are native, and the other, *Typha latifolia,* was introduced from Europe. The species invades slow moving waterways, and reduces water quality, reduces stock access to water and provides breeding places for vermin and mosquitoes (DPIF, 2007b). Cumbungi also has the potential to alter the flow characteristics of streams, resulting in localised flooding.

The aquatic weed hymenachne, (*Hymenachne aplexicaulis*) was observed during the terrestrial ecology surveys undertaken for the project. The species was recorded in, and adjacent to, two small dams in the vicinity of Cullen Road, which intersects the northwest portion of the Northern Transport Infrastructure Corridor (approximately 6.7 km northwest of TWAF 8). This represents an extension to the known range of this species. The species can interfere with irrigation, infrastructure and wildlife habitats, and degrades water quality for recreational purposes (DPIF, 2010).

Aquatic ecosystems in the study area were generally devoid of emergent aquatic macrophytes during the pre wet season survey, although some colonisation by aquatic macrophytes was evident at many sites during the post wet season survey. Macrophytes consisted of a variety of emergent, floating, submerged and attached taxa. The desktop review and the outcome of the field studies for the project indicate listed conservation significant species are unlikely to be present within the study area.

A summary of the hydrology, habitat, stream order and macrophytes of each aquatic field inspection site is shown in Table 18.4.

Table 18.4 Freshwater aquatic ecology field inspection sites summary

Site and Waterway	Hydrology	Substrate/ Habitat	Stream Order	Macrophytes and Other Notes
1 (UC1)	Ephemeral or tidal	Gravel/rock	1	Macrophytes – emergent. Tidal at waypoint, ephemeral and fresh 500 m upstream.
2 (Boat Creek)	Ephemeral		2	Macrophytes – emergent.
3 (Boat Creek)	Permanent	Mud/silt/sand, gravel/rock, structural woody habitat	1	Permanent freshwater.
4 (Mosquito Creek)	Ephemeral	Mud/silt/sand, gravel/rock, structural woody habitat	1	Macrophytes - emergent, submerged, attached.
5 (UC2)	Ephemeral		1	-
6 (Scrubby Mountain Creek)	Ephemeral	Mud/silt/sand, gravel/rock	1	-
7 (UC3)	Ephemeral	Mud/silt/sand, structural woody habitat	1	-
8 (UC4)	Ephemeral	Mud/silt/sand	1	-
9 (UC5)	Ephemeral	Mud/silt/sand	1	-
10 (Larcom Creek)	Ephemeral	Mud/silt/sand, structural woody habitat	2	-
11 (UC6)	Ephemeral	Mud/silt/sand	1	-
12 (UC7)	Ephemeral	Mud/silt/sand	1	-
13 (Boat Creek)	Permanent	Too deep to identify, but likely mud/silt with embedded cobble.	2	Macrophytes - emergent, floating, submerged, attached. Permanent freshwater.
14 (UC8)	Ephemeral	Gravel/rock, structural woody habitat	1	Exposed tree roots from natural erosion.
15 (UC8)	Ephemeral	Gravel/rock, structural woody habitat	1	Exposed tree roots from natural erosion. Mildly incised channel with alternative flood channels.
16 (Munduran Creek)	Ephemeral	Mud/silt/sand, gravel/rock, structural woody habitat, undercuts	1	Macrophytes - emergent, submerged, attached. Relatively high quality aquatic habitat.
17 (Munduran Creek)	Ephemeral	Mud/silt/sand, gravel/rock, structural woody habitat, undercuts	1	Macrophytes - emergent, submerged, attached. Relatively high quality aquatic habitat.
18 (Munduran Creek)	Ephemeral	Mud/silt/sand	1	Macrophytes - emergent, floating, submerged, attached. Isolated ephemeral pool containing seasonal aquatic habitat.
19 (Spring Creek)	Ephemeral	Mud/silt/sand, gravel/rock, structural woody habitat, undercuts	1	Macrophytes - emergent, floating, submerged, attached. Moderate quality aquatic habitat.

Table 18.4 Freshwater aquatic ecology field inspection sites summary (cont'd)

Site and Waterway	Hydrology	Substrate/ Habitat	Stream Order	Macrophytes and Other Notes
20 (Larcom Creek)	Ephemeral	Mud/silt/sand, gravel/rock, structural woody habitat, undercuts	2	Macrophytes - emergent, floating, submerged, attached. Moderate quality aquatic habitat.
21 (UC8)	Ephemeral	Gravel/rock, structural woody habitat, undercuts	1	Creek channel dry during site inspections, but evidence of recent substantial flow. Some structural woody habitat and undercuts but generally poor aquatic habitat with no connectivity to permanent freshwater.
22 (UC8)	Ephemeral		1	
23 (UC8)	Ephemeral		1	
24 (UC8)	Ephemeral		1	
25 (UC8)	Ephemeral		1	

Notes: Stream order is a number assigned to waterways based on the number of tributaries associated with the waterway.

18.3.3 Aquatic Fauna Species

An EPBC Protected Matters search (DSEWPC, 2011c) was undertaken to identify whether matters of national environmental significance or matters protected by the EPBC Act are likely to occur within the study area. Two species relevant to freshwater ecology were listed as matters of national environmental significance; water mouse (*Xeromys myoides*) and saltwater crocodile (*Crocodylus porosus*). These are further discussed in Chapter 17, Terrestrial Ecology.

The Wildlife Online database search (DERM, 2010) found a total of 105 native aquatic, semi-aquatic or riparian fauna species within the extended freshwater aquatic ecology study area. These comprised 23 amphibians, 49 birds, 26 fish, 1 mammal and 6 reptiles. Four of the bird species were listed under the Nature Conservation Act (discussed further in Chapter 17, Terrestrial Ecology). No other species identified during the Wildlife Online database search were of conservation significance.

Field surveys for the Gladstone Area Water Board's Gladstone–Fitzroy Pipeline EIS (GAWB, 2008) identified a number of fish species of conservation significance. These species were noted to be restricted to the Fitzroy River catchment, to the north of the study area. Two species considered to be possibly present in the Calliope River catchment were the purple-spotted gudgeon (*Mogurnda adspersa*) and the Rendahl's tandan (*Porochilus rendahli*). Both of these species favour habitat containing submerged aquatic vegetation, a habitat that was found to be very sparse during surveys for the Arrow LNG Plant; neither species was noted.

The Gladstone–Fitzroy Pipeline EIS also noted six freshwater turtle species as being potentially present, including the EPBC listed Fitzroy River turtle (*Rheodytes leukops*). The project study area is outside the range of this species and possesses only marginal habitat for the species, lacking permanent pools and clear flowing water. The remaining five species are common and widespread.

The Gladstone–Fitzroy Pipeline EIS found relatively high macroinvertebrate diversity. Permanent streams with rocky substrates were present, indicating that water pollution is not a major consideration. Ephemeral streams with minimal habitat diversity (such as those observed in the Arrow LNG Plant study area) generally yielded much poorer community structure and waterways within the study area were described as being marginal temporary habitat during flows for several species of conservation significance, none of which are protected under legislation.

Field surveys for the QCLNG Project (QGC, 2009) indicated that the Fitzroy River turtle, Queensland lungfish (*Neoceratodus forsteri*) and Murray cod (*Macullochella peelii peelii*) were potentially impacted by the feed gas pipeline component of that project. These species are all

unlikely to occur within the study area as it is outside their natural range, and habitat is marginal for these species.

Field surveys for the Conoco Philips/Origin Energy APLNG gas pipeline (APLNG, 2009) identified the kroombit tinkerfrog (*Taudactylus pleione*) as potentially being impacted by that project. This species was assessed as being unlikely to occur within the APLNG study area, and is unlikely to be present within the Arrow LNG Plant study area either, as it is outside the natural range of this species and habitat is marginal for the species.

Observations during the Arrow LNG Plant surveys did not identify any EPBC Act listed nationally significant aquatic fauna or any aquatic fauna species of state significance listed under the Nature Conservation Act. Eight species of aquatic fauna were observed during the two surveys at sites within the study area. Only one site held aquatic taxa; Site 13, Boat Creek. Aquatic fauna species present at this site were:

- Fork-tailed catfish (*Arius graeffei*).
- Eastern rainbowfish (c.f. *Melanotaenia splendida*).
- Mosquitofish (c.f. *Gambusia holbrooki*).
- Barred grunter (*Amnitaba percoides*).
- Sea mullet (*Mugil cephalus*).
- Tarpon (*Megalops cyprinoides*).
- Barramundi (*Lates calcarifer*).
- Saw-shelled turtle (*c.f. Elseya latisternum*).

The mosquitofish (*Gambusia holbrooki*) is an exotic species. Although not listed under the Land Protection (Pest and Stock Route Management) Act, the species is known to dominate many habitats where it is introduced. It is frequently found in ephemeral streams and may colonise systems within the study area during wetter periods.

A number of freshwater fish species have a tendency to move into ephemeral systems such as those found within the study area during floods. In the Gladstone area, the most likely native species to utilise these systems are spangled perch (*Leiopotherapon unicolor*), eastern rainbowfish and bony bream (*Nematolosa erebi*).

18.3.4 Water Quality

The only recognised freshwater creeks potentially impacted by the project are Boat Creek (which flows north of the mainland tunnel entry shaft and tunnel spoil disposal area on mudflats near Fishermans Landing) and the upper reaches of Targinie Creek (in the vicinity of TWAF 8).

Water quality monitoring was not undertaken as part of field surveys due to the ephemeral nature of the water resource within the study area and the difficulty in obtaining information of value. The impacts of the project on water quality are discussed in Chapter 13, Surface Water, Hydrology and Water Quality.

18.3.5 Sensitivity of Ecological Values

The combination of the desktop review and field surveys found no features of aquatic conservation significance within the study area. Listed species, which occur in other systems within the region, are unlikely to be present. Aquatic habitat within the study area is of very marginal value on a local or regional scale. The majority of waterways are ephemeral and contain minimal, low value aquatic habitat with limited connectivity to permanent waterbodies.

Most systems within the study area are unnamed first or second-order systems, which flow for very limited periods each year. These systems are often little more than drainage lines through agricultural or forested areas. The most significant waterway within the study area is Larcom Creek in the western section of the study area. This creek is well away from the project area and upstream from the influence of project activities.

Overall, ephemeral streams (and the ephemeral headwaters of Larcom and Boat creeks) have a low sensitivity to impacts associated with the project, and exhibit the following values:

- They are moderately intact, with limited disturbance from existing land use activities such as agriculture and industry.
- They have low conservation status due to no formal conservation status, no species, habitat or aquatic communities of special conservation significance, no fisheries values and no ecotourism potential.
- They provide marginal, low quality aquatic habitat due to the short periods during which they contain water, lack of connectivity to larger permanent waterways and minimal spawning/nursery habitat.
- They are not unique on a local or regional scale and represent a very small proportion of similar aquatic habitat regionally.
- They are likely to be opportunistically utilised by aquatic fauna and flora that are tolerant of significant disturbance events and which are adapted to rapidly colonise and regenerate when conditions are suitable.

Permanent freshwater aquatic ecosystems are Mosquito Creek and the lower reaches of Boat Creek. These systems have moderate sensitivity to impacts associated with the project and exhibit the following values:

- They have limited potential for species of local conservation significance (but not currently listed species) to utilise these areas.
- They provide marginal recreational fishing opportunities.
- They are only moderately disturbed by existing catchment activities, with moderate to good quality aquatic habitat.
- They provide some opportunities for the movement of aquatic biota during the wet season, although they do not provide connectivity to more permanent waterways.
- They are likely to contain communities that are moderately tolerant of the impacts of the project, although recovery following a disturbance event will be slower than for ephemeral streams.

18.4 Issues and Potential Impacts

This section identifies the potential issues and impacts arising from project activities (construction, operation and decommissioning) on the existing freshwater aquatic environment.

The project will not abstract water. No wetlands or spring-fed streams were observed during surveys for the freshwater aquatic ecology or terrestrial ecology studies, and these communities are not considered further in this assessment.

No effluent will be discharged directly to freshwater ecosystems on either the mainland or Curtis Island, and this issue is not considered further in this assessment.

Waterway crossings are not anticipated to be required on the mainland for the construction of the feed gas pipeline, or on Curtis Island, as the pipeline traverses elevated terrain between the reception shaft and the proposed LNG plant.

At TWAF 8, service pipelines, security fences and access tracks will cross an ephemeral watercourse, with limited associated works required.

At the LNG plant site, construction of the perimeter fence and diversion of the drainage feature UC8 (and associated side gullies) will require works within and adjacent to this watercourse. DERM has advised that this drainage feature is not a watercourse as defined by the Water Act.

The diversion of UC8 east and west of its current alignment will intercept the drainage feature, associated side gullies and overland flows. Design of two conceptual routes, one around the north and west of the LNG plant and the other to the north and east of the LNG plant will be further investigated. The route selection will be based on minimising the overall impact.

Activities such as blasting (or other processes) that may directly cause injury or mortality to freshwater fish or turtles are not currently planned within the study area. The diversion of the ephemeral drainage line UC8 on Curtis Island will remove this ephemeral drainage feature and will have no impact upon freshwater fauna species. Injury to aquatic fauna or mortality as a result of project activities is not considered further in this assessment.

No direct impacts on freshwater aquatic ecosystems such as Boat Creek will occur from construction at the mainland tunnel launch site or from disposal of tunnel spoil, due to the distance from the nearest area of disturbance (approximately 500 m to the north at the closest point). The activities are not within freshwater systems and there will be no disposal to land or stream systems. There is limited potential for sediment or chemicals from the tunnelling operation to be transported into Boat Creek by tidal influences. The freshwater reaches of the creek will not be impacted.

The potential impacts on freshwater ecology within the study area are discussed below.

18.4.1 Loss of Riparian and Aquatic Vegetation

Construction activities will remove riparian and aquatic vegetation on Curtis Island and the mainland. These activities will result in the loss or degradation of aquatic habitat for shelter or foraging by aquatic species and the loss of potential spawning/nursery areas (although suitable habitat is limited within the study area). The loss of vegetation may also degrade water quality due to increased sediment transport, biochemical oxygen demand and nutrient loads. Impacts on water quality are discussed in Chapter 13, Surface Water, Hydrology and Water Quality. The removal of vegetation within or adjacent to the watercourse will reduce shading and increase diurnal temperature variations. These changes may render the habitat unsuitable for species that prefer more consistent temperatures and shaded conditions.

The unnamed ephemeral drainage feature (UC8) on Curtis Island will be completely removed during construction of the Arrow LNG Plant within the footprint of the site. This will permanently replace aquatic ecosystems at this site with a lined channel. The main drainage feature is over 1 km in length, with additional associated side gullies and channels. It is dry for large parts of the year, and, as a consequence, has little or no aquatic vegetation present. Riparian vegetation along the length of the drainage feature will be removed.

The magnitude of the impacts at UC8 on Curtis Island will be high, due to the complete removal of this system in its lower reaches, and the permanence of the impact. The significance of the impact is assessed as being **moderate** at this site because the sensitivity of the aquatic ecosystems is low, as:

- UC8 is ephemeral and contains water for only very short periods of time. It did not contain water at the time of the post wet season survey, when many of the ephemeral streams on the mainland contained the last remnants of pools, and the occasional one still had minor flow. This suggests that UC8 flows only during and immediately after rainfall events, with the annual flow period likely to be measured in weeks rather than months.
- At the time of the post wet season survey, the entire length of UC8 was walked and no remnant pools were found; therefore, UC8 could only support aquatic communities that can colonise rapidly and have short life cycles or are able to move between waterways (e.g., flying insects with aquatic larval stages).
- Due to the very short flow period, UC8 is unlikely to provide significant habitat for species moving up from marine environments during floods.
- There are no pools, lakes or headwater refuges for aquatic fauna to move into and no connectivity to permanent watercourses; therefore, UC8 has no value as a movement corridor for aquatic species.
- Database searches indicate there are no listed species or species of conservation significance that might utilise habitat of this nature within the study area.
- There are multiple examples of similar ephemeral, first-order stream systems on Curtis Island that discharge into marine environments; hence, the loss of this habitat represents only a very small proportion of similar habitat in the local area.

Construction of the perimeter fence, firebreak and intra-site access road at TWAF 8 will necessitate crossings of the upper reaches of Targinie Creek. Riparian vegetation will need to be cleared at crossings and a suitable crossing constructed, such as box culverts (or similar) to enable fauna to move under the road and along the wildlife corridor.

The magnitude of the impacts of the project on upper reaches of Targinie Creek will be medium. The significance of impacts is assessed as being **low** due to the low sensitivity of this watercourse.

18.4.2 Changes to Bank and Bed Profile or Flow Regime

Watercourse crossings are not anticipated to be required on the mainland. Construction activities will result in a potential short-term decline in water quality due to increased sediment mobilisation and transport (with changes in scouring and deposition patterns), and mobilisation of acid sulfate soils. Any works within a watercourse will impede passage of aquatic biota, creating barriers to the movement of fish, macrofauna or seeds.

Construction on Curtis Island will permanently replace aquatic ecosystems within the LNG plant footprint. The main drainage feature is over 1 km in length, with additional associated side gullies and channels. It is dry for large parts of the year and, as a consequence, has little or no aquatic vegetation present. Riparian vegetation along the length of the drainage feature will be removed. The magnitude of impacts at this site is high. The low sensitivity of this site means the significance of impacts is assessed as being **moderate.**

All other impacts (relating to changes to bank and bed profile or flow regime) on aquatic ecosystems within the study area will be short term and localised, and impacts at TWAF 8 are assessed as being of **negligible** significance.

18.4.3 Aquatic Habitat Fragmentation

Linear projects involving water crossings may create barriers to the movement of fish, macrofauna or seeds, particularly if infrastructure is placed within the stream beds or on the banks. This may result in increased vulnerability to local extinction and changes in species composition within aquatic communities within the study area. Species with large home ranges may be unable to persist in smaller patches of habitat.

Changes in hydrology may exacerbate aquatic habitat fragmentation by reducing the depth of water over barriers or by creating velocity barriers. Edge effects such as predation and competition would increase as aquatic fauna becomes trapped at stream barriers.

No watercourse crossings are anticipated on the mainland. Should the feed gas pipeline cross a waterway, it will potentially create a flow velocity barrier. The construction of the perimeter fence, firebreak and the intra-site access road at TWAF 8 will cross the upper reaches of Targinie Creek.

Aquatic habitat in the lower reaches of UC8 on Curtis Island will be permanently displaced. The drainage feature does not provide connectivity to any permanent aquatic environments, or to permanent watercourses, or act as a migratory route or connective habitat for aquatic species. The removal of over 1 km of this system and replacement with an artificial, lined channel results in a high magnitude of impact. Due to the low sensitivity of this site, the significance of impacts is assessed as being **moderate.**

Impacts from aquatic habitat fragmentation at TWAF 8 will be localised (with works adjacent to the watercourse restricted to the construction of the perimeter fence, firebreak and the intra-site access road) and of short-term duration. They have been assessed as of low magnitude and the significance rated as **negligible**.

18.4.4 Sedimentation or Pollution Release to Watercourse

During construction, increased sediment loading to adjacent watercourses could occur as a result of excavations, runoff from stockpiles, plant washdown, runoff from site roads and earthworks. Sediments can cause damage to aquatic invertebrates and fish through deposition smothering suitable habitat or interfering with feeding and respiratory systems. Increased sediment loading may also smother aquatic plants and increased turbidity levels can lead to decreased dissolved oxygen levels.

Activities requiring the use of chemicals or fuels within the vicinity of watercourses and drainage lines may result in accidental spills and pollution of waterbodies and associated loss of aquatic communities. Construction and operation activities across the area of disturbance have the potential to impact on water quality through accidental spills.

Accidental spills of organic pollution such as effluent would result in enrichment of waterways with nutrients, resulting in noxious algal blooms, proliferation of aquatic weeds and contamination with pathogens. This could further result in potential exposure of humans and aquatic organisms to pathogens such as giardia and cryptosporidium (see Appendix 27, Health Impact Assessment).

Aquatic habitat in the lower reaches of UC8 on Curtis Island, within and downstream of the LNG plant, will be subject to increased sediment loading as a result of extensive earthworks activities, and greater potential for accidental spills from construction activities. The magnitude of these

impacts is medium. Due to the low sensitivity of this site, the significance of impacts is assessed as **low.**

As a result of earthworks and construction activities at TWAF 8, impacts on aquatic communities in upper reaches of Targinie Creek have been assessed as of medium magnitude. The significance of impacts from aquatic habitat fragmentation is rated as **low**.

18.4.5 Translocation of Pest Flora and Fauna

There is the potential for all construction, operation and decommissioning activities to facilitate the spread of pest aquatic flora and fauna, such as cumbungi and hymenachne, especially when machinery is moved between catchments and regions close to watercourses.

Introduction of invasive or listed noxious aquatic plant species can displace native species and result in degraded habitat for aquatic and semi-aquatic fauna. Invasive plant species may alter flow characteristics of waterways, affecting habitat quality and geomorphic processes.

Introduction of some pest aquatic plant species can result in 'choking' of waterways, reducing light penetration and leading to organic/nutrient loading when blooms die back during winter months. Pest aquatic fauna can displace native species, with a resultant loss of biodiversity and changes in ecosystem dynamics.

The very limited availability of aquatic habitat on Curtis Island and the ephemeral nature of aquatic ecosystems will limit colonisation of natural waterways by most aquatic fauna species. Some aquatic flora species that are tolerant of periods of desiccation (e.g., cumbungi) could be introduced, although the area where this could potentially occur is restricted by tidal incursion and very limited availability of water. The significance of impacts is assessed as **negligible**.

On the mainland, waterways exhibit greater connectivity with greater potential for spread of these species across a wider spatial range. At the mainland tunnel entry site, impacts will be restricted to the area around the tunnel launch shaft and tunnel spoil disposal area. Impacts are unlikely to reach at Boat Creek over 500 m to the north and, although tidal movements have the potential to transfer pest flora and fauna to Boat Creek, the significance of impacts is **low**. The freshwater reaches of the creek will not be impacted. At TWAF 8, the magnitude of impacts is moderate due to greater connectivity to nearby systems, although the significance of impacts is also **low**.

18.4.6 Increase in Mosquitoes and Biting Midges

The project will increase the potential for the breeding of biting insects and mosquitoes. Although no new aquatic habitat, such as marshes or standing water, will be created as a result of the project, water pooling at construction sites or in, for example, wheel ruts, provides breeding grounds for biting insects such as mosquitoes. These may occur anywhere in the study area where ground-breaking, vegetation removal or vehicle access activities occur (see Appendix 10, Pest Management Plan).

The project is located close to mangrove habitat and mudflats, which are favoured mosquito breeding areas. Species in these areas may be saline dependent and will not spread as a result of project activities in terrestrial areas.

Biting insects, including mosquitoes, have the potential to spread diseases such as dengue fever and Ross River virus (see Chapter 29, Hazard and Risk).

The sensitivity rating protocols used for other impacts are not applicable for assessing this particular issue, and the sensitivity is assessed based on proximity to residences. This issue has been assigned a medium sensitivity rating since the majority of works will be located more than

5 km from significant residential populations or proposed construction camps, however the presence of biting insects at worksites also requires consideration.

The magnitude of impacts has been assessed as medium as a result of the widespread potential for small bodies of standing water to form across the project area. The significance of impacts is therefore assessed as **moderate**.

18.4.7 Altered Geomorphology and Runoff Patterns

The creation of large areas of hardstanding will reduce the permeability of large areas of catchments both on Curtis Island and the mainland, but predominantly at the LNG plant site. Reduced permeability will lead to increased surface runoff and altered geomorphology and runoff patterns.

This change may manifest in creation of velocity barriers to movement of biota if surface flows are significantly increased or creation of physical barriers to movement if surface flows are significantly decreased and deposition rates increase.

Increased deposition would lead to smothering of aquatic habitat, particularly cobble substrate, by reducing the availability of habitat for species reliant on these substrates. Increased or variable flow velocities would result in increased erosion of stream banks, with potential for incision, bank slumping, bar formation, scouring and other impacts depending on the specifics of the site and the magnitude of hydrological change.

The LNG plant site represents the largest area that will experience reduced permeability and increased surface water runoff (the area of disturbance on Curtis Island is approximately 265 ha). Natural flows and upstream geomorphic processes in the ephemeral system of UC8 will not be affected. The removal of lower reaches of this system and replacement with areas of hardstanding results in impacts on Curtis Island and UC8 of high magnitude and **moderate** significance.

The construction of TWAF 8 may result in a minor alteration of surface water hydrology and geomorphic processes locally although there is greater potential for connectivity with more permanent systems and aquatic communities. The significance of impacts at TWAF 8 is **low**.

18.4.8 Summary of Impacts

Key impacts and threatening processes resulting from project activities are summarised in Table 18.5. The highest magnitude impacts are associated with the construction of the LNG plant and associated infrastructure on Curtis Island, and the resultant removal of downstream reaches of the ephemeral drainage feature UC8.

Table 18.5 Likely impacts from project activities on freshwater ecology

Likely Affected Aquatic Ecosystems	Activity	Nature of Impacts	Sensitivity	Magnitude	Significance Prior to Mitigation
UC8 (Curtis Island Arrow LNG Plant)	Removal of riparian and aquatic vegetation to allow for access and construction of the LNG plant and supporting infrastructure on Curtis Island, and infrastructure on the mainland.	Disturbance of riparian and aquatic vegetation. General impacts include: • Loss or degradation of aquatic habitat for shelter, foraging or spawning/nursery areas. • Water quality decline due to sediment transport, biochemical oxygen demand, nutrient loads, etc. • Reduced shading from vegetation, resulting in greater diurnal temperature variations. • Physical disturbance of riparian and aquatic vegetation in the vicinity of stream crossings.	Low	High	Moderate
Targinie Creek at TWAF 8			Low	Medium	Low
UC8 (Curtis Island Arrow LNG Plant)	All access and construction activities within the vicinity of a watercourse.	Changes to bank and bed profile or flow regime. General impacts include: • Potential short-term water quality decline due to sediment transport, biochemical oxygen demand and mobilisation of acid sulfate soils (see Chapter 12, Land Contamination and Acid Sulfate Soils). • Potential for altered erosion processes, with changes in scouring and deposition patterns. • Potential for impedance of passage for aquatic biota.	Low	High	Moderate
Targinie Creek at TWAF 8			Low	Low	Negligible

Table 18.5 Likely impacts from project activities on freshwater ecology (cont'd)

Likely Affected Aquatic Ecosystems	Activity	Nature of Impacts	Sensitivity	Magnitude	Significance Prior to Mitigation
UC8 (Curtis Island Arrow LNG Plant)	All access and construction activities within the vicinity of a watercourse.	Aquatic habitat fragmentation including obstacles to fish movement. General impacts include: • Increased vulnerability to local extinction as a result of stochastic events and medium to long term decline in genetic diversity. • Changes in species composition as a result of the local extinction of some species from a community. Species with large home ranges may be unable to persist in small patches. • Increased edge effects such as predation, competition and weed invasion. • Inability for migratory species to access spawning habitat or for juvenile recruitment back into the stream. • Increased predation as a result of migrating adult or juvenile animals becoming trapped at in-stream barriers.	Low	High	Moderate
Targinie Creek at TWAF 8			Low	Low	Negligible
UC8 (Curtis Island Arrow LNG Plant)	All construction and operational activities within the vicinity of a watercourse. Activities requiring use of chemicals or fuels within the vicinity of watercourses.	Sedimentation or pollution release to watercourse impacting on aquatic systems and processes. General impacts include: • Damage to aquatic invertebrates and fish through sediment loading and smothering of aquatic plants. • Loss of aquatic communities as a result of pollution with fuels or other toxic substances. • Enrichment of waterways with nutrients, resulting in noxious algal blooms and proliferation of aquatic weeds. • Loss of aquatic communities due to oxygen depletion of waterways. • Contamination and exposure of humans and aquatic organisms to pathogens such as giardia and cryptosporidium. • Loss of aesthetic amenity due to odour and unsightly scums.	Low	Medium	Low
Targinie Creek at TWAF 8			Low	Medium	Low

Table 18.5 Likely impacts from project activities on freshwater ecology (cont'd)

Likely Affected Aquatic Ecosystems	Activity	Nature of Impacts	Sensitivity	Magnitude	Significance Prior to Mitigation
UC8 (Curtis Island Arrow LNG Plant)	All construction, operation and decommissioning activities may facilitate the spread of pest aquatic flora and fauna, especially when machinery is moved between catchments and regions close to watercourses.	Translocation of pest flora and fauna. General impacts include: • Introduction of invasive or listed noxious aquatic plant species that can displace native species and result in degraded habitat for aquatic and semi-aquatic fauna. • Introduction of invasive plant species that may affect the flow characteristics of watercourses, with associated changes in habitat quality, geomorphic processes and visual/recreational amenity. • Introduction of some pest aquatic plant species that could result in 'choking' of waterways, reduction of light penetration, and organic/nutrient loading when blooms die back during winter months. • The introduction of noxious aquatic plants and animals that could result in the displacement of native species, with a resultant loss of biodiversity and changes in ecosystem dynamics. • Introduction of diseases, parasites or pathogens not currently found within waterways in the study area that may adversely impact on existing aquatic communities.	Low	Low	Negligible
Targinie Creek at TWAF 8			Low	Medium	Low
Freshwater reaches of Boat Creek and UC1			Medium	Low	Low
All project locations	All activities creating standing water, especially earthworks.	Increase in mosquitoes and biting midges. General impacts include: • Increase in potential for the breeding of biting insects and mosquitoes in areas of standing water pooling at construction sites. • The potential for biting insects, including mosquitoes, to spread diseases such as dengue fever and Ross River virus.	Medium	Medium	Moderate

Table 18.5 Likely impacts from project activities on freshwater ecology (cont'd)

Likely Affected Aquatic Ecosystems	Activity	Nature of Impacts	Sensitivity	Magnitude	Significance Prior to Mitigation
UC8 (Curtis Island Arrow LNG Plant)	All construction activities. The creation of large areas of hardstanding will reduce the permeability of large areas of catchments both on Curtis Island and the mainland, but predominantly at the LNG plant site.	Altered geomorphology and runoff patterns. General impacts include: • Creation of velocity barriers to movement of biota if surface flows are significantly increased. Creation of physical barriers to movement if surface flows are significantly decreased. • Smothering of aquatic habitat, particularly cobble substrate, by sediment transport. • Increased erosion of stream banks if surface flows are increased or become more variable, with potential for incision, bank slumping, bar formation, scouring and other impacts (dependent on the specifics of the site and the magnitude of hydrological change).	Low	High	Moderate
Targinie Creek at TWAF 8			Low	Medium	Low

18.5 Avoidance, Mitigation and Management Measures

This section describes management measures to address the potential impacts on aquatic ecology. Mitigation proposed follows a hierarchy that first avoids the impact, if practical (through project design), then reduces the impact through mitigation and management at general and site specific levels.

Foreseen direct and indirect effects on aquatic flora and fauna are discussed, including strategies for protecting rare or threatened species and any obligations, legislation or policies imposed by the Queensland and Australian governments.

18.5.1 Designing Out Impacts

The following principles have been incorporated into the design of the project to minimise impacts on aquatic ecology:

- Design TWAF 8 to minimise disturbance to the 'Of Concern' RE 11.3.4 ('*Eucalyptus tereticornis* and/or *Eucalyptus* spp. tall woodland on alluvial plains') to maintain connectivity of habitat along the Targinie Creek riparian zone. [C13.04]
- Where practical, align the perimeter fence at TWAF 8 to adopt the alignment of the existing fence where it crosses Targinie Creek. [C13.05]
- Design any intra-site access road crossing of Targinie Creek at TWAF 8 to include box culverts (or similar) to enable fauna movement under the road and along the wildlife corridor. [C13.06]

18.5.2 General Environmental Controls

Strategies and protocols relevant to the protection of freshwater aquatic communities, habitat and processes, as detailed in the Australian Pipeline Industry Association Code of Environmental Practice: Onshore Pipelines (APIA, 2009) will be implemented as part of the project. [C18.01] These measures are discussed further within Chapter 13, Surface Water, Hydrology and Water Quality. In addition, the following measure will be implemented:

- Induct all personnel prior to entering a project site, including on measures for managing the impacts on flora and fauna likely to be present. [C17.22]

The following specific mitigation measures will also be applied to reduce the impacts from project activities on aquatic ecology.

Working Within and Adjacent to Watercourses

The following mitigations relating to works within and adjacent to watercourses, specific to aquatic ecology will be implemented:

- Do not abstract freshwater from watercourses, or dispose of effluent directly into freshwater watercourses except clean stormwater. [C13.15]
- Keep the footprint of the mainland tunnel entry shaft and tunnel spoil disposal area to a minimum of 500 m clear of Boat Creek. [C13.07]
- Where works are required in watercourses, they will be confined to reduced width construction right of ways that preserve, to the extent practical, the integrity of the riparian vegetation and any associated wildlife corridors. [C13.22]
- Limit the clearing of riparian vegetation to that necessary for safety. [C18.02]

- Where waterway crossings are necessary, cross ephemeral streams in preference to permanent streams, where practical. Where pipeline crossings are necessary, approach stream crossings perpendicular to the stream where practical, to reduce bank erosion risk and minimise the footprint within the bed and riparian zone. [C13.16]
- Avoid works near stream banks during periods of heavy rainfall where possible. If works cannot be timed to avoid heavy rainfall, adopt additional measures, such as the use of berms and silt fences. [C11.09]

Translocation of Pest Flora and Fauna

Pest management mitigation measures are set out in the pest management plan for the project (see Appendix 10, Pest Management Plan). Staff and contractors will be prevented from camping, fishing or carrying out other recreational activities in waterways in the project area while on shift, to prevent the accidental introduction of aquatic pest species on fishing gear or bait. [C18.03]

Increase in Mosquitoes and Biting Midges

Pest management mitigation measures are set out in the pest management plan for the project (see Appendix 10, Pest Management Plan). Undertake earthworks and rehabilitation activities to facilitate drainage and reduce the potential for standing water to accumulate. [C13.20]

Measures to Protect Fish of Regional Conservation Significance

Two fish species were identified in the Gladstone–Fitzroy Pipeline Project EIS as having regional conservation significance (although not listed under either EPBC or Nature Conservation acts) and as being potentially present in the lower reaches of Boat Creek. Purple spotted gudgeon and Rendahl's tandan both require permanent water with an abundance of submerged aquatic vegetation.

The following measures will be implemented when works are undertaken in the vicinity of Boat Creek:

- Avoid discharging tail water from the tunnel spoil disposal area into Boat Creek. [C13.21]
- Define and adhere to machinery hygiene protocols, to prevent the translocation of pest species, particularly weeds such as salvinia, cumbungi and para grass. [C18.04]

18.6 Residual Impacts

The assessment of residual impacts upon freshwater ecology values assumes that all the mitigation measures are implemented successfully. The magnitude of impacts upon the ecological values defined across the project area will be reduced in some cases, reducing the overall significance of the impact of the project on aquatic flora and fauna. A summary of the significance of residual impacts following the implementation of mitigation is presented in Table 18.6.

Specific controls to reduce the impacts at the LNG plant site are not practical, as a large section of the ephemeral system at this site (over 1 km in length) will be removed. With the exception of translocation of pest flora and fauna, the impacts from the project at this site on aquatic ecosystems remain as of **moderate** significance in all cases.

Impacts on the mainland for upper reaches of Targinie Creek at TWAF 8 and Boat Creek north of the mainland tunnel entry shaft and tunnel spoil disposal area remain at the premitigation levels. Construction will not take place within 500 m of Boat Creek, and the significance of impacts on this site will be **low**. Likewise at Targinie Creek, construction activities being kept to a minimum adjacent to the watercourse resulted in premitigation impacts being assessed as low significance, and these impacts remain **low** post mitigation.

Table 18.6 Significance of residual impacts relating to freshwater ecology

Likely Affected Aquatic Ecosystems	Sensitivity	Impact	Significance Prior to Mitigation	Relevant Proposed Mitigation	Significance of Residual Impacts
UC8 (Curtis Island Arrow LNG Plant)	Low	Disturbance of riparian and aquatic vegetation.	Moderate	Strategies and protocols relevant to freshwater aquatic communities, as detailed in the Australian Pipeline Industry Association Code of Environmental Practice: Onshore Pipelines (APIA, 2009) will be implemented as part of the project.	Moderate
Targinie Creek at TWAF 8	Low		Low		Low
UC8 (Curtis Island Arrow LNG Plant)	Low	Changes to bank and bed profile and/or flow regime.	Moderate		Moderate
Targinie Creek at TWAF 8	Low		Negligible		Negligible
UC8 (Curtis Island Arrow LNG Plant)	Low	Aquatic habitat fragmentation including obstacles to fish movement.	Moderate		Moderate
Targinie Creek at TWAF 8	Low		Negligible		Negligible
UC8 (Curtis Island Arrow LNG Plant)	Low	Sedimentation or pollution release to watercourse impacting on aquatic systems and processes.	Low		Low
Targinie Creek at TWAF 8	Low		Low		Low
UC8 (Curtis Island Arrow LNG Plant)	Low	Translocation of pest flora and fauna.	Negligible	Staff and contractors will be prevented from camping, fishing or other recreational activities within waterways of the project area while on shift to prevent the accidental introduction of aquatic pest species on fishing gear or bait.	Negligible
Targinie Creek at TWAF 8	Low		Low		Low
Freshwater reaches of Boat Creek and UC1	Medium		Low		Low
All project locations	Medium	Increase in mosquitoes and biting midges.	Moderate	Pest management mitigation measures are set out in the pest management plan for the project (Appendix 10, Pest Management Plan). Earthworks and rehabilitation activities will be undertaken to facilitate drainage and reduce the potential for standing water to accumulate.	Low
UC8 (Curtis Island Arrow LNG Plant)	Low	Altered geomorphology and runoff patterns.	Moderate	Strategies and protocols relevant to freshwater aquatic communities, as detailed in the Australian Pipeline Industry Association Code of Environmental Practice: Onshore Pipelines (APIA, 2009) will be implemented as part of the project.	Moderate
Targinie Creek at TWAF 8	Low		Low		Low

The significance of an increase in mosquitoes and biting midges as a result of the project was reduced from moderate to **low**, following implementation of the mitigation measures.

The project is not expected to have significant impacts on freshwater aquatic ecosystems, water quality or aquatic resources. The most significant impact is the removal of downstream reaches of UC8 at the LNG plant site.

18.7 Inspection and Monitoring

Likely inspection and monitoring activities during construction include:

- Inspect for exotic flora and fauna species within the project area of disturbance and immediately adjacent areas.
- Inspect erosion and sediment control measures following significant rainfall events until ground stabilisation is achieved.
- Inspect spill containment controls and spill response kits on a monthly basis.
- Develop a detailed site environmental monitoring program and document in the construction and operations EMPs.

Stormwater monitoring measures and monitoring of the diversion of UC8 at the LNG plant site are detailed in Chapter 13, Surface Water Hydrology and Water Quality.

18.8 Commitments

The measures (commitments) that Arrow Energy will implement to manage impacts on freshwater ecology are set out in Table 18.7.

Table 18.7 Commitments: Freshwater ecology

No.	Commitment
C13.04	Design TWAF 8 to minimise disturbance to the 'Of Concern' RE 11.3.4 ('*Eucalyptus tereticornis* and/or *Eucalyptus* spp. tall woodland on alluvial plains') to maintain connectivity of habitat along the Targinie Creek riparian zone. Common with Chapter 13, Surface Water Hydrology and Water Quality, and Chapter 17, Terrestrial Ecology.
C13.05	Where practical, align the perimeter fence at TWAF 8 to adopt the alignment of the existing fence where it crosses Targinie Creek. Common with Chapter 13, Surface Water Hydrology and Water Quality, and Chapter 17, Terrestrial Ecology.
C13.06	Design any intra-site access road crossing of Targinie Creek at TWAF 8 to include box culverts (or similar) to enable fauna movement under the road and along the wildlife corridor. Common with Chapter 13, Surface Water Hydrology and Water Quality, and Chapter 17, Terrestrial Ecology.
C18.01	Implement strategies and protocols relevant to the protection of freshwater aquatic communities, habitat and processes, as detailed in the Australian Pipeline Industry Association Code of Environmental Practice: Onshore Pipelines (APIA, 2009) as part of the project.
C13.07	Keep the footprint of the mainland tunnel entry shaft and tunnel spoil disposal area to a minimum of 500 m clear of Boat Creek. Common with Chapter 13, Surface Water Hydrology and Water Quality.
C17.22	Induct all personnel prior to entering a project site, including on measures for managing the impacts on flora and fauna likely to be present. Common with Chapter 17, Terrestrial Ecology.
C13.22	Where works are required in watercourses, they will be confined to reduced width construction right of ways that preserve, to the extent practical, the integrity of the riparian vegetation and any associated wildlife corridors. Common with Chapter 13, Surface Water Hydrology and Water Quality.

Table 18.7 Commitments: Freshwater ecology (cont'd)

No.	Commitment
C18.02	Limit the clearing of riparian vegetation to that necessary for safety.
C13.16	Where waterway crossings are necessary, cross ephemeral streams in preference to permanent streams, where practical. Where pipeline waterway crossings are necessary, approach stream crossings perpendicular to the stream where practical, to reduce bank erosion risk and minimise the footprint within the bed and riparian zone. Common with Chapter 13, Surface Water Hydrology and Water Quality
C11.09	Avoid works near stream banks during periods of heavy rainfall where possible. If works cannot be timed to avoid heavy rainfall, adopt additional measures, such as the use of berms and silt fences. Common with Chapter 11, Geology, Landform and Soils, and Chapter 13, Surface Water Hydrology and Water Quality.
C18.03	Prevent staff and contractors from camping, fishing or carrying out other recreational activities in waterways in the project area while on shift, to prevent the accidental introduction of aquatic pest species on fishing gear or bait.
C13.20	Undertake earthworks and rehabilitation activities to facilitate drainage and reduce the potential for standing water to accumulate. Common with Chapter 13, Surface Water Hydrology and Water Quality
C13.21	Avoid discharging tail water from the tunnel spoil disposal area into Boat Creek. Common with Chapter 13, Surface Water Hydrology and Water Quality
C18.04	Define and adhere to machinery hygiene protocols to prevent the translocation of pest species, particularly weeds such as salvinia, cumbungi and para grass.
C13.15	Do not abstract freshwater from watercourses, or dispose of effluent directly into freshwater watercourses, except clean stormwater. Common with Chapter 13, Surface Water Hydrology and Water Quality