APPENDIX 11

ARROW LNG PLANT

Freshwater Ecology and Water Quality Impact Assessment

arrow energy
go further

Arrow LNG Plant
Freshwater Aquatic Ecology Impact Assessment

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Prepared for:
Arrow CSG Australia Pty Ltd and Coffey Environments Pty Ltd

Aquateco Consulting Pty Ltd
PO Box 336
Tewantin,
Qld 4565

Telephone: 61 (07) 5335 8500
Email: info@aquateco.com
Website: www.aquateco.com

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Executive Summary

Freshwater Aquatic Ecology Impact Assessment

This evaluation of freshwater aquatic communities, habitat and processes has been undertaken by:

- Searching and reviewing relevant environmental databases such as the *Environment Protection and Biodiversity Conservation Act (EPBC) (1999)* and *Nature Conservation Act (NC Act) (1992)* online search tools.
- Review of the environmental approvals documentation produced by other LNG proponents in the Gladstone/Curtis Island area.
- Wet and dry season inspections of waterways within the study area and a much broader freshwater ecology study area.
- Development of appropriate criteria for determining the sensitivity of aquatic ecosystem values within the study area to the types of disturbance likely to occur as a result of a project of this nature.
- Development of criteria for assessing the magnitude of impacts associated with a project of this nature.
- Using ecological sensitivity and impact criteria (magnitude) to determine the significance of impacts on aquatic ecosystems within the study area.
- Recommendation of appropriate management options for avoiding, minimising and/or mitigating impacts of the project on aquatic ecosystems.
- Determination of the expected significance of residual impacts (i.e., post-mitigation) using the same sensitivity and magnitude criteria.
- Evaluation of the degree to which this project might contribute to the cumulative impacts associated with a gamut of other development projects in the region, including LNG, resource development, ports development and infrastructure projects.
- Consideration of appropriate aquatic ecosystem monitoring and/or inspection protocols for the project.

Overview of Existing Aquatic Environments

Aquatic ecosystems within the study area and immediate surrounds are sparse and are generally ephemeral in nature. A small number of remnant pools were noted in the freshwater ecology study area during dry season conditions, but none of these are within the boundaries of the project area.

The quality of aquatic habitat was generally low, with most streams dry for much of the year, and with minimal variability or structural habitat present to provide refuge for aquatic communities during periods of flow.

State and Commonwealth database searches indicated that the project area may potentially support populations of two listed aquatic species – water mouse (*Xeromys myoides*) and estuarine crocodile (*Crocodylus porosus*). The former of these two species has been addressed in the terrestirial flora and fauna technical report, while site inspections have revealed that the habitat within and adjacent to the study area is not suitable for saltwater crocodiles. No other aquatic species of conservation significance have been previously recorded in the area and site inspections confirmed the area is unlikely to support communities or species of conservation significance.

Sensitivity of Freshwater Aquatic Ecosystems and Impact Assessment

Criteria were established to determine the sensitivity of freshwater aquatic ecosystems within the study area, as well as for assessing the magnitude (size and duration) of anticipated project impacts.

The application of these criteria indicated that the aquatic communities, habitat and processes within the study area are likely to be tolerant to a degree of disturbance, and that the disturbance anticipated as a result of the Arrow LNG Plant (hereafter referred to as the project) is unlikely to have significant impacts on these values except on Curtis Island, where the natural freshwater aquatic systems will be replaced by the LNG plant. This latter disturbance is unavoidable and permanent, although the freshwater habitat that will be lost is not of high conservation value, does not support significant aquatic species and represents a small proportion of similar habitat that exists locally.

Environmental management controls such as erosion/sediment and stormwater management protocols have been addressed in other technical studies and will be in place throughout the project.

Specific Mitigation Measures and Residual Impact Assessment

Due to the paucity of aquatic habitat and species within the study area, specific environmental controls above and beyond those normally included in an environmental management plan for this type of project are minimal. Recommendations in this regard focus on the protection of any areas of aquatic habitat not identified by these studies that might be discovered during construction (e.g., remnant waterholes or pools). These strategies are particularly relevant if the habitat is suitable for supporting two unlisted fish species listed as local conservation significance that have been identified as potentially present in the area (although very unlikely to be present within the study area).

Monitoring and Inspection

Due to the low conservation value of aquatic systems on the mainland portion of the site and the generally short-term impacts associated with activities in this area, no specific

inspection or monitoring protocols are suggested. Standard monitoring of compliance with the project environmental management plan are considered sufficient to protect freshwater aquatic environments.

The ephemeral aquatic ecosystems on Curtis Island will be displaced by the project, with the lower reaches diverted around the plant. This will not impact on the ecology of the upper reaches, and will render the lower reaches man-made, hence no monitoring or ongoing inspection of aquatic ecosystem values are required in this part of the project area.

Contribution of Arrow LNG Plant to Cumulative Impacts

As the impact of the project on freshwater aquatic ecosystems is considered to be low, the contribution of the project to cumulative impacts in association with other major development projects is also considered to be low. This is in part due to the nature of the project and the proposed approach to construction and operation, but is also largely due to the paucity of freshwater aquatic values and the tolerance of existing values within the study area to disturbance events.

Glossary of terms

Anadromous	Fish species that move into rivers from the sea for the purpose of spawning.
AusRivAs	Australian River Assessment System (AusRivAs). A standardised rapid assessment tool based on ecological, water quality and physical attributes of streams. AusRivAS has many components, but is most widely used for macroinvertebrate based assessments.
BOD	Biochemical oxygen demand (BOD). A measure of organic pollution based on the potential for oxygen depletion during biochemical breakdown. High BOD levels can result in mortality of aquatic fauna through asphyxiation.
Catadromous	Fish species that migrate from river systems into the ocean for the purpose of spawning.
Coleopterans	Order of insects commonly referred to as beetles. Numerous aquatic species and/or species whose life history involves an aquatic phase.
Dynoflagellate	Flagellated unicellular protists. Microbial organisms responsible for toxic blooms known as “red tides”.
Ephemeral	In the context of streams, a system that only flows during and immediately after rainfall events, usually drying completely during the dry season, although some may contain remnant pools that persist for much of all of the year. The latter may also be referred to as “semi-permanent”.
Fluvial	Associated with rivers and streams.
GDE	See groundwater dependent ecosystems (GDE).
Groundwater dependent ecosystems	Aquatic or subterranean ecosystems that are dependent on groundwater influences to maintain suitable habitat. See also stygofauna and troglofauna.
Hemipterans	Order of insects commonly referred to as bugs. Numerous aquatic species and/or species whose life history involves an aquatic phase.
Lacustrine	Associated with lakes and ponds.
Macroinvertebrates	Aquatic fauna that do not bear a spine. Includes insects, molluscs and crustaceans.
O/E Score	Observed over expected. A measure used in AusRivAS to quantify the macroinvertebrate species recorded at a test site with those expected based on historical surveys of suitable reference sites
Palustrine	Associated with wetlands, swamps, marshes and bogs.
PET Score	Total number of aquatic macroinvertebrates of the orders Plectoptera, Ephemeroptera and Tricoptera recorded at a survey

	site. These orders are known to be pollution sensitive, hence high PET scores indicate good water quality. However, there is some debate about the applicability of this measure in Queensland, as the order Plecoptera is poorly represented in this state.
Potadromous	Fish species undertake migratory movement within the freshwater reaches of a river for the purposes of spawning or foraging.
Propagules	Seeds, spores, shoots or cuttings of vegetation that can disperse and propagate into new plants.
Signal Score	Alternative pollution sensitivity score for aquatic macroinvertebrates.
Stygofauna	Small aquatic macroinvertebrates that live within the aquifers and subterranean pore spaces. Sensitive to changes in groundwater level, pressure, quality and flow rates.
Troglofauna	Subterranean macroinvertebrates that live only in caves and cavities. Can be sensitive to changes in groundwater level, pressure, quality or flow rates.

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1 Arrow LNG Plant Project Description

1.1 Proponent

Arrow CSG (Australia) Pty Ltd (Arrow Energy) proposes to develop a liquefied natural gas (LNG) facility on Curtis Island off the central Queensland coast near Gladstone. The project, known as the Arrow LNG Plant, is a component of the larger Arrow LNG Project.

The proponent is a subsidiary of Arrow Energy Holdings Pty Ltd which is wholly owned by a joint venture between subsidiaries of Royal Dutch Shell plc and PetroChina Company Limited.

1.2 Arrow LNG Plant

Arrow Energy proposes to construct the Arrow LNG Plant in the Curtis Island Industry Precinct at the southwestern end of Curtis Island, approximately 6 km north of Gladstone and 85 km southeast of Rockhampton, off Queensland's central coast. In 2008, approximately 10% of the southern part of the island was added to the Gladstone State Development Area to be administered by the Queensland Department of Local Government and Planning. Of that area, approximately 1,500 ha (25%) has been designated as the Curtis Island Industry Precinct and is set aside for LNG development. The balance of the Gladstone State Development Area on Curtis Island has been allocated to the Curtis Island Environmental Management Precinct, a flora and fauna conservation area.

The Arrow LNG Plant will be supplied with coal seam gas from gas fields in the Surat and Bowen basins via high-pressure gas pipelines to Gladstone, from which a feed gas pipeline will provide gas to the LNG plant on Curtis Island. A tunnel is proposed for the feed gas pipeline crossing of Port Curtis.

The project is described below in terms of key infrastructure components: LNG plant, feed gas pipeline and dredging.

1.3 LNG Plant

Overview.
The LNG plant will have a base-case capacity of 16 Mtpa, with a total plant capacity of up to 18 Mtpa. The plant will consist of four LNG trains, each with a nominal capacity of 4 Mtpa. The project will be undertaken in two phases of two trains (nominally 8 Mtpa), with a financial investment decision taken for each phase.

Operations infrastructure associated with the LNG plant includes the LNG trains (where liquefaction occurs; see 'Liquefaction Process' below), LNG storage tanks, cryogenic pipelines, seawater inlet for desalination and stormwater outlet pipelines, water and wastewater treatment, a 110 m high flare stack, power generators (see 'LNG Plant Power' below), administrative buildings and workshops.

Construction infrastructure associated with the LNG plant includes construction camps (see 'Workforce Accommodation' below), a concrete batching plant and laydown areas.
The plant will also require marine infrastructure for the transport of materials, personnel and product (LNG) during construction and operations (see 'Marine Infrastructure' below).

Construction Schedule.
The plant will be constructed in two phases. Phase 1 will involve the construction of LNG trains 1 and 2, two LNG storage tanks (each with a capacity of between 120,000 m^3 and 180,000 m^3), Curtis Island construction camp and, as if additional capacity is required, a mainland workforce accommodation camp. Associated marine infrastructure will also be required as part of Phase 1. Phase 2 will involve the construction of LNG trains 3 and 4 and potentially a third LNG storage tank. Construction of Phase 1 is scheduled to commence in 2014 with train 1 producing the first LNG cargo in 2017. Construction of Phase 2 is anticipated to commence approximately five years after the completion of Phase 1 but will be guided by market conditions and a financial investment decision at that time.

Construction Method.
The LNG plant will generally be constructed using a modular construction method, with preassembled modules being transported to Curtis Island from an offshore fabrication facility. There will also be a substantial stick-built component of construction for associated infrastructure such as LNG storage tanks, buildings, underground cabling, piping and foundations. Where possible, aggregate for civil works will be sourced from suitable material excavated and crushed on site as part of the bulk earthworks. Aggregate will also be sourced from mainland quarries and transported from the mainland launch site to the plant site by roll-on, roll-off vessels. A concrete batching plant will be established on the plant site. Bulk cement requirements will be sourced outside of the batching plant and will be delivered to the site by roll-on roll-off ferries or barges from the mainland launch site.

1.3.1 LNG Plant Power

Power for the LNG plant and associated site utilities may be supplied from the electricity grid (mains power), gas turbine generators, or a combination of both, leading to four configuration options that will be assessed:

- Base case (mechanical drive): The mechanical drive configuration uses gas turbines to drive the LNG train refrigerant compressors, which is the traditional powering option for LNG facilities. This configuration would use coal seam gas and end flash gas (produced in the liquefaction process) to fuel the gas turbines that drive the LNG refrigerant compressors and the gas turbine generators that supply electricity to power the site utilities. Construction power for this option would be provided by diesel generators.
- Option 1 (mechanical/electrical – construction and site utilities only): This configuration uses gas turbines to drive the refrigerant compressors in the LNG trains. During construction, mains power would provide power to the site via a cable (30-MW capacity) from the mainland. The proposed capacity of the cable is equivalent to the output of one gas turbine generator. The mains power cable would be retained to power the site utilities during operations, resulting in one less gas turbine generator being required than the proposed base case.
- Option 2 (mechanical/electrical): This configuration uses gas turbines to drive the refrigerant compressors in the LNG trains and mains power to power site utilities. Under this option, construction power would be supplied by mains power or diesel generators.
- Option 3 (all electrical): Under this configuration mains power would be used to supply electricity for operation of the LNG train refrigerant compressors and the site utilities. A switchyard would be required. High-speed electric motors would be used to drive the LNG train refrigerant compressors. Construction power would be supplied by mains power or diesel generators.

1.3.2 Liquefaction Process

The coal seam gas enters the LNG plant where it is metered and split into two pipe headers which feed the two LNG trains. With the expansion to four trains the gas will be split into four LNG trains.

For each LNG train, the coal seam gas is first treated in the acid gas removal unit where the carbon dioxide and any other acid gases are removed. The gas is then routed to the dehydration unit where any water is removed and then passed through a mercury guard

bed to remove mercury. The coal seam gas is then ready for further cooling and liquefaction.

A propane, precooled, mixed refrigerant process will be used by each LNG train to liquefy the predominantly methane coal seam gas. The liquefaction process begins with the propane cycle. The propane cycle involves three pressure stages of chilling to pre-cool the coal seam gas to -33°C and to compress and condense the mixed refrigerant, which is a mixture of nitrogen, methane, ethylene and propane. The condensed mixed refrigerant and precooled coal seam gas are then separately routed to the main cryogenic heat exchanger, where the coal seam gas is further cooled and liquefied by the mixed refrigerant. Expansion of the mixed refrigerant gases within the heat exchanger removes heat from the coal seam gas. This process cools the coal seam gas from -33°C to approximately -157°C. At this temperature the coal seam gas is liquefied (LNG) and becomes 1/600th of its original volume. The expanded mixed refrigerant is continually cycled to the propane precooler and reused.

LNG is then routed from the end flash gas system to a nitrogen stripper column which is used to separate nitrogen from the methane, reducing the nitrogen content of the LNG to less than 1 mole per cent (mol%). LNG separated in the nitrogen stripper column is pumped for storage on site in full containment storage tanks where it is maintained at a temperature of -163°C.

A small amount of off-gas is generated from the LNG during the process. This regasified coal seam gas is routed to an end flash gas compressor where it is prepared for use as fuel gas.

Finally, the LNG is transferred from the storage tanks onto LNG carriers via cryogenic pipelines and loading arms for transportation to export markets. The LNG will be regasified back into sales specification gas on shore at its destination location.

1.3.3 Workforce Accommodation

The LNG plant (Phase 1), tunnel, feed gas pipeline, and dredging components of the project each have their own workforces with peaks occurring at different stages during construction. The following peak workforces are estimated for the project:

- LNG plant Phase 1 peak workforce of 3,500, comprising 3,000 construction workers: 350 engineering, procurement and construction (EPC) management workers and 150 Arrow Energy employees.
- Tunnel peak workforce of up to 100.
- Feed gas pipeline (from the mainland to Curtis Island) peak workforce of up to 75.

- A dredging peak workforce of between 20 and 40.

Two workforce construction camp locations are proposed: the main construction camp at Boatshed Point on Curtis Island, and a possible mainland overflow construction camp, referred to as a temporary workers accommodation facility (TWAF). Two potential locations are currently being considered for the mainland TWAF; in the vicinity of Gladstone city on the former Gladstone Power Station ash pond No.7 (TWAF7) or in the vicinity of Targinnie on a primarily cleared pastoral grazing lot (TWAF8). Both potential TWAF sites include sufficient space to accommodate camp infrastructure and construction laydown areas. The TWAF and its associated construction laydown areas will be decommissioned on completion of the Phase 1 works.

Of the 3,000 construction workers for the LNG plant, it is estimated that between 5% and 20% will be from the local community (and thus will not require accommodation) and that the remaining fly-in, fly-out workers will be accommodated in construction camps. The 350 EPC management workers and 150 Arrow Energy employees are expected to relocate to Gladstone with the majority housed in company facilitated accommodation.

The tunnel workforce of 100 people and gas pipeline workforce of 75 people are anticipated to be accommodated in the mainland in company facilitated accommodation. The dredging workforce of 20 to 40 workers will be housed onboard the dredge vessel.

Up to 2,500 people will be housed at Boatshed Point construction camp. Its establishment will be preceded by a pioneer camp at the same locality which will evolve into the completed construction camp.

1.3.4 Marine Infrastructure

Marine facilities include the LNG jetty, materials offloading facility (MOF), personnel jetty and mainland launch site.

LNG Jetty
LNG will be transferred from the storage tanks on the site to the LNG jetty via above ground cryogenic pipelines. Loading arms on the LNG jetty will deliver the product to an LNG carrier. The LNG jetty will be located in North China Bay, adjacent to the northwest corner of Hamilton Point.

MOF
Delivery of materials to the site on Curtis Island during the construction and operations phases will be facilitated by a MOF where roll-on, roll-off or lift-on, lift-off vessels will dock

to unload preassembled modules, equipment, supplies and construction aggregate. The MOF will be connected to the LNG plant site via a heavy-haul road.

Boatshed Point (MOF 1) is the base-case MOF option and would be located at the southern tip of Boatshed Point. The haul road would be routed along the western coastline of Boatshed Point (abutting the construction camp to the east) and enters the LNG Plant site at the southern boundary. A quarantine area will be located south of the LNG plant and will be accessed via the northern end of the haul road.

Two alternative options are being assessed, should the Boatshed Point option be determined to be not technically feasible:

- South Hamilton Point (MOF 2): This MOF option would be located at the southern tip of Hamilton Point. The haul road from this site would traverse the saddle between the hills of Hamilton Point to the southwest boundary of the LNG plant site. The quarantine area for this option will be located southwest of the LNG plant near the LNG storage tanks.
- North Hamilton Point (MOF 3): This option involves shared use of the MOF being constructed for the Santos Gladstone LNG Project (GLNG Project) on the northwest side of Hamilton Point (south of Arrow Energy's proposed LNG jetty). The GLNG Project is also constructing a passenger terminal at this site, but it will not be available to Arrow Energy contractors and staff. The quarantine area for this option would be located to the north of the MOF. The impacts of construction and operation of this MOF option and its associated haul road were assessed as part of the GLNG Project and will not be assessed in this EIS.

Personnel Jetty

During the peak of construction, base case of up to 1,100 people may require transport to Curtis Island from the mainland on a daily basis. A personnel jetty will be constructed at the southern tip of Boatshed Point to enable the transfer of workers from the mainland launch site to Curtis Island by high-speed vehicle catamarans (Fastcats) and vehicle or passenger ferries (ROPAX). This facility will be adjacent to the MOF constructed at Boatshed Point. The haul road will be used to transport workers to and from the personnel jetty to the construction camp and LNG plant site. A secondary access for pedestrians will be provided between the personnel jetty and the construction camp.

Mainland Launch Site

Materials and workers will be transported to Curtis Island via the mainland launch site. The mainland launch site will contain both a passenger terminal and a roll-on, roll-off facility. The passenger terminal will include a jetty and transit infrastructure, such as

amenities, waiting areas and car parking. The barge or roll-on ,roll-off facility will have a jetty, associated laydown areas, workshops and storage sheds.

The two location options for the mainland launch site are:

- Launch site 1: This site is located north of Gladstone city near the mouth of the Calliope River, adjacent to the existing RG Tanna coal export terminal.
- Launch site 4N: This site is located at the northern end of the proposed reclamation area for the Fishermans Landing Northern Expansion Project, which is part of the Port of Gladstone Western Basin Master Plan. The availability of this site will depend on how far progressed the Western Basin Dredging and Disposal Project is at the time of construction.

1.3.5 Feed Gas Pipeline

An approximately 8-km long feed gas pipeline will supply gas to the LNG plant from its connection to the Arrow Surat Pipeline (formerly the Surat Gladstone Pipeline) on the mainland adjacent to Rio Tinto's Yarwun alumina refinery. The feed gas pipeline will be constructed in three sections:

- A short length of feed gas pipeline will run from the proposed Arrow Surat Pipeline to the tunnel launch shaft, which will be located on a mudflat south of Fishermans Landing, just south of Boat Creek. This section of pipeline will be constructed using conventional open-cut trenching methods within a 40-m wide construction right of way.
- The next section of the feed gas pipeline will traverse Port Curtis harbour in a tunnel to be bored under the harbour from the mainland tunnel launch shaft to a receival shaft on Hamilton Point. The tunnel under Port Curtis will have an excavated diameter of up to approximately 6 m and will be constructed by a tunnel boring machine that will begin work at the mainland launch shaft. Tunnel spoil material will be processed through a de-sanding plant to remove the bentonite and water and will comprise mainly a finely graded fill material, which will be deposited in a spoil placement area established within bund walls constructed adjacent to the launch shaft. Based on the excavated diameter, approximately 223,000 m^3 of spoil will be treated as required for acid sulfate soil and disposed of at this location.
- From the tunnel receival shaft on Hamilton Point, the remaining section of the feed gas pipeline will run underground to the LNG plant, parallel to the above ground cryogenic pipelines. This section will be constructed using conventional open-cut trenching methods within a 30-m wide construction right of way. A permanent easement up to 30-m wide will be negotiated with the relevant land manager or owner.

Should one of the electrical plant power options be chosen, it is intended that a power connection will be provided by a third party to the tunnel launch shaft, whereby Arrow Energy would construct a power cable within the tunnel to the LNG plant.
Other infrastructure, such as communication cables, water and wastewater pipelines, may also be accommodated within the tunnel.

1.3.6 Dredging

Dredging required for LNG shipping access and swing basins has been assessed under the Gladstone Ports Corporation's Port of Gladstone Western Basin Dredging and Disposal Project. Additional dredging within the marine environment of Port Curtis may be required to accommodate the construction and operation of the marine facilities. Up to five sites may require dredging:

- Dredge site 1 (dredge footprint for launch site 1): The dredging of this site would facilitate the construction and operation of launch site 1. This dredge site is located in the Calliope River and extends from the intertidal area abutting launch site 1, past Mud Island to the main shipping channel. The worst-case dredge volume estimated at this site is approximately 900,000 m^3.
- Dredge site 2 (dredge footprint for launch site 4N): The dredging of this site would facilitate the construction and operation of launch site 4N. This dredge site would abut launch site 4N and extend east from the launch site to the shipping channel. The worst-case dredge volume identified at this site is approximately 2,500 m^3.
- Dredge site 3 (dredge footprint for Boatshed Point MOF 1): The dredging of this site would facilitate the construction and operation of the personnel jetty and MOF at Boatshed Point. This dredge site would encompass the area around the marine facilities, providing adequate depth for docking and navigation. The worst-case dredge volume identified at this site is approximately 50,000 m^3.
- Dredge site 4 (dredge footprint for Hamilton Point South MOF 2): The dredging of this site would facilitate the construction and operation of the MOF at Hamilton Point South. This dredge site would encompass the area around the marine facilities, providing adequate depth for docking and navigation. The worst-case dredge volume identified at this site is approximately 50,000 m^3.
- Dredge site 5 (dredge footprint for LNG jetty): The dredging of this site will facilitate the construction of the LNG jetty at Hamilton Point. This dredge site extends from the berth pocket to be dredged as part of the Western Basin Strategic Dredging and Disposal Project to the shoreline and is required to enable a work barge to assist with construction of the jetty. The worst-case dredge volume identified is approximately 120,000 m^3.

The spoil generated by dredging activities will be placed and treated for acid sulfate soils (as required) in the Port of Gladstone Western Basin Dredging and Disposal Project reclamation area.

1.4 Study Objectives

The objectives of the freshwater aquatic ecology technical study are to:

- Fulfill the requirements of the Final Terms of Reference (ToR) for the (then) Shell Australia LNG Project Environmental Impact Statement (EIS), as issued by the Coordinator-General of the State of Queensland (Coordinator-General), January 2010 with respect to freshwater aquatic ecosystems and values.
- Discuss the legislative context of the project in terms of freshwater aquatic ecological values and processes.
- Identify existing freshwater aquatic ecosystem values and sensitive receptors within the project area that may potentially be affected by the project.
- Evaluate the potential impacts on freshwater aquatic ecosystem values of the study area, including an assessment of any potential residual and cumulative impacts of the project.
- Describe strategies to avoid, minimise, mitigate or offset potential impacts on freshwater aquatic ecosystems within or adjacent to the study area.

Relevant details of the ToR are provided in Appendix A, including cross references to the location within this document where each of the ToR's has been addressed. Note that fluvial geomorphology and hydrology issues related to water resources are considered in a separate report.

2 Legislative Context

A review of Commonwealth, Queensland state and local government legislation, plans and policies was undertaken to identify legislative instruments which may be relevant to the aquatic ecology component of the EIS (Table 2-1).

Table 2-1: Legislative Instruments Relevant to Aquatic Ecosystem Values.

Legislative Instrument	Administering Authority	Description
Commonwealth		
Environment Protection and Biodiversity Conservation (EPBC) Act 1999	Department of Sustainability, Environment, Water, Population and Communities (DSEWPC)	Instrument for protection of Matters of National Environmental Significance (MNES). Projects with potential to impact on MNES are referred to DSEWPC for designation as 'controlled actions' or 'non-controlled actions', which determined the need for further assessment. The project has been determined to be a controlled action and will be assessed as a bilateral agreement with the Queensland Government. The aquatic ecology impact assessment has utilised both the EPBC database and approvals documentation for other projects to identify any MNES within the study area.
State		
State Development and Public Works Organisation (SDPWO) Act 1971	Department of Employment, Economic Development and Innovation (DEEDI)	Provides for state planning and development through a coordinated system of public works organisation and environmental coordination. Instrument through which the Gladstone State Development Area Development Scheme is administered. The Gladstone State Development Area (GSDA) was created under the SDPWO Act with the aim of guiding development in a way that is considerate of existing industry, providing certainty to industry, protecting environmental values and ensuring an effective development assessment process.
Gladstone State Development Area (GSDA) GSDA Development Scheme Policies	Department of Local Government and Planning	

Legislative Instrument	Administering Authority	Description
Sustainable Planning (SP) Act 2009 Sustainable Planning Regulations 2009 (SP Reg)	DIP	Framework for sustainable planning by: • managing the process by which development takes place. • managing the effects of development on the environment. • coordinating and integrating local, regional and state planning. This assessment has included site inspections and reviews of state government environmental databases governed under the SP Act and SP Reg.
CQ – A New Millennium Regional Plan	DIP Gladstone Regional Council	Sets out policy frameworks for matters including physical, socio-cultural, education and governance, which are relevant to future growth management of the region. This plan relates not to environmental values, but the social, cultural and educational values associated with the region.
Water Act 2000	DERM	Provides a basis for the planning and allocation of Queensland water resources, and sets out permitting and licencing requirements for taking or interfering with water.
Water Resource (Calliope River Basin) Plan 2006	Department of Natural Resources and Water (DNRW)	Provides for water from the Calliope River basin to be allocated and sustainably managed.
Calliope River Basin Resource Operations Plan 2008	DNRW	Implements the Water Resource (Calliope River Basin) Plan 2006.
Environmental Protection (Water) Policy 2009 EPP (Water)	DERM	Seeks to protect Queensland's waters whilst allowing for development that is ecologically sustainable. The EPP (Water) is intended to achieve the object of the act through identification of environmental values, derivation of water quality guidelines and objectives to enhance or protect these values and through monitoring and reporting on the condition of Queensland waters.

Legislative Instrument	Administering Authority	Description
Nature Conservation (NC) Act 1992	DERM	Based on principles to conserve biological diversity, ecologically sustainable use of wildlife and ecologically sustainable development (ESD). Places requirements on any person taking, using or interfering with protected fauna. The Nature Conservation Act provides a framework for the management of protected species listed under the Nature Conservation (Wildlife) Regulation 2006. The potential for freshwater species listed under the Nature Conservation Act to be present within the Freshwater Aquatic Ecology Study Area has been assessed through site inspections, database searches and review of approvals documentation for other projects in the region.
Draft Policy for Biodiversity Offsets	DERM	Guides the application of biodiversity offsets to address biodiversity impacts of development projects.
Land Protection (Pest and Stock Route Management) Act 2002	Department of Employment, Economic Development and Innovation (DEEDI)	Provides a framework for the management of pest plants and animals. Pest species identified in the study will be checked against the act for declared status.
Fisheries Act 1994	DEEDI	Regulates commercial and recreational fisheries, coastal areas important as fisheries habitat, and marine plants.

Local – No Local Government regulations specifically pertaining to the conservation or management of freshwater ecosystems

Industry Specific Codes

Australian Pipeline Industry Association (APIA) Code of Environmental Practice – Onshore Pipelines (2005)	APIA	Identifies best practice management measures to avoid, minimise and mitigate the environmental impacts of feed gas pipeline construction and operation.

3 Study Method

3.1 Overview

The approach to assessing the potential impacts of the project on freshwater aquatic ecosystems, communities and processes involved:

1. Baseline assessment of freshwater aquatic ecosystems through archival, government database and site inspections. Application of a risk-based framework for identifying freshwater aquatic values requiring further assessment through targeted field surveys.
2. Consideration of the potential impacts to freshwater aquatic ecosystems associated with construction, operation, maintenance and decommissioning of project within and adjacent to the study area, assuming normal environmental management principles and practices are applied.
3. Consideration of any additional mitigation actions that may be required by Arrow Energy above and beyond normal practices to avoid, minimise, mitigate or offset impacts on specific high value aquatic species, communities or habitat (where these exist) and might not be adequately protected by standard environmental management practices.
4. Reassessment of project impacts in light of recommended management practices and analysis of residual impact.
5. Assessment of the pre- and post-mitigation significance of freshwater aquatic ecosystems, communities and processes.
6. Assessment of cumulative impacts of the project on aquatic ecosystems, communities and processes within and adjacent to the study area in the context of other, relevant large-scale projects in the region.

3.2 Definition of Study and Project Areas

For the purpose of this assessment, four geographic regions have been defined:

- Areas within the footprint of project infrastructure and/or directly impacted by project activities are referred to as the “project area”.
- Areas adjacent to the project area that may experience impacts associated with the project are referred to as the “study area”.
- A broader area has been assessed to provide a local and regional context to aquatic ecology impact and significance assessments. This area includes waterways outside of the study area (reference or contextual sites) and is referred to as the “freshwater aquatic ecology study area”.
- For the purposes of database searches, a further buffer of 20 km has been added to the freshwater aquatic ecology study area, to provide additional surety that any

aquatic species, communities or habitat of state or national conservation significance are adequately considered. This is the “extended freshwater aquatic ecology study area”.

These four areas are shown in Figure 3-1 and described in more detail below.

3.2.1 Project Area

For the purposes of this freshwater aquatic ecology and water resources assessment, the project area includes all areas on the mainland above tidal influences where the feed gas pipeline, access tracks and/or other infrastructure will be constructed, as well as those parts of Curtis Island within the Arrow LNG Plant site and associated access corridors.

3.2.2 Study Area

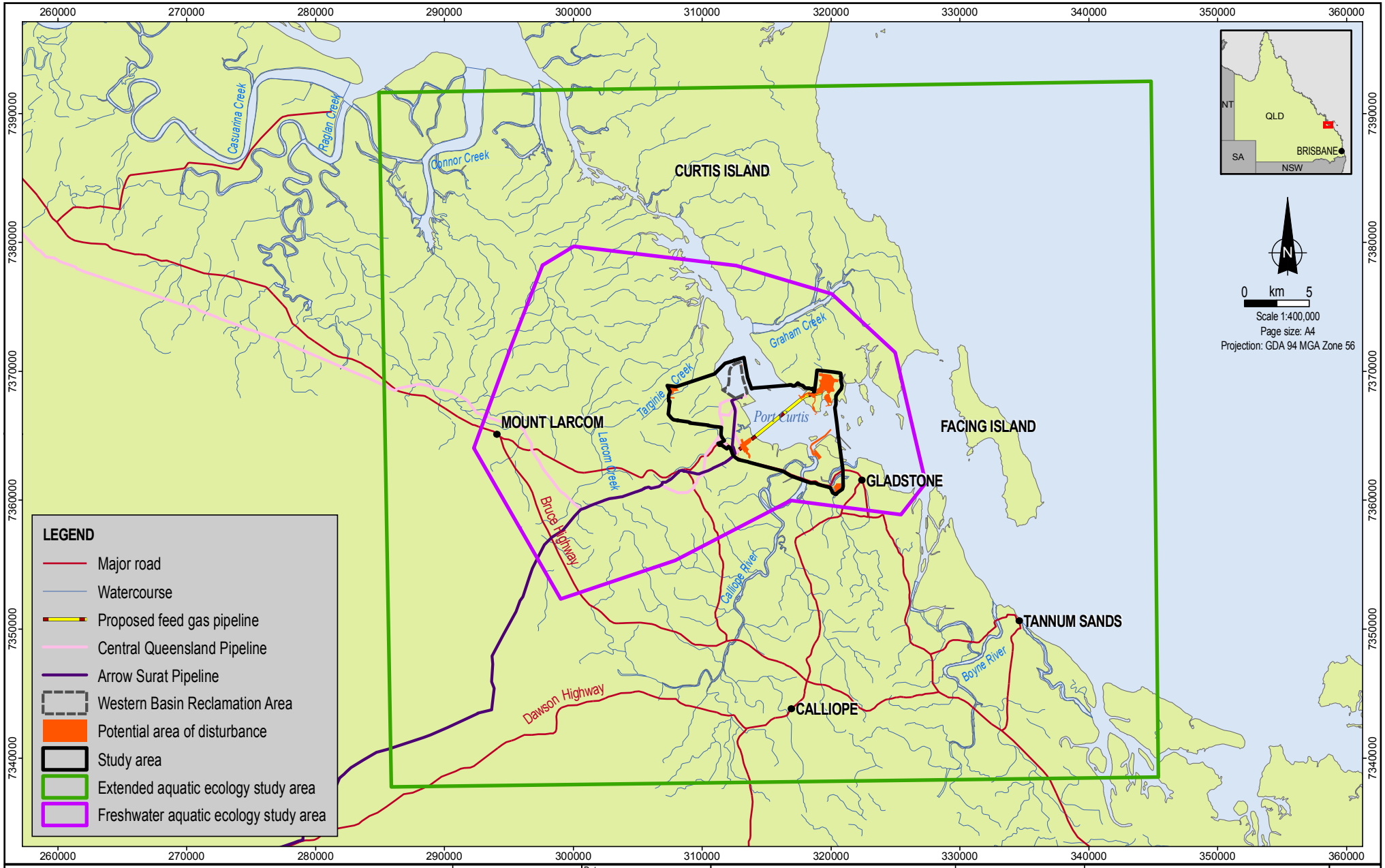
The study area has been prescribed for the EIS and is the area of indirect impact associated with the project. The study area covers each of the aspects of the project and spans from the base of Mount Larcom, east to Curtis Island. The area extends south picking up part of the Calliopie River and coastal areas within Gladstone (Figure 3-1).

3.2.3 Freshwater Aquatic Ecology Study Area

The boundaries of the freshwater aquatic ecology (and water resource) study area are by necessity broader than those of the study area. The intention is to provide a local and regional context for aquatic values, which is of benefit when assessing the significance of any impacts, as it enables the affected habitat or communities to be assessed as a proportion of similar habitat or communities in the region.

Aquatic and riparian flora was used to delineate the boundary between freshwater aquatic and marine ecology study areas (marine ecosystems being outside of the scope of this assessment):

- Sites at which riparian and aquatic vegetation was dominated by marine/estuarine species (e.g., mangroves, seagrasses) were excluded from this assessment on the basis that the terrestrial ecology impact assessment undertaken by Ecosure (Ecosure, 2011) and marine and estuarine ecology impact assessment (Coffey Environments, 2011) will consider these zones.
- Sites at which riparian and aquatic vegetation was dominated by freshwater species were included in the assessment.



Source:
Place names, roads and watercourses from DME.
Study area and pipelines from Arrow Energy.
Proposed feed gas pipeline and area of disturbance from Coffey Environments.
Aquatic study areas from Aquateco.

coffey environments

Date: 20.07.2011
MXD: 7033CA_AEC_GIS001_v0_1
File Name: 7033CA_AEC_F03.1_GIS

Arrow Energy

Arrow LNG Plant

arrow energy go further

Arrow LNG Plant study area and freshwater aquatic ecology study area

Figure No: 3-1

3.3 Archival Review

3.3.1 Environmental Databases

The following environmental database searches were performed on 17 April 2011 using a 20 km buffer (Figure 3.1):

- An EPBC protected matters report was generated to identify MNES within or adjacent to the study area.
- A Queensland state (Wildnet - Wildlife Online) report was generated to ensure species listed under state legislation (*Nature Conservation Act* 1992) were included in the assessment.
- The Queensland state wetland mapping database (Wetlandinfo) for records of wetlands within or adjacent to the study area.

3.3.2 Review of Relevant Literature

Relevant projects for which the environmental components of the IAS, EIS and Coordinator-General's reports have been reviewed to assist in the baseline assessment of aquatic ecosystem values include:

- Additional LNG projects (LNG plants and feed gas pipelines) within the vicinity of the project area.
- Other resource and infrastructure development projects within the Gladstone State Development Area (GSDA) and common infrastructure corridor including water, nickel, aluminium, coal, steel and oil facilities.
- Relevant planning instruments, including the Development Scheme for the GSDA (Queensland Government, 2010), 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 (Gladstone Area Water Board, 2008 and 2009).

Other technical documents such as the Queensland DERM Biodiversity Planning Assessments were also reviewed. A number of additional projects are less comparable to the Arrow LNG Plant, but have been assessed and included in the cumulative impacts assessment (Section 8).

3.4 Site Inspections

The review of existing information informed the prioritisation of habitat areas and locations for the field survey program. The survey program comprised the following field work:

- An initial (early wet season) inspection was conducted on the 14 to 16 December 2009. Access during this inspection was limited to public roads on the mainland and to existing tracks on Curtis Island.
- A second (post wet season) survey was undertaken on 15 to 17 June 2010.

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

It was initially intended that sampling of fish and macroinvertebrates would be undertaken. However, it was found during the December site inspection that almost all of the watercourses within the study area were dry. High quality habitat (e.g., permanent or semi-permanent waterholes and pools, structural woody or rocky habitat) that might support aquatic communities during periods of flow were largely absent.

The ephemeral nature of the stream also precluded the usefulness of collecting water samples to describe baseline stream water quality conditions. When present, 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 landuse, condition and soil types. In order to properly assess water in systems of this type, it is necessary to overcome the high degree of variability by undertaking sampling across all limbs of the ephemeral stream hydrocycle and at multiple locations including appropriate reference streams.

3.5 Impact Assessment

The construction and operation of the project may result in a range of direct and indirect impacts to freshwater aquatic ecosystems, including:

- Riparian/aquatic vegetation clearing and/or disturbance.
- Loss or fragmentation of aquatic habitat.
- Creation of physical or velocity barriers to the movement of aquatic organisms.
- Physical disturbance to stream banks or beds.
- Changes in water or sediment quality or quantity.
- Sediment transport, change in sediment scouring/deposition patterns or smothering of habitat.
- Translocation of pest flora and fauna.

These impacts have been assessed in the context of activities undertaken during construction, operation, maintenance and decommissioning of the project. The potential impacts have been quantified as a function of the sensitivity of freshwater aquatic values and the magnitude of the impact, using the matrix shown in Figure 3-2.

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

Figure 3-2: Impact assessment matrix for freshwater aquatic ecosystems within the freshwater aquatic ecology study area

3.5.1 Sensitivity Criteria for Aquatic Ecosystem Values

The sensitivity of a particular aquatic community or value to impacts associated with the project is determined through consideration of the following attributes:

Conservation status	Is the waterway listed as having special conservation status (e.g., wild rivers, world heritage, Ramsar listing)? Does the waterway potentially support species of conservation significance (e.g., EPBC/Nature Conservation listed species)? Does the waterway support commercial or recreational fisheries or other legislatively managed values? Is the waterway highly valued as an ecotourism destination (e.g., river cruises)?
Intactness	Does the aquatic ecosystem represent pristine, undisturbed wilderness environments, or has it been impacted by urbanisation and industrial operations? Is the aquatic ecosystem within the site an important corridor for movement of aquatic fauna between other areas of high quality aquatic habitat? Does the aquatic ecosystem at the study site represent high quality habitat in an otherwise highly disturbed system?
Uniqueness	Is aquatic habitat unique in terms of flora/fauna communities, aquatic ecology processes, habitat value?
Resilience to change	Are the aquatic communities, values and processes within the waterway tolerant of prolonged or permanent disturbance events, or are they sensitive to short-term, moderate impacts?
Replacement potential	How rapidly and how completely will aquatic ecosystems, communities and processes recover following an impact or disturbance event?

Table 3-1 shows the criteria used to assign sensitivity rankings to freshwater aquatic ecosystem values. 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.

3.5.2 Magnitude of Impact

The magnitude of impacts associated with project activities during construction, operation, maintenance and decommissioning of the project have been assessed following the criteria below:

Geographic extent of impact	Will the potential impact disturb aquatic systems across a wide spatial range, or will impacts be localised?
Duration of impact	Is the impact a very short term issue (e.g., excavator noise during trenching), or will the effects persist for some time following the disturbance (e.g., oil spill or land contamination)?
Severity of Impact	Is the effect of the impact very severe (e.g., fish kill, loss of entire aquatic community) or is it likely to be within the natural variability of the system?

Table 3-1 includes the criteria used to evaluate the magnitude of impacts expected on aquatic ecosystems as a result of the project with normal environmental controls for the protection of aquatic ecosystems and surface water quality and minimisation of soil erosion in place.

Table 3-1: Criteria used to evaluate the sensitivity of aquatic ecosystems and the magnitude of impacts potentially arising from the project.

	High	Moderate	Low
Sensitivity			
Conservation status	• wild river status • world heritage status • Ramsar status • EPBC/Nature Conservation listed flora/fauna/communities • high value fishery • International eco-tourism destination	• local government management • species of conservation interest (currently unlisted) • moderate/marginal fishery values • state or local eco- tourism 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 value
Uniqueness	• unique on a national/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

	High	Moderate	Low
Resistance 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/regenerating after disturbance events
Magnitude			
Geographic extent of impact	• impact has potential to affect aquatic ecosystems over a wide spatial range (>20 km)	• impact has potential to affect aquatic ecosystems within a range 0.5 km to 20 km radius	• impact has the potential for localised effects on aquatic ecosystems up to 0.5 km away
Duration of impact	• impact period is from 2 years to perpetuity	• impacts affects aquatic ecosystems for 3 months to 2 years	• impact is short term (<3 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

4 Description of Existing Freshwater Aquatic Ecosystems

4.1 Freshwater Aquatic Ecology Study Area Overview

The freshwater aquatic ecology study area encompasses a range of land tenures and land uses, including:

- Freehold and leasehold land, primarily used for grazing.
- The Gladstone State Development Area.
- Targinie State Forest.
- Strategic Port Land.
- Other tenures such as state land, road reserves and infrastructure easements.

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

Estuarine and tidal systems, including the Calliope River and Auckland Creek, were excluded from the scope of work for the freshwater aquatic ecology surveys and are not discussed herein, and are covered by the marine ecology study. Riparian flora and fauna is discussed in the terrestrial ecology study.

4.2 Archival Review

4.2.1 Environmental Databases

Protected Matters Search Tool (Commonwealth)

An EPBC protected matters report was generated on 17 April 2011 using the extended freshwater aquatic ecology study area boundary outlined in Figure 3-1 and is presented in Appendix C.

Table 4-1 summarises the EPBC Protected Matters Search results.

Of the MNES identified in the EPBC protected matters report, only two species were considered relevant to the aquatic ecology assessment, the remainder of listed species being terrestrial, or having an ecology and life history that are not critically dependent on aquatic habitat values. The relevant aquatic species were:

- Water mouse (*Xeromys myoides*) communities and/or habitat may potentially be present. This species, its habitat requirements, any potential impacts of the project

and the significance of these impacts have been considered in the terrestrial ecology (flora and fauna) assessment (Ecosure, 2011).

- Saltwater crocodile (*Crocodylus porosus*) and/or habitat are identified in the EPBC database search as potentially present within the study area. However, these are anecdotally extremely rare in the area and the generally small ephemeral watercourses with in the study area would represent small areas of very marginal habitat for this species.

Table 4-1: Summary of EPBC protected matters report for the extended freshwater aquatic ecology study area.

Protected Matter	Number
World Heritage Properties	1
National Heritage Places	1
Wetlands of International Significance (Ramsar Sites)	0
Great Barrier Reef Marine Park	Relevant
Commonwealth Marine Areas	Relevant
Threatened Ecological Communities	4
Threatened Species	45
Migratory Species	54

Wildnet (Wildlife Online, Qld State) database search

A list of species that utilise or depend on aquatic habitat, either permanently or at various stages of their life history, has been prepared from the Wildlife Online database search results or is presented in Appendix B and a summary is provided in Table 4-2.

Table 4-2: Summary of Wildlife Online database search for aquatic, semi-aquatic and riparian species and their conservation status.

Kingdom	Species Recorded	Conservation significance (Qld.)*	Conservation significance (Aust.)**	Exotic species
Amphibia	23	0	0	1
Birds	49	4	0	0
Fish	26	0	0	2
Mammals	1	0	0	0
Reptiles	6	0	0	0
Plants	75	0	0	10

* Listed under *Nature Conservation Act* (1992)

** Listed under EPBC Act (1999)

Species of conservation significance include any species listed as near threatened, endangered or vulnerable (Nature Conservation Act, Qld) or as conservation dependent, critically endangered, endangered or vulnerable (EPBC Act, Commonwealth).

The four bird species that utilise aquatic habitats and are of significance under the Nature Conservation Act (1992) are:

- *Nettapus coromandelianus* (cotton pygmy goose)
- *Tadorna radjah* (radjah shelduck)
- *Ephippiorhynchus asiaticus* (black-necked stork)
- *Lewinia pectoralis* (Lewin's rail).

These species have been addressed in the terrestrial ecology (flora and fauna) assessment (Ecosure, 2011).

4.2.2 Existing Studies

Table 4-3 summarises the findings of a number of previous studies relevant to aquatic ecosystems within the freshwater aquatic ecology study area. The more significant of these studies, from an aquatic ecology perspective, are discussed in greater detail below.

Gladstone-Fitzroy Pipeline EIS

Aquatic ecology surveys for the Gladstone-Fitzroy Pipeline EIS (GAWB, 2008) identified the following in the Bajool - Gladstone reach of the study area:

- Five macrophyte species (*Nymphaea* spp, bunchy sedge (*Cyperus polystachyos*), Typha spp. hornwort (*Ceratophyllum demersum*) and an unidentified emergent sedge. These were associated with permanent pools along Larcom Creek, Boat Creek and 12 Mile Creek.
- Relatively high macroinvertebrate diversity and good SIGNAL scores were recorded for permanent streams with rocky substrates, indicating that water pollution is no a major consideration. However, ephemeral streams with minimal habitat diversity (such as those observed in the Arrow LNG Plant study area) generally yielded much poorer community structure. Some ephemeral streams sampled within 1 to 3 weeks following flow events were found to support greater diversity of macroinvertebrates.
- A number of fish species considered to be of conservation significance (although not specifically listed under state or Commonwealth legislation) were mentioned, but noted to be restricted to the Fitzroy River Catchment (Berghuis & Long, 1999). Species of interest that were thought likely/possibly present in the Calliope catchment included *Mogurnda adspersa* (purple spotted gudgeon) and *Porochilus rendahli* (Rendahl's tandan). Both of these species favour habitats containing submerged aquatic vegetation (Midgley, 1979; Pusey *et.al.*, 2004), which was found to be very scarce during the site inspections for the Arrow LNG Plant. *P. rendahli* in particular may utilise flooded ephemeral streams to move between more permanent pools. The Gladstone Fitzroy Pipeline EIS identified the ephemeral and low order streams within and adjacent to the study area as corridors for fish movement, but noted that they are of marginal value, largely due to the lack of permanent pools to provide dry season refugia and the absence of larger upstream water bodies into which fish may migrate.

- Six freshwater turtle species are potentially present; including the EPBC listed *Rheodytes leukops* (Fitzroy River turtle). The study area is outside of *R. leukops* normal range and in any case represents only marginal habitat for the species due to a lack of permanent pools, and clear, flowing water (Tucker *et.al*., 2001; Gordos *et.al*., 2004; Latta & Latta, 2005). The remaining species are widespread and common.
- Larcom Creek is the waterway within the study area that is most likely to contain aquatic habitat or species of conservation value and is described in the Gladstone-Fitzroy Pipeline EIS as, "*Marginal, temporary habitat (during flows) for several fish species of conservation significance (except during floods), none of which are protected under legislation*".

Queensland Curtis Liquefied Natural Gas Project (QCLNG Project)

Field surveys for the QCLNG Project identified three listed aquatic flora species as potentially being within their study area - *Aponogeton queenslandicus* (Queensland lace plant), *Eleocharis blakeana* (Blake's spikerush), and *Fimbristylis vagans* (no common name) (GHD, 2009). All of these species are restricted to areas in the Surat basin far to the west of the study area, hence are highly unlikely to be within the study area.

Likewise, the EPBC listed *Maccullochella peeli peeli* (Murray cod) and *Neoceratodus forsteri* (Queensland lungfish) are discussed as potentially impacted by the feed gas pipeline component of the QCLNG project but have never been recorded from within the Arrow Energy freshwater aquatic ecology study area, which is well outside of the normal range for these species and does not contain suitable habitat.

The QCLNG report does not refer to the ephemeral habitat in the eastern portion of the Arrow Energy freshwater aquatic ecology study area and does not discuss aquatic habitat or species potentially present on Curtis Island that may be impacted by the LNG plant component of the project.

Gladstone Liquefied Natural Gas Project (GLNG Project) EIS and Supplementary EIS

EIS studies for the GLNG Project (URS, 2009) reported no permanent freshwater bodies within the Curtis Island gas transmission gas pipeline study area. No water was present in the ephemeral waterways during the study and the waterways were deemed unlikely to support an assemblage of fish species as there are were no core populations present within the location to act as sources for migration and reintroduction of species.

GLNG found that the majority of waterways within their gas pipeline study area were ephemeral. Habitat features such as undercut banks, a variety of substrate types and in-stream debris and plants were found to be present, however the ephemeral nature of the watercourses reduced the value of these attributes to aquatic biota, including fish. This was deemed to hold true even during periods of flow.

Table 4-3: Summary of relevant environmental documents from other projects in the freshwater aquatic ecology study area.

Proponent/project	Document	Aquatic Issues	Comments
Conoco Philips/Origin Energy (APLNG gas pipeline)	EPBC referral 2009/4976	Kroombit tinkerfrog (*Taudactylus pleione*)	Reported as unlikely within the APLNG study area. Also unlikely to be found within the Arrow LNG study area due to lack of suitable habitat.
		Murray cod (*Macullochella peeli peeli*)	Extremely unlikely with freshwater aquatic ecology study area, which is well outside normal range and has no suitable habitat.
		Water mouse (*Xeromys myoides)*	Likely to be present on both APLNG site and within Arrow LNG Plant freshwater aquatic ecology study area. Assessed within scope of terrestrial flora and fauna report.
		Fitzroy River turtle (*Rheodytes leukops*)	Likely on APLNG site. Arrow LNG Plant study area outside of natural range and with minimal suitable habitat.
Queensland Gas and Coal/British Gas (QCLNG project)	EPBC referral 2008/4399	Murray cod (*Macullochella peeli peeli*)	Extremely unlikely with freshwater aquatic ecology study area, which is well outside normal range and has no suitable habitat.
		Water mouse (*Xeromys myoides)*	Likely to be present on both QCLNG site and within Arrow LNG Plant freshwater aquatic ecology study area. Assessed within scope of terrestrial flora and fauna report.
		Fitzroy River turtle (*Rheodytes leukops*)	Likely on QCLNG site. Arrow LNG Plant freshwater

Proponent/project	Document	Aquatic Issues	Comments
			aquatic ecology study area outside of natural range and with minimal suitable habitat.
Comalco Smelter Expansion	EPBC Referral 2001/477	Water mouse (*Xeromys myoides)*	Was considered likely, but was not found during EIS field surveys. Likelihood with Arrow LNG Plant study area has been assessed within the scope of the terrestrial flora and fauna report.
Gladstone Fitzroy Pipeline project	EIS Chapter 8 – Aquatic Flora and Fauna	Discussed further in section 4.2.2	Extensive aquatic surveys completed, discussed in section 4.2.2

4.3 Site Inspections

A desktop review of topographical maps and aerial photographs indicated that watercourses within the study area were largely first and second order ephemeral streams. This was confirmed during site inspections, the first of which was completed during the early wet season (December 2009) and the latter post-wet season in June 2010.

Permanent water was found at only two sites during the early wet season inspection, with watercourses at all other road crossings being dry and devoid of remnant waterholes or wetlands. On the mainland side of the study envelope surveys were restricted to public roads and access areas, hence some tracts of the study area were not accessed. However, the limited size of the study area and the relatively uniform topography and geography indicated that watercourses on private land were very similar to those observed at the roadsides.

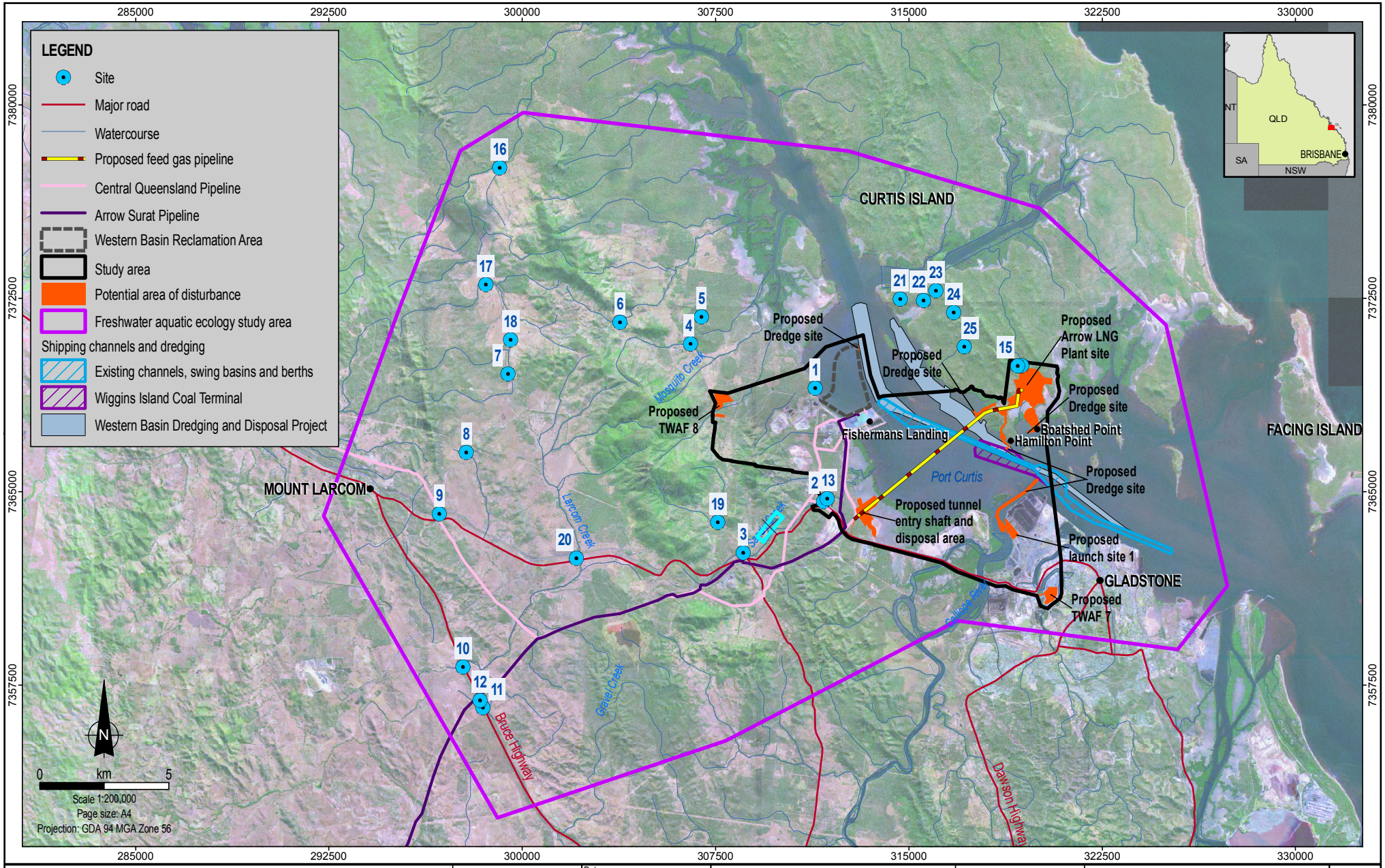
The majority of the ephemeral watercourses were still flowing post-wet season survey or contained remnant pools due to an unusually intense wet season. Flow in these smaller systems was minimal and most would be expected to have ceased flowing within a few weeks of the site inspection. Small remnant pools may persist for some time after flow ceases, but would likely be dry by the end of the dry season, as observed during the early wet season site inspection.

Larcom Creek is a larger waterway and although completely dry at the Bruce Highway site in during the early wet season, contained significant water when revisited during the post-wet site inspection. This system exhibits variability in substrate, hydrology and depth. It also contains structural woody habitat and undercut banks that are likely to provide temporary refugia and act as a corridor for the movement of aquatic fauna during periods of flow.

Figure 4-1 shows the location of watercourses that were visited during the field inspections and Table 4-4 provides details of the locations. It should be noted that the study area is criss-crossed by numerous additional drainage lines that would undoubtedly contain water during the wetter months. Whilst these were observed in the field they are of negligible consequence in terms of aquatic habitat and were not included in this assessment.

Table 4-5 shows basic aquatic habitat attributes observed at each of the inspection points.

Table 4-6 presents aquatic taxa observed during the site inspections.



Source:
Place names, roads and watercourses from DME.
Study area, pipelines, proposed auxiliary facilities and marine infrastructure from Arrow Energy.
Proposed feed gas pipeline from Coffey Environments.
Sites and freshwater aquatic study area from Aquateco.
Imagery from SPOT (2004-2007).

coffey environments

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File Name: 7033CA_AQ1_F04.1_GIS

Arrow Energy

Arrow LNG Plant

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Sites visited during early and post wet site inspections

Figure No: 4-1

Table 4-4: Location of aquatic field inspection sites. (All sites are within the freshwater aquatic ecology study area, however only five sites (highlighted are within the study area (Note: Altitude estimated from GPS data only)).

Site	Waterway	Description	Coordinates	Altitude (m)
1	UC1	Unnamed stream north of Fishermans Landing	S23 46 44.2, E151 08 55.5	5
2	Boat Creek	Boat Creek at Landing Road	S23 49 07.4, E151 09 05.2	9
3	Boat Creek	Boat Creek at Calliope River - Targinie Road	S23 50 10.7, E151 07 14.1	24
4	Mosquito Creek	Mosquito Creek at Calliope River - Targinie Road	S23 45 46.4, E151 06 05.8	33
5	UC2	Unnamed Creek at Chernin Road	S23 45 12.5, E151 06 21.1	25
6	Scrubby Mountain Creek	Scrubby Mountain Creek at Nichols Road	S23 45 18.1, E151 04 29.5	49
7	UC3	Unnamed Creek at The Narrows Road	S23 46 21.3, E151 01 54.9	62
8	UC4	Unnamed Creek at The Narrows Road	S23 47 59.7, E151 00 56.5	93
9	UC5	Unnamed Creek at Gladstone - Mount Larcom Road	S23 49 16.5, E151 00 18.5	68
10	Larcom	Larcom Creek at Bruce Highway	S23 52 29.9, E151 00 47.6	49
11	UC6	Unnamed Creek at Bruce Highway	S23 53 21.7, E151 01 14.2	50
12	UC7	Unnamed Creek at Bruce Highway	S23 53 12.3, E151 01 10.7	53

Site	Waterway	Description	Coordinates	Altitude (m)
13	Boat Creek	Boat Creek from public reserve	S23 49 03.8, E151 09 10.2	9
14	UC8	Unnamed Creek on Curtis Island at LNG site	S23 46 19.2, E151 13 38.8	41
15	UC8	Unnamed Creek on Curtis Island at LNG site	S23 46 19.6, E151 13 33.3	23
16	Munduran Creek	Munduran Creek at Narrows Rd	S23 42 01.2, E151 01 47.5	39
17	Munduran Creek	Munduran Creek at Mattson Rd	S23 44 28.0, E151 01 26.4	54
18	Munduran Creek	Munduran Creek at Nichols Rd	S23 45 38.0, E151 01 59.4	73
19	Spring Creek	Spring Creek at Calliope River Targinie Rd	S23 49 31.8, E151 06 39.8	40
20	Larcom Creek	Larcom Creek at Mt Larcom Gladstone Rd	S23 50 14.7, E151 03 25.4	51
21	UC8	Unnamed Creek, Curtis Island Pipeline Envelope	S23 44 53.6, E151 10 53.9	44
22	UC8	Unnamed Creek, Curtis Island Pipeline Envelope	S23 44 55.4, E151 11 25.8	20
23	UC8	Unnamed Creek, Curtis Island Pipeline Envelope	S23 44 43.6, E151 11 42.8	30
24	UC8	Unnamed Creek, Curtis Island Pipeline Envelope	S23 45 11.3, E151 12 06.8	51
25	UC8	Unnamed Creek, Curtis Island Pipeline Envelope	S23 45 54.6, E151 12 20.8	39

Table 4-5: Physical and habitat attributes of aquatic inspection sites.

Site	Hydrology			Substrate/Habitat				Stream order	Macrophytes				Fish	Notes
	Permanent	Ephemeral	Tidal	Mud/silt/sand	Gravel/rock	Structural woody habitat	Undercuts		Emergent	Floating	Submerged	Attached		
1		●	●		●			1	●					Tidal at waypoint, but ephemeral and fresh 500 m upstream
2		●						2	●					
3		●		●	●	●		1						
4	●			●	●	●		1	●		●	●	●	Outside study area, but downstream reaches within study area
5		●						1						
6		●		●	●			1						
7		●		●		●		1						
8		●		●				1						
9		●						1						
10		●		●		●		2						
11		●		●				1						
12		●						1						
13	●			?				2	●	●	●	●	●	Too deep to identify substrate, likely mud/silt and embedded cobble. Biologically diverse site. Only permanent freshwater within study

Site	Hydrology			Substrate/Habitat				Stream order	Macrophytes				Fish	Notes
	Permanent	Ephemeral	Tidal	Mud/silt/sand	Gravel/rock	Structural woody habitat	Undercuts		Emergent	Floating	Submerged	Attached		
														area.
14		●			●	●		1						Exposed tree roots resulting from natural erosion.
15		●			●	●		1						Exposed tree roots resulting from natural erosion. Mildly incised channel with alternative flood channels.
16		●		●	●	●	●	1	●		●	●		Relatively high quality aquatic habitat outside study area.
17		●		●	●	●	●	1	●		●	●		Relatively high quality aquatic habitat outside study area.
18		●		●				1	●	●	●	●		Isolated ephemeral pool containing seasonal aquatic habitat.
19		●		●	●	●	●	1	●	●	●	●		Moderate quality aquatic habitat adjacent to study area.
20		●		●	●	●	●	2	●	●	●	●		Moderate quality aquatic habitat adjacent to study area.
21		●			●	●	●	1						Creek channel dry during inspections, but evidence of recent substantial flow. Some structural
22		●			●	●	●	1						
23		●			●	●	●	1						

Site	Hydrology			Substrate/Habitat				Stream order	Macrophytes				Fish	Notes
	Permanent	Ephemeral	Tidal	Mud/silt/sand	Gravel/rock	Structural woody habitat	Undercuts		Emergent	Floating	Submerged	Attached		
24		●			●	●	●	1						woody habitat and undercuts but generally poor aquatic habitat with no connectivity to permanent freshwater.
25		●			●	●	●	1						

Table 4-6: Aquatic taxa observed during site inspections in December 2009 and June 2010. Exotic species have been highlighted, sites that were dry, outside of the freshwater aquatic ecology study area or at which no aquatic taxa were observed have been omitted.

	Species	Common Name	Site				
			1	2	13	14	15
Aquatic vegetation	*Typha orientalis*	Cumbungi	●		●		
	Pragmites australis	Common reed	●	●	●		
	Azolla pinnata	Pacific azolla			●		
	Nymphaea violacea	Native water lily			●		
	Nymphoides indica	Water snowflake			●		
	Persicaria decipiens	Slender knotweed			●		
	Ludwigia peploides	Water primrose			●		
	Cyperus eragrostris	Umbrella sedge			●		
	Urochloa mutica	Para grass			●		
	Potamogeton crispus	Curly pondweed			●		
	Rumex crispus	Curled dock			●		
	Brasenia schreberi	Watershield			●		
	c.f. *Myriophyllum* spp.*	Water millfoil			●		
	Filamentous algae	Pondslime			●		
Fish	*Arius graeffei*	Fork-tailed catfish			●		
	c.f. *Melanotaenia splendida**	Eastern rainbowfish			●		
	c.f. *Gambusia holbrooki**	Mosquitofish			●		
	*Amnitaba percoides**	Barred grunter			●		
	Mugil cephalus	Sea mullet			●		
	Megalops cyprinoides	Tarpon			●		
	Lates calcarifer	Barramundi			●		
Misc	*c.f. Elseya latisternum**	Saw-shelled turtle			●		

*Likely taxa based on field observations. Positive identification requires collection of specimens.

4.3.1 Ephemeral Waterways

The majority of the waterways within the study area are ephemeral and did not contain any water at the time of the December 2009 site inspection. Most contained minimal flow or had been reduced to small remnant pools when revisited in June 2010. Unusually high wet season rainfall is suspected to have resulted in these holding water later into the dry season than would occur when more typical rainfall is experienced.

Streams on Curtis Island, both within the study area and the freshwater aquatic ecology study area were exclusively ephemeral. The major watercourse flows from South of Graham Creek to the Arrow LNG Plant site at the southern end of the Island. This watercourse was walked for its entire length during the June 2010 surveys and were devoid of any remnant pools, despite the existence of relatively large and well defined channels and floodways.

Ephemeral waterways 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.

First and second order streams are simple in terms of branching and are at the upper end of river systems, typically with relatively sparse aquatic habitat and simple aquatic communities. Within the study area these systems 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. The channels were often incised, sometimes with associated floodplains or secondary channels, features frequently observed in systems that experience rapid flooding.

Habitat within the ephemeral streams was generally of relatively poor quality. Substrates were often mud or silt, although some rocky substrate was observed. Structural woody habitat was generally sparse, although exposed tree roots (resulting from erosion) were occasionally present and provided some woody habitat.

A number of freshwater fish species have a tendency to move into systems of this nature during floods. In the Gladstone area the most likely native species to utilise these systems are spangled perch (*Leiopotherapon unicolor*), eastern rainbowfish (*Melanotaenia splendida*) and bony bream (*Nematolosa erebi*). The exotic mosquito fish (*Gambusia holbrooki*) is frequently found in ephemeral streams and may colonise systems within the study area during wetter periods.

Seasonal movement of freshwater fish species into the study area requires connectivity to a more permanent water body such as a stream, waterhole or wetland. For coastal streams on the mainland and for streams on Curtis Island no such permanent water bodies were identified, the streams being very short and arising within a few kilometres of the coast. It is possible that these streams would provide seasonal habitat for some estuarine species that tolerate relatively low salinity.

Streams at the western end of the study area tend to flow south into increasingly higher order streams, so there is greater potential for fish communities from the more permanent watercourses to move up to forage or spawn during floods. Larcom Creek is the most significant of these, and may contain some permanent or semi-permanent pools. Larcom Creek was dry at the site of the Bruce Highway Crossing during the December site inspection, but contained significant water when revisited in June 2010. A number of fish species were observed, including *Melanotaenia splendida* (eastern rainbowfish), *Nematolosa erebi* (bony bream), *Arius Graeffei* (fork-tailed catfish) and the exotic *Gambusia holbrooki* (mosquitofish).

Macroinvertebrate communities within ephemeral systems tend to be dominated by hardy taxa that are capable of colonising rapidly, such as coleopterans and hemipterans. The presence, absence, or abundance of these families is therefore of very limited value when assessing stream health, water quality or ecosystem function. Conversely, taxa that tend to be indicators of good stream health (e.g., plecopterans, ephemeropterans and tricopterans, the three families from which AusRivAS PET scores are derived) tend to be absent or sparse, since many species within these families have lengthy larval periods and ephemeral systems tend not to hold water long enough for these to develop.

Ephemeral streams often receive a poor health rating when using AusRivAS style assessments, as the hydrology necessitates sampling outside of the standardised sampling period for which the models are calibrated. This is unfortunate, since the observed assemblages may in fact be perfectly natural for a stream of this nature.

Recent evidence suggests that systems containing pools that become disconnected during the dry season provide significant refuge for invertebrates and contain a disproportionate diversity of these organisms. Conversely, moist and/or dry sediments, leaf litter and stones support only very sparse macroinvertebrate communities (Robson, B., Chester, E. *et.al.,* 2008). The lack of permanent pools within streams in the study area is expected to result in very poor abundance and diversity of macroinvertebrates, with the possible exception of Larcom Creek, which is well outside of the study area.

4.3.2 Permanent Water Bodies

Mosquito Creek and Boat Creek (Site 13) were the only permanent water bodies identified within the freshwater aquatic ecology study area. Both contained remnant, standing water at the time of the December 2009 site inspection, but were flowing during the June 2010 inspection.

Fork-tailed catfish (*Arius graeffei*) were observed at Mosquito Creek in what appeared to be relatively high numbers (a school of more than 30 fish within the very small section of stream was visible from the roadside). This species is able to tolerate a wide range of salinities, including marine environments. Its presence in Mosquito Creek would tend to indicate either that the stream contains significant habitat upstream of the road crossing (there was no water below), or that this species moves into the stream from tidal systems downstream when the stream flows. All individuals observed were less than the 270 mm length at which sexual maturity is believed to occur in this species.

Of the species positively identified from Boat Creek, all are known to utilise estuarine environments:

- Mature tarpon (*Megalops cyprinoides*) were observed. This species is estuarine dependent with adults spawning in the marine/estuarine environment during the wet season and juveniles returning to freshwater environments.
- Relatively large barramundi (*Lates calcarifer*) were observed (6 to 8 fish of 450-600 mm length visible in the pool). These fish would be sexually immature and would be approximately 2 to 3 years of age.
- Large numbers of fork-tailed catfish (*Arius graeffei*), both mature and juvenile, were observed.
- Sea mullet (*Mugil cephalus*) were observed, both mature and juvenile. This species is thought to be estuarine dependent, with mature adults moving to estuarine environments during autumn and winter to spawn.

These observations indicate that Boat Creek is connected to the estuarine environment even during the drier months, since this is a habitat requirement for *M. cephalus*.

A number of other fish species were observed but could not be positively identified as sampling was not possible due to the nature of the site. The abundance of distinctively freshwater macrophytes indicates that Boat Creek is not tidal as far upstream as Site 13, which is approximately 2 km from the mouth of the stream. An absence of water 5 km upstream at Site 3, (or at road crossings even further upstream) during the December 2009 inspection, suggests that the remnant pool system is confined to the lower reaches of the river system immediately above the tidal influence. However, water was abundant

upstream of Site 13 during the June 2010 site inspection, and all of the fish species observed at Site 13 would be expected to utilise these temporary habitats, retreating to the permanent pools as water levels fall.

Database searches and the previous surveys for other projects indicate that these systems are very unlikely to support populations of listed aquatic species. However, as the only sites within the study area to permanently support populations of aquatic species, Boat Creek and Mosquito Creek are of minor significance as aquatic ecosystems at a local scale.

Given the diversity of macrophytes and aquatic habitat at these two sites, it is likely that an equally diverse macroinvertebrate population also exists at both of these sites. However, no listed species have been indicated for the study area, and standard assessment techniques (e.g., AusRivAS) were unsuitable due to the nature of the sites, which were too deep to wade safely and were largely inaccessible due to marshy banks and dense aquatic vegetation.

There was a diverse aquatic macrophyte community at Site 13, with nine native and four exotic species recorded. A number of the observed taxa were submerged species, and it is likely that these populations undergo significant disturbance on a seasonal basis, as higher flows and turbid water would tend to result in loss of the submerged and many of the attached species. None of the species present were of conservation significance. Para grass (*Urochloa mutica*) and cumbungi (*Typha orientalis*) are invasive exotic species that have the potential to alter the flow characteristics of streams, resulting in localised flooding or erosion.

4.3.3 Sensitivity of Existing Aquatic Ecosystems

Ephemeral waterways

A high proportion of the ephemeral systems within the freshwater aquatic ecology study area are unnamed first or second order systems that flow for very limited periods each year. These systems are often little more than drainage lines through agricultural or forested areas.

The more substantial streams (e.g., Larcom and Boat creeks) contain water for longer periods of time and have slightly higher value as freshwater aquatic habitat.

Overall, ephemeral streams (and the ephemeral headwaters of Larcom and Boat creeks) within the freshwater aquatic ecology study area are considered to have moderate sensitivity to impacts associated with the project because:

- They are relatively intact, having only experienced moderate disturbance by existing landuse activities.
- Their conservation status is low, as they have no formal conservation status, no species, habitat or aquatic communities of special conservation significance, no fisheries values and no eco-tourism potential.
- They provide marginal 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 waterways

Permanent freshwater aquatic ecosystems include Mosquito Creek and the lower reaches of and Boat Creek. These systems have also been assigned a “moderate” sensitivity rating because:

- There is limited potential for species of conservation significance locally (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.
- Some opportunities are provided 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 to the impacts of the project, although recovery following a disturbance event will be slower than for the ephemeral streams.

4.4 Water Resources

4.4.1 Catchment Basins

DERM divides the state into regions based on catchment basins to assess water-related issues (DERM, 2009). Waterways within the study area fall within two separate basins in the Central region of the East Coast drainage division. These two basins are Calliope River (Basin 131), which contains streams draining from the mainland, and Curtis Island (Basin 132).

The Calliope River catchment is bounded by the Calliope Range to the west and Mt Larcom Range to the north and encompasses the central valley of the Calliope Shire and western parts of Gladstone City. The Calliope River flows eastward from the Calliope Range for about 100 km to its mouth on the coast just to the north of Gladstone, and has a relatively small catchment area of 2236 km^2. The rivers main tributaries are Oakey, Paddock, Double and Larcom creeks. The Calliope River basin also includes creeks that flow directly to the coast rather than to the Calliope River. Waterways within the freshwater aquatic ecology study area, i.e., Boat, Targinie, Mosquito and Auckland creeks, are such coastal creeks. About two thirds of the native vegetation has been cleared from the basin, however a near continuous remnant remains intact along the riparian corridor of the Calliope River supporting aquatic ecosystems of value (DNRW, 2007).

Cattle grazing on the coastal plains is the main land-use in the area and the dominant water use is irrigation for cattle-feed production. However the Calliope River Basin also encompasses portions of the GSDA, established by the Queensland Government in 1993. The purpose of the GSDA is to provide a suitable area of land with ready access to a deepwater port for large-scale industrial development over a 30 to 50 year timeframe (DNRW, 2007). Water for these industrial users is supplied from the adjacent Boyne River Basin, however the Calliope River Basin may be affected by release into its watercourses and construction of structures that affect overland flow.

The Calliope River Basin Resource Operations Plan (DNRW, 2008) and Water Resouces (Calliope River Basin) Plan 2006 have recently been developed to provide enhanced certainty and security for water users and the natural environment of the basin. The desired outcomes of these plans are to:

- Provide for the use of all water entitlements and continued use of all existing works.
- Make water available to sustain and provide growth in economic activity.
- Support water-related social and cultural values of communities.
- Encourage continual improvement in the efficient use of water.
- Support natural ecosystems by minimising changes to natural flow regimes.
- Maintain adequate water flows to protect the health of riparian vegetation and aquatic ecosystems.
- Maintain adequate freshwater outflows to The Narrows and the natural wetlands.

Assessment of stream conditions within the basin as part of the 2000–2002 National Land and Water Resources Audit found the basin condition was susbtantially modified based on nutrients and suspended solids loads in the waterways. This finding was reviewed by the

Queensland river condition workshop expert panel which considered that water quality had some change from natural (ANRA, 2011).

The Great Barrier Reef Management Authority classifies sediment export from the Calliope River catchment to be a high risk and total nitrogen and total phosphorus export to be a medium risk (GBRMPA, 2011).

The Curtis Island Basin is about 45 km long with a maximum width of 14 km, and contains many sub-catchments throughout its total catchment area of 570 km^2. The largest drainage feature is Graham Creek, which is mostly estuarine in nature, to the north of the study area. Within the study area on Curtis Island, drainage features only contain water during and immediately after rainfall events. As described in Section 4.3.1, the major drainage feature on the proposed LNG plant site was surveyed along its entire length in June 2010 and was was devoid of any remnant pools. Advice received from DERM is that the drainage features in the project area on Curtis Island are not watercourses as defined by the *Water Act 2000* (Carter et al., 2011).

4.4.2 Environmental Values of Basin Streams

The EPP (Water) provides for the ecologically sustainable management of Queensland waters by establishing environmental values to be protected, and management goals and water quality objectives to ascertain whether protection of these values is achieved. The water quality management framework involves establishing these environmental values and management goals for specific waters through a community consultation process, including consideration of social and economic impacts. When agreed, and approved by government, these environmental values can be included in Schedule 1 of the EPP (Water).

The main nationally recognised environmental values or uses of water are:

- Ecosystem protection (aquatic plants, fish and other flora and fauna, habitat), with EPP Water recognising four possible levels of ecosystem condition and corresponding management intent (high ecological value, slightly disturbed, moderately disturbed and highly disturbed).
- Agricultural use (irrigation, stock watering).
- Recreational use (swimming, boating, passive recreation).
- Human consumption of aquatic species.
- Drinking water supply.
- Cultural and spiritual values.

Each of these environmental values has its own specific set of water quality guidelines since the acceptable guideline to maintain one type of environmental value may not be acceptable to maintain another environmental value. Protection of aquatic ecosystems generally requires the most stringent water quality guidelines.

Currently, no site-specific environmental values or associated water quality objectives have been established for any watercourses in the Calliope River or Curtis Island basins. The Queensland Water Quality Guidelines described in DERM (2009) are therefore applicable as default objectives for these streams. For protection of ecosystems within the freshwater segment of streams within the study area, the applicable guidelines for physicochemical indicators 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-moderately disturbed systems.

The Queensland Water Quality Guidelines recognise that application of guidelines to ephemeral waters is problematic given that these values are derived from physicochemical reference data that is generally representative of stream conditions under normal baseflow regimes, or applicable to chronic exposure in the case of toxicants. Water quality varies markedly in ephemeral streams depending upon whether it is the short-lived high flow period, very short baseflow period or long period of nil flow that is characteristic of these streams. Under extreme high or low-flow conditions, careful consideration is required when applying guideline values.

4.4.3 Water Quality of Project Area Streams

The only recognised fresh watercourses 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 Targinie Creek in the vicinity of the temporary workers accommodation facility (TWAF8). Approximately 223,000 m^3 of spoil from the feed gas pipeline tunnel to Curtis Island will be deposited in a spoil placement area established within bund walls adjacent to the tunnel launch shaft. This spoil will be treated as required to mitigate impacts due to the presence of any acid sulfate soils. TWAF8 is on primarily cleared pastoral grazing land near Targinie, and will be decommissioned on completion of Phase 1 LNG plant construction works.

Boat Creek was one of only two permanent waterbodies identified during the surveys of the study area, the other being Mosquito Creek immediately to the north of Targinie Creek (see Section 4.3.2). The headwaters of Boat Creek are formed by Sandy and Spring creeks, which are ephemeral streams that drain from Mount Larcom.

Monitoring of water and sediment quality and metal accumulation in oysters is undertaken in the lower estuarine reach of Boat Creek, downstream of the tunnel launch site, as part of the Port Curtis Integrated Monitoring Program (PCIMP). The program was established by a consortium of industry, government and research institutes to develop a cooperative integrated program to assess the ecosystem of Port Curtis and ensure the environmental sustainability of the Port of Gladstone. Water quality monitoring commenced in 2005 and is conducted annually in winter. This monitoring has indicated anomalous conditions in Boat Creek in comparison with other Port Curtis estuaries, namely lower pH, higher conductivity and higher concentrations of bioavailable aluminium, copper, cobalt and manganese (as measured by diffusive gradient in thin films (DGT) samplers) (Andersen *et al*., 2008). Groundwater intrusions or surface water runoff from the upper reaches of Boat Creek are postulated to be possible sources requiring further investigation.

Water quality sampling was undertaken in Targinie Creek in May 2010 to provide supplemental information for the Australia Pacific LNG Project EIS (APLNG, 2010). This sampling occurred at five sites in the lower estuarine reach of the creek well downstream of the proposed site of TWAF8. Concentrations of ammonia, total nitrogen and total phosphorus exceeded Queensland guideline values for Central Coast region mid-estuarine systems described in DERM (2009). However, levels of total suspended solids were well below the guideline value. Metal concentrations were mostly below detection limits, however these limits were insufficiently low to allow comparison with water quality guidelines. Total petroleum hydrocarbons (TPHs), benzene, toluene, ethylbenzene and xlenes (BTEX compounds) and polynuclear aromatic hydrocarbons (PAHs) were also measured. Concentrations of these hydrocarbon caompounds were all less than detection limits, except TPHs at one site. It was postulated that this could be due to inputs from recreational boating activity since several vessels were in the area at the time of sampling.

4.5 Summary of Aquatic Ecosystem Assessment

Database searches, review of the relevant EIS studies and environmental approval documents for other projects and site inspections undertaken as part of this study all indicate that aquatic habitat within the freshwater aquatic ecology study area are of very marginal value on a local or regional scale. The systems within this area are unlikely to support aquatic species, communities or processes of conservation significance.

The majority of the waterways within the study area are ephemeral, contain minimal, low value aquatic habitat and do not provide connectivity to more permanent waterways. Larcom Creek is the most significant waterway and is at the western end of the study area, but is well away and upstream from the influence of activities within the project area. This waterway is ephemeral but has the potential to contain some permanent or semi-

permanent waterholes and exhibits good quality aquatic habitat. Approximately 4.8 km of the middle reaches of Larcom Creek are within the freshwater aquatic ecology study area. This stream flows west through the freshwater aquatic ecology study area and does not provide connectivity to any permanent watercourses that may be affected by the project.

Government databases and recent surveys for other projects have not recorded any aquatic species of conservation significance within the study area.

The project will not involve water extraction and will not impact on groundwater quality or quantity; therefore it is very unlikely to impact on groundwater dependent aquatic ecosystems. No wetlands or spring-fed streams were observed during site inspections; hence it is unlikely that aquatic communities that depend on groundwater seepage or baseflow contributions exist within the freshwater aquatic ecology study area.

5 Issues and Potential Impacts on Freshwater Ecosystems, Communities and Processes

The purpose of this section is to provide a summary of the strategies and protocols relevant to the protection of freshwater aquatic communities, habitat and processes (APIA, 2009). The assessment of impacts of the project on freshwater aquatic ecosystems is based on the assumption that generic environmental controls for projects of this nature are implemented. These controls are described below.

5.1 Generic Environmental Controls

The purpose of this section is to provide a summary of the strategies and protocols relevant to the protection of freshwater aquatic communities, habitat and processes (APIA, 2009).

5.1.1 Overarching Controls

- Induction of all site personnel, including environmental management principles prior to accessing the project area.
- Minimisation of operations in close proximity to watercourses and strict compliance with environmental management plan requirements and additional permits where this is unavoidable.
- Establishment of an incident reporting procedure for environmental issues, including not authorised aquatic ecosystem impacts. This procedure should be made clear during site inductions.
- Where possible, site works should be timed to avoid periods during which significant storm events are likely.

5.1.2 Disturbance of Riparian and Aquatic Vegetation

- Clearing of riparian vegetation is to be minimised to the greatest extent practicable. In areas identified as of significant environmental value, the ROW is to be reduced to the minimum width practicable.
- Clearing of riparian vegetation is undertaken only after all other options are exhausted. Other options include retention of vegetation, selecting alternate sites, selective clearing and trimming of vegetation.
- Where vegetation is removed from streambanks and riparian zones, care should be taken to ensure that root systems responsible for stabilizing substrates are allowed to remain in place where possible.

- A vegetation management plan, which details the permit requirements, clearing methods, areas to be cleared and management of vegetation removal is prepared for the project.
- No vegetation removal shall occur until permits and approvals are obtained. All riparian vegetation removal will be in strict accordance with approval conditions.
- Where possible, riparian vegetation disturbance and loss will be minimised during planning and construction. Removal of vegetation will be restricted to the construction footprint where possible. Construction personnel and equipment will not be permitted outside of these areas.
- Areas for vegetation clearing are clearly demarcated through the use of high visibility fencing prior to any works in the project area.

5.1.3 Disturbance to Stream Bed and Banks

- Where waterway crossings are necessary, pipeline should approach stream crossings perpendicular to the stream where possible, to minimise the footprint within the bed and riparian zone.
- The use of vehicles and machinery within the riparian zones and beds of waterways should be avoided where possible and kept to a minimum where this is unavoidable, both in terms of the number and size of vehicles and the duration for which they are operating in the area.
- Trenching should occur progressively to minimise the length of open trench and the time for which the trench is open. Rehabilitation following trenching operations should include returning the contours of the site to their original condition. The creation of pools, depressions or trenches in which fish and other aquatic biota might become stranded by receding water levels should be avoided.
- Where possible, works involving disturbance to stream beds and banks would be avoided during periods of flow. If works cannot be timed to avoid flow, additional measures, such as the use of berms, silt fences and other mitigating structures would be adopted.

5.1.4 Aquatic Habitat Fragmentation

- Avoid placing infrastructure that may create barriers to the movement of aquatic species either physically or hydraulically.
- Where the placement of infrastructure in watercourses is unavoidable, a waterways barrier permit must be obtained from DERM and works must be in accordance with the conditions therein.

5.1.5 Water Quality, Sediment Transport and Deposition

- The use of vehicles and machinery within the riparian zones and beds of waterways should be avoided where possible and kept to a minimum where this is unavoidable, both in terms of the number and size of vehicles and the duration for which they are operating in the area.
- Where infrastructure may affect the hydrology of the system, and hence the potential sediment transport characteristics, appropriate engineering and soft engineering techniques should be adopted to ensure that excessive erosion does not occur with subsequent flow events.
- Appropriate sediment and stormwater management controls (e.g., silt fences, sedimentation ponds etc.) should be in place prior to the commencement of vegetation clearing works to prevent the transport of particulates into waterways during rainfall events. These must be maintained until such time as the disturbed area has been rehabilitated and should then be removed.
- To minimise BOD loading and oxygen depletion, cleared vegetation should not be stockpiled in, or within 100 m of watercourses.
- Where possible, grasses and other ground cover should remain in place to assist with trapping mobilised sediments. The use of herbicides within riparian zones or directly over watercourses should be avoided. Where this is not possible, products specifically approved for this purpose should be used.
- Fuels, oils and chemicals must be stored in appropriate, bunded storage facilities at least 100 m away from watercourses. Refuelling must not be carried out within 100 m of waterways.
- Chemical spill prevention and containment kits and protocols in place at all work fronts.

5.1.6 Translocation of Pest Species

- Pest species include Weeds of National Significance (WONS), as well as declared plants and animals under Queenslands Land Protection (Pest and Sotck Route Management) Act 2002.
- Where access tracks transect riparian vegetation or areas of significant weed invasion, site specific pest management measures should be implemented.
- Machinery and equipment used in or near waterways should be thoroughly cleaned before entering or leaving that waterway to prevent the transfer of invasive aquatic weeds between systems. Appropriate wash down procedures include the use of hot water, bleach or other biocidal chemicals.
- Contractors should be prevented from camping, fishing or other recreational activities within waterways of the project area to prevent the accidental introduction of pest species on fishing gear or bait.

5.2 Impacts of the Project on Aquatic Ecosystems

5.2.1 Disturbance of Riparian and Aquatic Vegetation

Description of activity/impact:

The removal of riparian or aquatic vegetation to provide access to the site for construction of the mainland tunnel entry shaft and mainland tunnel entry shaft and tunnel spoil disposal area, operation of the feed gas pipeline, tunnel, LNG plant, TWAF and supporting infrastructure.

The LNG plant and supporting infrastructure on Curtis Island represent the greatest area of vegetation within the study are that will be cleared for the project. Clearing of vegetation will be required at TWAF8, however it is understood that vegetation in close proximity to the creeks will not be disturbed. (Note: Aquatic ecosystems in the vicinity of TWAF7 are marine/estuarine in nature and are outside of the scope of this study).

Potentially affected aquatic ecosystems and sensitivity

(Refer to section 4.3.3 for derivation of sensitivity ratings)

- TWAF8 – Targinnie Creek Mosquito Creek, Scrubby Mountain Creek and UC2, all assigned a moderate sensitivity rating.
- Ephemeral systems on Curtis Island (UC8) at Arrow LNG Plant site (moderate sensitivity)

Magnitude of potential impacts

(Refer to table 3-1 for criteria used to assess the magnitude of impacts)

Anticipated impacts include:

- Loss or degradation of aquatic habitat for shelter, foraging and/or spawning/nursery areas.
- Water quality decline due to sediment transport, biochemical oxygen demand (BOD), 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

With the exception of Curtis Island (UC8), these activities will affect a limited geographic area with minor, short term impairment of aquatic communities anticipated, although the

duration of disturbance will be slightly longer at stream crossings. At the LNG Plant (UC8), construction will permanently replace aquatic ecosystems (high magnitude impact).

Impact assessment

(Refer to figure 3-2 for impact assessment matrix)

Table 5-1: Impact of riparian and aquatic vegetation disturbance.

Location	Sensitivity	Magnitude	Impact	Notes
Targinnie, Mosquito and Scrubby Mountain Creeks, UC2	Moderate	Moderate	Moderate	Depends on proximity to watercourse
Curtis Island (UC8)	Moderate	High	High	Creek and riparian zone replaced with LNG infrastructure. No mitigation possible.

5.2.2 Disturbance of Stream Beds/Banks

Description of activity/impact:

The disturbance of stream beds and banks will be both inevitable and permanent on Curtis Island, as UC8 passes directly through the LNG Plant site and must be diverted for the project.

The construction of additional access tracks and the movement of vehicles in the vicinity of other waterways are expected to be minimal and are unlikely to contribute significantly to impacts on stream beds or banks.

Potentially affected aquatic ecosystems and sensitivity

(Refer to section 4.3.3 for derivation of sensitivity ratings)

- Freshwater reaches of Boat Creek and UC1 (moderate sensitivity).
- TWAF8 – Targinnie Creek, Mosquito Creek, Scrubby Mountain Creek and UC2, all assigned a moderate sensitivity rating.
- Ephemeral systems on Curtis Island (UC8) at Arrow LNG Plant site (moderate sensitivity).

Magnitude of potential impacts

(Refer to table 3-1 for criteria used to assess the magnitude of impacts)

Anticipated impacts include:

- Potential short-term water quality decline due to sediment transport, BOD, nutrient loads etc.
- Potential for altered erosion processes, with changes in scouring and deposition patterns.
- Potential for impedance of passage for aquatic biota, although this is likely to be avoided by trenching in the dry season.
- Physical disturbance of small areas of stream bed and bank in the vicinity waterway crossings.

With the exception of the LNG Plant site on Curtis Island (UC8), these impacts are expected to be localised and short-term, with only minor impairment of aquatic communities (low impact). At the LNG Plant (UC8), construction will permanently replace aquatic ecosystems (high magnitude impact).

Impact assessment

Table 5-2: Impact of disturbance to stream beds/banks.

Location	Sensitivity	Magnitude	Impact	Notes
Targinnie, Mosquito and Scrubby Mountain Creeks, UC2	Moderate	Low	Low	Depends on proximity to watercourse
Boat Creek and UC1	Moderate	Low	Low	Nil
Curtis Island (UC8)	Moderate	High	High	Creek and riparian zone replaced with LNG infrastructure. No mitigation possible.

5.2.3 Aquatic Habitat Fragmentation

Description of activity/impact:

Linear projects involving water crossings may create barriers to the movement of fish, macrofauna or vegetation propagules, particularly if infrastructure is placed within the stream beds or on the banks. Changes in hydrology may exacerbate aquatic habitat fragmentation by reducing the depth of water over barriers or by creating velocity barriers.

No waterway crossings are anticipated as part of this process, therefore this strategy will minimise or avoid physical fragmentation of habitat. Activities within the mainland portion of the study area are not expected to alter surface or groundwater hydrology; hence flow velocity barriers will not be created.

Potentially affected aquatic ecosystems and sensitivity

(Refer to section 4.3.3 for derivation of sensitivity ratings)

- Freshwater reaches of Boat Creek and UC1 (moderate sensitivity).
- Ephemeral systems on Curtis Island (UC8) at Arrow LNG Plant site (moderate sensitivity).
- Short to medium term physical barriers to fish passage during the construction of stream crossings and subsequent rehabilitation of the project footprint.

Magnitude of potential impacts

(Refer to table 3-1 for criteria used to assess the magnitude of impacts)

Potential 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 (anadromous or catadromous) 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.

Aquatic habitat in the lower reaches of UC8 on Curtis Island will be permanently displaced by the LNG Plant. This stream does not provide connectivity to any permanent aquatic

environments such as lakes or wetlands; however the permanent nature of the impact results in a high impact rating.

Boat Creek and UC1 contain limited aquatic habitat, and as the project does not involve the creation of physical or velocity barriers any impacts will be localised, short-term and of minor consequence to aquatic communities, hence have been assigned a low impact rating.

Impact assessment

Table 5-3: Impact of aquatic habitat fragmentation

Location	Sensitivity	Magnitude	Impact	Notes
Targinnie, Mosquito and Scrubby Mountain Creeks, UC2	Moderate	Low	Low	Depends on proximity to watercourse
Boat Creek and UC1	Moderate	Low	Low	Nil
Curtis Island (UC8)	Moderate	High	High	Creek and riparian zone replaced with LNG infrastructure. No mitigation possible.

5.2.4 Water and Sediment Quality Impacts on Aquatic Systems and Processes

Description of activity/impact:

The greatest potential for water quality impacts is likely during construction of the project, although some potential may also exist if maintenance operations require digging up a section of the feed gas pipeline. The main issues are linked with vegetation removal and direct disturbance of bed and stream banks and hence have already been addressed in prior sections of this chapter.

Additional water quality impacts are associated with the use of chemicals and fuels in the vicinity of watercourses and drainage lines and with the management of sewage and waste generated on site. These will largely be addressed by standard best practices for construction (fuel management, chemical bunding etc.).

Regarding services for TWAF8, it is understood that the base case is that public services such as sewerage and potable water will be available onsite. If not then potable water will be trucked in and sewerage collected and trucked offsite.

Potentially affected aquatic ecosystems and sensitivity

(Refer to section 4.3.3 for derivation of sensitivity ratings)

Areas that may potentially be impacted by poor water or sediment quality include:

- Targinnie Creek, Mosquito Creek, Scrubby Mountain Creek and UC2 may be affected by activities associated with TWAF8 (moderate sensitivity).
- Boat Creek and UC1 may be affected by the mainland tunnel entry shaft and tunnel spoil disposal area and feed gas pipeline construction (moderate sensitivity).
- UC8 may be affected during the construction phase of the LNG Plant on Curtis Island (moderate sensitivity).

Magnitude of potential impacts

(Refer to table 3-1 for criteria used to assess the magnitude of impacts)

- Loss of aquatic communities as a result of pollution with fuels or other toxic substances.
- Loss of aquatic communities due to BOD loading and oxygen depletion of waterways.
- Enrichment of waterways with nutrients, resulting in noxious algal blooms, proliferation of aquatic weeds and, in downstream marine environments, potential for dynoflagellate blooms, loss of seagrass beds etc.
- Contamination with pathogens, exposure of humans and aquatic organisms to giardia, cryptosporidium etc.
- Loss of aesthetic amenity due to odour and unsightly scums.

The application of the generic environmental controls described herein is expected to result in minimal impact on water and sediment quality, hence water and sediment contamination is generally expected to have a low impact rating. However, the impact will be of longer duration if waterway crossings are required and this impact has been assigned a moderate rating for mainland sites in the study area. No watercourse crossings are anticipated as part of the project on the mainland, but should a crossing of an ephemeral watercourse be required, the impact has been assigned a moderate rating. The Curtis Island ephemeral waterbody will be removed within the footprint of the Arrow LNG Plant, and replaced with diversion channels around the west and east of the LNG Plant site. The impact of this loss of aquatic habitat has already been assessed, and there is no connectivity to any permanent aquatic environments such as lakes or wetlands, therefore the magnitude of water and sediment quality impacts is low.

Impact assessment

Table 5-4: Impact of water/sediment quality.

Location	Sensitivity	Magnitude	Impact	Notes
Targinnie, Mosquito and Scrubby Mountain Creeks, UC2	Moderate	Moderate	Moderate	Removal of sewage, waste negates issue
Boat Creek and UC1	Moderate	Moderate	Moderate	Nil
Curtis Island (UC8)	Moderate	Low	Low	Nil

5.2.5 Translocation of Pest Flora and Fauna

Description of activity/impact:

The translocation of pest plant and animal species is a significant issue for all large scale construction projects, but particularly for projects, where machinery is moved over large areas and between catchments/bioregions. It has been assumed for the purposes of this assessment that standard plant and machinery hygiene procedures and pest plant/animal management protocols will be implemented; hence the issue of translocation will largely be avoided.

There is also some potential for deliberate translocation of some species, particularly fauna, for recreational purposes. These include fish or crustaceans intended for stocking waterways to create fishing opportunities, organisms intended for use as live bait and live fish or crustaceans brought to the site for consumption at a later time.

In terms of translocation of aquatic flora and fauna to the Curtis Island site, the very limited availability of aquatic habitat, along with its ephemeral nature will limit colonisation of natural waterways by most aquatic fauna species. There is potential for the introduction of some aquatic flora species that are tolerant of periods of desiccation, (e.g., cumbungi), although the area where this could potentially occur is restricted by tidal incursion and by very limited availability of water.

If water is to be stored on site at the LNG plant, there is potential for the inadvertent introduction of a range of aquatic flora and fauna species, including fish, reptiles, amphibians and aquatic weeds. Normal plant and machinery hygiene, pest plant/animal management protocols and restricted access to any water storage can be expected to largely eliminate this issue.

Of greater concern is the potential for the spread of pest aquatic species, particularly plant species, during construction and operational activities along the feed gas pipeline route.

There is potential for pest species to be inadvertently introduced via machinery operated close to watercourses in the mainland portion of the study area. Due to greater connectivity of some of these waterways, the potential for spread of these species across a wider spatial range is greater than is possible on Curtis Island. This is particularly important given that the exotic species *Salvinia molesta* (salvinia), *Salix nigra* (black willow), *Sphagneticola trilobata* (Singapore daisy) and *Eichhornia crassipes* (water hyacinth) have been recorded within the study area and are all invasive species capable of spreading through the downstream dispersion of propagules or vegetative tissue.

There is also potential for the introduction of pest aquatic species into waterways in the vicinity of TWAF8, as a result of the movement of machinery or materials between sites.

Potentially affected aquatic ecosystems and sensitivity

(Refer to section 4.3.3 for derivation of sensitivity ratings)

- Targinnie Creek, Mosquito Creek, Scrubby Mountain Creek and UC2 may be affected by activities associated with TWAF8 (moderate sensitivity).
- Boat Creek and UC1 may be affected by the mainland tunnel entry shaft and tunnel spoil disposal area and feed gas pipeline construction (moderate sensitivity).
- UC8 may be affected during the construction phase of the LNG Plant on Curtis Island (moderate sensitivity).

Magnitude of potential impacts

(Refer to table 3-1 for criteria used to assess the magnitude of impacts)

- 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 can 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 can result in the displacement of native species, with a resultant loss of biodiversity and changes in ecosystem dynamics.
- The introduction of exotic species as a result of the project may necessitate an ongoing program of monitoring and inspection.

- Introduction of diseases, parasites or pathogens not currently found within waterways in the study area that may adversely impact on existing aquatic communities.

Impact assessment

Table 5-5: Impacts of translocated flora and fauna.

Location	Sensitivity	Magnitude	Impact	Notes
Targinnie, Mosquito and Scrubby Mountain Creeks, UC2	Moderate	Low	Low	Assumes normal protocols followed
Boat Creek and UC1	Moderate	Low	Low	Assumes normal protocols followed
Curtis Island (UC8)	Moderate	Low	Low	Assumes normal protocols followed

5.2.6 Altered Geomorphology and Runoff Patterns

Description of activity/impact:

The greatest potential for impacts on aquatic values as a result of disturbed surface runoff or geomorphological processes occurs where the permeability of large areas of catchment is altered.

Spatially, the LNG plant and supporting infrastructure represents the most significant area that will experience reduced permeability and hence increased surface water runoff. This impact will be both permanent and unavoidable, but will affect only the lower reaches of an ephemeral system that does not support any aquatic species of conservation significance and is very unlikely to represent significant habitat for aquatic communities due to its isolation from more permanent systems and the absence of permanent pools or upstream aquatic habitat such as wetlands or lakes. Although there was no water in this system during either of the site inspections, it is likely that aquatic macroinvertebrates typical of ephemeral systems colonise temporary pools seasonally. This is unlikely to be dependent on the movement of fauna from the lower reaches of the stream and will be unaffected by the project. Natural flows and upstream geomorphic processes in this ephemeral system will not be affected.

The construction of TWAF8 is expected to impact on catchment permeability to a lesser extent than the LNG Plant, but may result in minor alteration of surface water hydrology and geomorphic processes locally. Normal best practice for stormwater and erosion

management during construction and operation can be expected to mitigate these impacts.

The removal of vegetation and the process of trenching and laying the feed gas pipeline may result in short-term increases in surface water runoff, though these will be partially restored once the feed gas pipeline is buried and grasses become re-established over the surface. Due to the rehabilitation requirements above a gas pipeline, (suitable species are shrubs and groundcover without extensive root systems), the lack of canopy cover might change the surface water hydrology. However, the permeability of the land will not be substantially altered and hence the reduced canopy cover is not expected to have a measurable impact on surface water hydrology.

Potentially affected aquatic ecosystems and sensitivity

(Refer to section 4.3.3 for derivation of sensitivity ratings)

- Targinnie Creek, Mosquito Creek, Scrubby Mountain Creek and UC2 may be affected by activities associated with TWAF8 (moderate sensitivity).
- Boat Creek and UC2 may be affected by the mainland tunnel entry shaft and tunnel spoil disposal area and feed gas pipeline construction (moderate sensitivity).
- UC8 may be affected during the construction phase of the LNG Plant on Curtis Island (moderate sensitivity).

Magnitude of potential impacts

(Refer to table 3-1 for criteria used to assess the magnitude of impacts)

- 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.
- Enrichment of waterways with nutrients, resulting in noxious algal blooms, proliferation of aquatic weeds and, in downstream marine environments, potential for dynoflagellate blooms, loss of seagrass beds etc.

The application of the generic environmental controls contained herein is expected to minimise impacts on geomorphology and surface water hydrology across the freshwater aquatic ecology study area.

Impact assessment

Table 5-6: Impact of altered geomorphology and surface runoff.

Location	Sensitivity	Magnitude	Impact	Notes
Targinnie, Mosquito and Scrubby Mountain Creeks, UC2	Moderate	Low	Low	Nil
Boat Creek and UC1	Moderate	Low	Low	Nil
Curtis Island (UC8)	Moderate	Low	Low	Surfacing, flow diversion and stormwater management expected to alleviate surface hydrology related impacts

5.2.7 Tunnelling Activities, Tunnel Spoil and Dredge Spoil

Description of activity/impact:

The method for tunnelling is likely to be tunnel boring machine, although the use of horizontal directional drilling (and hence chemicals such as bentonite and lubricating fluids) has not yet been ruled out.

Tunnel spoil will be placed into a bunded area on the mudflat adjacent to the tunnel entry point in close proximity to the tidal reaches of Boat Creek, however, sediment will be contained and settled within this area and is not expected to impact on freshwater aquatic ecosystems in Boat Creek.

Spoil from dredging will be dewatered and used to reclaim intertidal areas north of Fishermans Landing, below the high tide mark and away from freshwater ecosystems.

Neither of these operations involves the disposal of water or slurry to terrestrial or freshwater aquatic environments, and as the scope of the aquatic ecology impact assessment is restricted to non-tidal areas, these operations will have no impact on the aquatic ecosystems under consideration.

Potentially affected aquatic ecosystems and sensitivity

(Refer to section 4.3.3 for derivation of sensitivity ratings)

- Boat Creek and UC1 are in the vicinity of tunnelling and spoil disposal activities associated with the mainland tunnel entry shaft and tunnel spoil disposal area (moderate sensitivity).
- UC8 on Curtis Island is in the vicinity of tunnelling activities (moderate sensitivity).

Magnitude of potential impacts

(Refer to table 3-1 for criteria used to assess the magnitude of impacts)

No direct impacts on freshwater aquatic ecosystems anticipated as 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 carried into Boat Creek by tidal influences, but this would not affect freshwater reaches of the creek.

Impact assessment

Table 5-7: Impact of tunnelling, tunnel spoil and dredge spoil.

Location	Sensitivity	Magnitude	Impact	Notes
Boat Creek and UC1	Moderate	Low	Low	Assumes normal protocols followed
Curtis Island (UC8)	Moderate	Low	Low	Assumes normal protocols followed

5.2.8 Aquatic Fauna Injury and Mortality

Description of activity/impact:

As previously discussed in this report, there is a general lack of high quality, permanent watercourses within the freshwater aquatic ecology study area, which is reflected in the lack of higher aquatic fauna previously recorded at the site. Of the two listed species potentially present, water mouse (*Xeromys myoides*) has been addressed in the terrestrial ecology (flora and fauna) assessment (Ecosure, 2011), whilst habitat at the site has been found to be marginal for saltwater crocodiles (*Crocodylus porosus*) due to a general lack of substantial pools. This species has also been addressed in the terrestrial ecology (flora and fauna) assessment (Ecosure, 2011).

Other higher aquatic fauna (or fauna with aquatic stages in their life history) previously recorded within the extended freshwater aquatic ecology study area include a number of frog, bird, reptile (turtle) and fish species. Frogs and birds have been addressed in the terrestrial ecology (flora and fauna) assessment (Ecosure, 2011).

Injury, illness or mortality of fish or turtles may result from indirect impacts, such as poor water quality, sedimentation, deoxygenation, nutrient enrichment or loss of riparian vegetation. However, these issues have been previously dealt with and are not discussed further in this section.

The project does not involve stream crossings, disturbance of stream banks, construction of infrastructure within or adjacent to aquatic habitat, blasting or other processes that might directly cause injury or mortality to fish or turtles within the freshwater aquatic ecology study area, with the exception of limited horizontal direct drilling and the diversion of the ephemeral stream UC8.

Potentially affected aquatic ecosystems and sensitivity

(Refer to section 4.3.3 for derivation of sensitivity ratings)

- Targinnie Creek, Mosquito Creek, Scrubby Mountain Creek and UC2 may be affected by activities associated with TWAF8 (moderate sensitivity).
- Boat Creek and UC2 may be affected by mainland tunnel entry shaft and tunnel disposal area and feed gas pipeline construction (moderate sensitivity).
- UC8 may be affected during the construction phase of the LNG Plant on Curtis Island (moderate sensitivity).

Magnitude of potential impacts

(Refer to table 3-1 for criteria used to assess the magnitude of impacts)

Mortality or injury of aquatic vertebrate fauna as a direct result of project activities is considered very unlikely. In the event that this issue should arise, it is expected to be minor, highly localised and comprised of isolated individual events. It is highly unlikely to impact on listed aquatic species, to result in widespread mortalities or to have a medium to long term impact on the viability of fauna communities.

Impact assessment

Table 5-8: Impact of aquatic fauna injury/mortalities.

Location	Sensitivity	Magnitude	Impact	Notes
Targinnie, Mosquito and Scrubby Mountain Creeks, UC2	Moderate	Low	Low	Assumes normal protocols followed
Boat Creek and UC1	Moderate	Low	Low	Assumes normal protocols followed
Curtis Island (UC8)	Moderate	Low	Low	Assumes normal protocols followed

5.2.9 Impacts on Groundwater Dependent Ecosystems

Description of activity/impact:

Groundwater dependent ecosystems (GDE's) are essentially comprised of:

- Subterranean communities (stygofauna and troglofauna).
- Lacustrine, palustrine or fluvial species or communities that depend on baseflow during the dry season to maintain habitat quality or availability.

Some terrestrial flora and fauna may also be dependent on groundwater and are discussed in the terrestrial ecology (flora and fauna) assessment (Ecosure, 2011).

Site inspections during the early wet season revealed no permanent wetlands, swamps, mound springs, lakes or other palustrine/lacustrine systems that might be maintained by groundwater influx. Likewise, post-wet season site inspections revealed no temporary palustrine environments; hence it is unlikely that any such systems exist within the freshwater aquatic ecology study area.

Detection of stygofauna and/or troglofauna communities is not possible by a simple site inspection, but the availability of suitable habitat is considered unlikely given the local geology and relatively flat topography.

GDE's can potentially be become impacted if the flow, water table level, pressure or quality of groundwater is altered by extraction, injection, pollution or alteration of the porosity of recharge and discharge zones. The project does not involve any activities that might result in impacts of this type.

As a result of the paucity of GDE's and the anticipated low impacts of the project on groundwater flow, level, pressure or quality, this issue has been assigned a low impact.

Potentially affected aquatic ecosystems and sensitivity

None identified.

Magnitude of potential impacts

No changes to groundwater flow, level, pressure or quality are anticipated, hence the magnitude of impacts is considered low.

Impact assessment

Table 5-9: Impacts on groundwater dependent ecosystems.

Location	Sensitivity	Magnitude	Impact	Notes
Any locations within freshwater aquatic ecology study area that might contain GDE's	Low	Low	Low	Nil

5.2.10 Mosquitoes and Biting Midges

Description of activity/impact:

Biting insects such as mosquito have the potential to spread diseases such as Dengue fever and Ross River virus, and are therefore of pest and health significance.

There is potential for infrastructure projects to create breeding habitat for mosquitoes and/or biting midges, or for existing aquatic habitats to be modified in a way that favours breeding of these insects or reduces predation of the larvae. Habitat that is particularly favourable for mosquitoes and biting midges includes still, stagnant and organic rich areas, particularly if these are temporary habitat that is not interconnected with more permanent waterways that contain fish and other biota that may predate on the larvae. A proliferation of aquatic vegetation can also assist breeding success by providing habitat that reduces predation on larvae.

The project will not result in the creation of new aquatic habitat such as swamps, marshes, bogs, ponds, pools or other standing water and will therefore not create new habitat for biting insects. Indirect impacts that may assist the breeding cycles of biting insects include nutrient enrichment, organic enrichment and other impacts on water quality, as well a surface water hydrology. These issues have been previously addressed in this document.

Biting insects are capable of breeding in very small pools of water, and the greatest

potential for this project to increase the numbers of these animals will come from the formation of small pools in areas where ground breaking activities occur, as well as in wheel ruts and similar small depressions.

Potentially affected aquatic ecosystems and sensitivity

No new standing water (pools, ponds etc) will be created by the project, hence there will be no increase in breeding habitat for biting insects.

Increased potential for the breeding of biting insects may result from water pooling at construction sites or in wheel ruts, posidrive tracks, etc. These may occur anywhere in the freshwater aquatic ecology study area where ground-breaking, vegetation removal or vehicle access activities occur.

The sensitivity rating protocols outlined in Table 3-1 are not applicable for assessing this particular issue and the protocols outlined in Table 5-10 have been developed and adopted instead.

The study area is in close proximity to mangrove and mudflat areas that are well known for harbouring mosquitoes and biting midges, however many of these species are likely to be specific to saline environments and may not be favoured by minor pooling of freshwater within the study area. The proportion of freshwater dependent species of biting insects is unknown, but is likely to be relatively high due to the flat topography and the abundance of small, though very short lived and disconnected pools during and immediately following rain events.

This issue has been assigned a moderate sensitivity rating since the majority of works will be located >5 km from significant residential populations. Standing water bodies will be limited to very small, temporary puddles, such as those left by the tracks of earthmoving machinery. No moderate to large areas of bog, marsh or swamp will be created by the project.

Table 5-10: Revised impact assessment criteria for mosquitoes and biting midges.

	High	Moderate	Low
Sensitivity			
Proximity to human populations	Within 1 km of a town or cluster of residences	1-5 km from a town or cluster of residences	>5 km from a town or cluster of residences
Suitability for mosquito breeding	Many small bodies of standing water, lots of submerged vegetation, minimal predation	Moderately suitable. Some areas of standing water and/or submerged vegetation	Poor breeding habitat. Limited standing water, high predation, limited submerged vegetation
Magnitude			
Geographic extent of impact	New habitat diffuse and widespread across project area	New habitat relatively confined	New habitat confined to one or two locations.
Duration of impact	New breeding habitat permanent	New breeding habitat medium –term, 2-3 year duration	New breeding habitat no longer available following construction/rehab.
Seasonality	New habitat provides perennial breeding opportunity	New habitat provides opportunity for extended wet season breeding	New habitat exists only during peak mosquito breeding (wet season) and does not extend season
Severity	Large area of new habitat: >10% increase in local breeding habitat	Moderate area of new habitat: 0.5-10% increase in local breeding habitat	Small area of new habitat: <0.5% increase in local breeding habitat

Magnitude of potential impacts

The magnitude of impact is expected to be low, since contouring and revegetating of the site will reduce the potential for pooling, hence new breeding habitat will constitute a very small propoirtion of available habitat, will not extend the peak breeding season and will only be present for very short periods during the construction works.

Impact assessment

Table 5-11: Impacts of mosquitoes and biting midges.

Location	Sensitivity	Magnitude	Impact	Notes
All areas within freshwater aquatic ecology study area	Moderate	Low	Low	Nil

Summary of Impact Assessment for Aquatic Ecosystems provides a summary of the potential impacts on freshwater aquatic ecosystems within and adjacent to the project.

The most substantial impacts are associated with the construction of the LNG plant and associated infrastructure on Curtis Island itself, where the disturbance of stream beds and banks, along with fragmentation of aquatic habitat is given an impact rating of “high” using the criteria outlined herein. This ranking reflects the permanent nature of the impacts, as all other aspects of the impact assessment indicated moderate to low impact.

The potential disturbance or removal of riparian vegetation for the construction of TWAF8 has been identified as having a low-moderate impact on aquatic systems, largely due to the area of land that would potentially be cleared and the potential for stormwater runoff to influence water and/or habitat quality in adjacent streams. The presence of a significant human population also increases the possibility of chemical/fuel spillage or impacts associated with vehicles, litter and greywater. The proposed removal of sewage and other waste for disposal to landfill significantly reduces the potential impacts of TWAF8.

Table 5-12: Summary of potential impacts of the Arrow LNG Plant on aquatic ecosystems within the study area.

	Targinnie Creek, Mosquito Creek, Scrubby Mountain Creek and UC2	Boat Creek and UC1	Curtis Island (UC8)
Disturbance of riparian vegetation	Moderate	N/A	High
Disturbance of stream beds and banks	Low	Low	High
Aquatic habitat fragmentation	Low	Low	High
Water quality and sediment	Moderate	Moderate	Low

	Targinnie Creek, Mosquito Creek, Scrubby Mountain Creek and UC2	Boat Creek and UC1	Curtis Island (UC8)
transport and deposition			
Altered hydrology and geomorphology	Low	Low	Low
Translocation of pest species	Low	Low	Low
Tunnelling activities, tunnel spoil and dredge spoil	Low	Low	N/A
Aquatic fauna injury and mortality	Low	Low	Low
Groundwater dependent ecosystems	Low	Low	Low
Mosquitoes and biting midges	Low	Low	Low

6 Avoidance, Mitigation and Management Measures

No highly sensitive aquatic environments, communities or values have been identified within the study area. The project has a minimal footprint on the mainland, although the LNG plant and supporting infrastructure will have a substantial footprint on Curtis Island.

In addition to the generic environmental controls described in Section 5.1, a number of project-specific avoidance, mitigation and management strategies should be implemented and are described herein. The residual impact assessment described in Section 7 assumes that both the generic and project-specific strategies are implemented.

6.1 Specific Measures for Identified Aquatic Values

This section focuses on specific avoidance, mitigation or management measures required to protect freshwater aquatic ecosystems above and beyond the standard best practice approaches, such as those outlined in the Environmental Code of Practice: Onshore Pipelines (APIA, 2009). Due to the nature of aquatic systems in the study area, these are very few in number.

6.1.1 Disturbance of Riparian and Aquatic Vegetation

With the exception of the diversion at UC8, the project is not expected to involve creek crossings or any works within or in close proximity to stream beds, banks or riparian zones. In the unlikely event that such disturbance becomes necessary, the following avoidance and mitigation strategies will be adopted:

- Feed gas pipeline route selection will avoid where possible areas of higher quality aquatic habitat (e.g., remnant pools and waterholes).
- Crossing of ephemeral streams in preference to permanent ones.

6.1.2 Disturbance to Stream Beds and Banks

With the exception of the diversion at UC8, the project is not expected to involve creek crossings or any works within or in close proximity to stream beds, banks or riparian zones. In the unlikely event that such disturbance becomes necessary, the following avoidance and mitigation strategies will be adopted:

- Feed gas pipeline route selection will avoid areas where possible of higher quality aquatic habitat (e.g., remnant pools and waterholes).

- In the unlikely event that stream crossings become necessary, these would cross ephemeral streams in preference to permanent ones.

The ephemeral creek diversion will be constructed to ensure diverted flows do not result in scouring or sedimentation within and downstream of the diversion channel, beyond that typically expected.

6.1.3 Aquatic Habitat Fragmentation

- The project has been designed to reduce, and where possible, avoid physical fragmentation of aquatic habitat and hence adverse effects are not expected.

6.1.4 Water Quality, Sediment Transport and Deposition

- In the unlikely event that stream crossings are necessary, the feed gas pipeline should approach stream crossings perpendicular to the stream where possible, to minimise the footprint within the bed and riparian zone. Ephemeral streams would be crossed in preference to permanent ones.
- Pipeline route selection currently avoids areas of higher quality aquatic habitat (e.g., remnant pools and waterholes).
- Erosion and sediment transport should be minimised by undertaking pipeline laying operations in the vicinity of ephemeral streams where possible during drier months. Trenching should occur during periods of dryness, and the backfilling and rehabilitation of the stream crossing should be completed well in advance of wet season flows.
- The removal of sewage and waste from TWAF8 for disposal at appropriate registered disposal facilities.

6.1.5 Translocation of Pest Species

Due to the strategy of avoiding aquatic ecosystems, no project specific strategies in addition to those described in Section 5.1 are required.

6.1.6 Altered Geomorphology and Runoff Patterns

No project specific strategies in addition to those described in Section 5.1 are required.

6.1.7 Tunnelling Activities, Tunnel Spoil and Dredge Spoil

As these activities are extremely unlikely to impact of freshwater aquatic ecology values no project specific strategies are necessary.

6.1.8 Aquatic Fauna Injury and/or Mortality

Due to the strategy of avoiding aquatic ecosystems, injury or mortality of aquatic fauna is very unlikely and no project specific strategies are necessary.

6.1.9 Impacts on Groundwater Dependent Ecosystems

No groundwater dependent ecosystems have been identified in the freshwater aquatic ecology study area and no project specific strategies are required to mitigate impacts on these values.

6.1.10 Mosquitoes and Biting Midges

- Care will be taken to contour and rehabilitate areas where ground breaking activities take place in order to facilitate drainage and minimise this issue.

6.2 Miscellaneous Measures to Protect Freshwater Aquatic Ecology Values

6.2.1 Fish of 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, or in Mosquito Creek adjacent to TWAF8. Purple spotted gudgeon (*Mogurnda adspersa*) and Rendahl's tandan (*Porochilus rendahli*); both require permanent water with an abundance of submerged aquatic vegetation (Pusey *et. al*., 2004). This type of habitat was scarce within the greater study area, but was present at the Mosquito Creek and Boat Creek sites. Rendahl's tandan may also utilise ephemeral habitat during flow periods in order to move through a system to colonise more permanent pools (Pusey *et. al*., 2004)

If these species are present within the freshwater aquatic ecology study area, they are most likely to be found in the western portion within Larcom Creek, remnant pools at the lower end of Boat Creek or permanent/remnant pools in Mosquito Creek. Larcom Creek is outside and upslope of the study area, hence populations of these species in Larcom Creek will be unaffected by the project.

Specific mitigation

The following protocols in addition to normal environmental controls are recommended when works are undertaken in the vicinity of water-bearing pools in either Boat or Mosquito Creeks:

- The alignment of the mainland tunnel entry shaft and tunnel spoil disposal area should be kept well clear of Boat Creek. Tail water discharge from the tunnel spoil disposal area should avoid Boat Creek.
- If stream crossings are necessary, they are best completed during the drier months through areas where the stream ceases to flow. Rehabilitation of stream beds and banks should be complete as soon as possible before the wet season flows.
- Extra care should be taken to adhere to machinery hygiene protocols and to avoid the translocation of pest species, particularly weeds such as salvinia, cumbungi and paragrass.
- During dry season works, care should be taken not to disturb bed or stream banks, aquatic or riparian vegetation in any remnant pools.

6.2.2 Previously Unidentified Pockets of Aquatic Habitat

It is possible that permanent or semi-permanent pools or waterholes exist within the study area that were not identified during the site inspections, although desktop assessment and targeted fieldwork will have minimised the likelihood of this being the case. If present, these are most likely to occur within the Larcom, Boat or Mosquito Creek channels and floodplains. Within the study area, the limited nature of the freshwater systems and their close proximity to tidal areas makes it unlikely, though not impossible that isolated pockets of aquatic habitat exist.

The potential impacts on such remnant systems have been considered in the impact assessment component of this report. However, such pools may represent locally important refuges for aquatic organisms and are worthy of specific environmental controls if identified during construction.

Specific mitigation

- The alignment of the feed gas pipeline should be modified, if possible, to avoid disturbance of remnant pools or waterholes if encountered along the route.
- If crossings are necessary, they are best completed during the drier months through areas where the stream ceases to flow. Rehabilitation of stream beds and banks should be complete as soon before the wet season flows as possible.

- Extra care should be taken to maintain and audit machinery hygiene protocols and to avoid the translocation of aquatic pest species, particularly weeds such as salvinia, cumbungi and paragrass.
- During dry season works, care should be taken not to disturb the bed or banks, aquatic or riparian vegetation in any remnant pools.

7 Residual Impact Assessment

The implementation of both the specific and generic environmental controls outlined in Section 6 of this report is important, as this will reduce the overall impact of each issue/activity. However, the reduction in significance of impact may be insufficient to result in a drop in risk level in the context of the impact assessment criteria outlined in Table 3-1.

Specific controls to avoid or minimise the impact of the LNG Plant site on the bed and bank structure and aquatic habitat fragmentation UC8 on Curtis Island are not practical, as natural systems within this part of the study area will be displaced by the LNG plant. Table 7.1 provides the results of the pre and post (residual) impact assessment.

Table 7-1: Residual impact assessment following implementation of generic and specific environmental controls.

	Targinnie Creek, Mosquito Creek, Scrubby Mountain Creek and UC2		Boat Creek and UC1		Curtis Island (UC8)	
	initial	residual	initial	residual	initial	residual
Disturbance of riparian or aquatic vegetation	Moderate	Low	N/A	N/A	High	High
Disturbance of stream beds and banks	Low	Low	Low	Low	High	High
Aquatic habitat fragmentation	Low	Low	Low	Low	High	High
Water quality and sediment transport deposition	Moderate	Low	Moderate	Low	Low	Low
Altered hydrology and geomorphology	Low	Low	Low	Low	Low	Low
Translocation of pest species	Low	Low	Low	Low	Low	Low
Tunnelling Activities, Tunnel Spoil and Dredge Spoil	Low	Low	Low	Low	N/A	N/A
Aquatic fauna injury/mortality	Low	Low	Low	Low	Low	Low

	Targinnie Creek, Mosquito Creek, Scrubby Mountain Creek and UC2		Boat Creek and UC1		Curtis Island (UC8)	
Groundwater dependent ecosystems	Low	Low	Low	Low	Low	Low
Mosquitoes and biting midges	Low	Low	Low	Low	Low	Low

The construction of the Arrow LNG plant on Curtis Island represents the greatest impact on aquatic ecosystems and on water quality. Whilst this particular activity has a high impact on aquatic ecosystems and water quality, these impacts should be considered in light of the following qualifications:

- The stream is ephemeral and contains water for only very short periods of time. It did not contain water at the time of the June 2010 site inspection, 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 the stream 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 June inspection, the entire length of the stream was walked and no remnant pools were found, therefore the stream could only support aquatic communities that can colonise rapidly and have short life cycles, or able to move between waterways (e.g., flying insects with aquatic larval stages).
- Due to the very short flow period, the stream 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, so the stream has no value as a movement corridor for aquatic species.
- Water quality is typically poor in ephemeral systems during storm events and the relatively minor contribution that the Arrow LNG Plant may potentially make is unlikely to be detectable abvove normal baseline variability.
- Database searches indicate 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.

8 Cumulative Impact Assessment

A review of the expected cumulative impacts on aquatic ecosystems of key energy, infrastructure and resource development projects within and adjacent to the study area is summarised in Table 8-1 and 8-2.

8.1.1 LNG Projects

All of the LNG projects involve a linear (feed gas pipeline) component and the construction of an LNG plant and supporting infrastructure.

In terms of impacts on aquatic ecosystems, the feed gas pipeline component of all of the LNG projects has the potential to alter aquatic communities, values or processes through:

- The loss or decline of riparian and/or aquatic vegetation in the vicinity of stream crossings.
- Disturbance of stream beds or banks at stream crossings.
- Fragmentation of aquatic habitat and impedance to the movement of aquatic biota as a result of physical or velocity barriers.
- Impacts on water quality and/or increased erosion/sediment transport.
- Altered surface water hydrology and geomorphological processes as a result of altered catchment permeability.
- Spread or introduction of pest aquatic organisms.

The degree to which these impacts are likely to occur varies between projects, depending on the route to be taken by the feed gas pipeline and any ancillary infrastructure associated with it (e.g., access tracks). However, due to the nature of the watercourses and aquatic habitat/communities within the study area it is considered likely that the impacts of each of these individual projects will be minimal, and comparable to those expected for the Arrow LNG Plant.

Each of the LNG projects involves the construction of an LNG plant on Curtis Island in close proximity to the proposed Arrow LNG Plant. Aquatic habitat at the southern end of Curtis Island is very sparse, with the ephemeral stream that passes through the proposed Arrow project site being the most substantial waterway. The impact of other LNG projects on freshwater communities on Curtis Island is therefore less than is anticipated for the Arrow LNG Plant.

Arrow LNG Plant Contribution to Cumulative Impacts of LNG Projects

This assessment indicates that the impact of linear components of the project on local and regional aquatic values is expected to be negligible. It is therefore the case that the contribution of the project in these areas can also be expected to be negligible.

The construction of TWAF8 may result in minor localised impacts on ephemeral waterways adjacent to this site, although normal environmental practice including stormwater management, selection of sites away from watercourses and the removal of waste and sewage for off-site disposal will largely overcome these issues. These impacts are considered negligible in the context of contribution to the combined impacts of all LNG projects considered.

The construction of the Arrow LNG plant on Curtis Island represents the greatest impact on aquatic ecosystems and on water quality. Whilst this particular impact adds to the cumulative effects of all LNG projects, the impacts to the ephemeral waterbody that currently flows through the site are negated in light of the qualifying factors raised in Section 7.

Table 8-1: Potential impacts of significant projects within and adjacent to the study area on aquatic ecosystem values.

Projects	Potential Impact									
	Disturbance of Aquatic /Riparian Vegetation	Disturbance of Stream Beds and Banks	Aquatic Habitat Fragmentation	Water Quality, Sediment transport and Deposition	Altered hydrology and Geomorphology	Translocation of Pest Species	Tunnel Activities, Tunnel Spoil & Dreedge Spoil	Aquatic Fauna Injury /Mortality	Groundwater Dependent Ecosystems	Mosquitoes and Biting Midges
LNG Projects										
Queensland LNG*	✓	✓	✓	✓	✓	✓	-	✓	✓	✓
Gladstone LNG*	✓	✓	✓	✓	✓	✓	-	✓	✓	✓
Australia Pacific LNG	✓	✓	✓	✓	✓	✓	-	✓	✓	✓
Central Queensland Pipeline	✓	✓	✓	✓	✓	✓	-	✓	✓	✓
Arrow Surat Pipeline	✓	✓	✓	✓	✓	✓	-	✓	✓	✓
Port of Gladstone Projects										
Western Basin Strategic Dredging and Disposal	-	-	-	-	-	-	-	-	-	-
Fishermans Landing Northern Expansion	-	-	-	-	-	-	-	-	-	-

Projects	Potential Impact									
	Disturbance of Aquatic /Riparian Vegetation	Disturbance of Stream Beds and Banks	Aquatic Habitat Fragmentation	Water Quality, Sediment transport and Deposition	Altered hydrology and Geomorphology	Translocation of Pest Species	Tunnel Activities, Tunnel Spoil & Dreedge Spoil	Aquatic Fauna Injury /Mortality	Groundwater Dependent Ecosystems	Mosquitoes and Biting Midges
Wiggins Island Coal Export Terminal	-	-	-	-	-	-	-	-	-	-
Resource Development Projects										
Gladstone Nickel	✓	✓	✓	✓	✓	✓	-	✓	✓	✓
Aldoga Aluminium Smelter	✓	-	-	-	-	-	-	-	-	-
Gladstone Steel Plant Project	-	✓	-	✓	✓	-	-	-	-	-
Coke and Power Plant	✓	-	-	✓	✓	✓	-	✓	✓	✓
Boyne Is. Aluminium Smelter extension of reduction lines	-	-	-	-	-	-	-	-	-	-

Projects	Potential Impact										
	Disturbance of Aquatic /Riparian Vegetation	Disturbance of Stream Beds and Banks	Aquatic Habitat Fragmentation	Water Quality, Sediment transport and Deposition	Altered hydrology and Geomorphology	Translocation of Pest Species	Tunnel Activities, Tunnel Spoil & Dreedge Spoil	Aquatic Fauna Injury /Mortality	Groundwater Dependent Ecosystems	Mosquitoes and Biting Midges
Infrastructure Projects										
Gladstone – Fitzroy Pipeline Project	✓	✓	✓	✓	✓	✓	-	✓	✓	✓
Moura Link -Aldoga Rail Project	✓	✓	✓	✓	-	✓	-	✓	✓	✓
Hummock Hill Island Community Project	-	-	-	-	-	-	-	-	-	-

Figure 8-1: Potential impacts of significant projects within and adjacent to the study area on water resources.

Projects	Potential Impact						
	Turbidity and sediment transport	Fuel/oil/chemical spill during construction or maintenance	Herbicide use	Pipeline rupture	Stormwater runoff	Fuel/oil/chmical spill during operation	Disturbance of acid sulphate soils
LNG Projects							
Queensland LNG*	✓	✓	✓	✓	✓	✓	✓
Gladstone LNG*	✓	✓	✓	✓	✓	✓	✓
Australia Pacific LNG	✓	✓	✓	✓	✓	✓	✓
Central Queensland Pipeline	✓	✓	✓	✓	✓	✓	✓
Arrow Surat Pipeline	✓	✓	✓	✓	✓	✓	✓
Port of Gladstone Projects							
Western Basin Strategic Dredging and Disposal	-	-	-	-	-	-	-
Fishermans Landing Northern Expansion	-	-	-	-	-	-	-

Projects	Potential Impact						
	Turbidity and sediment transport	Fuel/oil/chemical spill during construction or maintenance	Herbicide use	Pipeline rupture	Stormwater runoff	Fuel/oil/chmical spill during operation	Disturbance of acid sulphate soils
Wiggins Island Coal Export Terminal	-	-	-	-	-	-	-
Resource Development Projects							
Gladstone Nickel	✓	✓	✓	-	✓	✓	✓
Aldoga Aluminium Smelter	✓	✓	✓	-	✓	✓	✓
Gladstone Steel Plant Project	✓	✓	✓	-	✓	✓	✓
Coke and Power Plant	✓	✓	✓	-	✓	✓	✓
Boyne Is. Aluminium Smelter extension of reduction lines	✓	✓	✓	-	✓	✓	✓

Projects	Potential Impact						
	Turbidity and sediment transport	Fuel/oil/chemical spill during construction or maintenance	Herbicide use	Pipeline rupture	Stormwater runoff	Fuel/oil/chmical spill during operation	Disturbance of acid sulphate soils
Infrastructure Projects							
Gladstone – Fitzroy Pipeline Project	✓	✓	✓	✓	✓	✓	✓
Moura Link -Aldoga Rail Project	✓	✓	✓	-	✓	✓	✓
Hummock Hill Island Community Project	-	-	-	-	-	-	-

8.1.2 Port of Gladstone Projects

Three Port of Gladstone projects have been considered:

- The Western Basin Dredging and Disposal Project.
- Fishermans Landing Northern Expansion Project.
- Wiggins Island Coal Export Terminal.

The footprint of each of these projects is entirely within marine environments; hence no impacts on aquatic ecosystems are anticipated.

8.1.3 Resource Development Projects

The Gladstone Nickel Project is comprised a high pressure acid leach refinery, tailing storage and slurry/water pipelines. The Coordinator-General has accepted that the refinery and pipelines will not impact significantly on aquatic ecosystem values or water quality at this site due to the small number of highly ephemeral systems present. He has further concluded that the tailings storage facility will impact on aquatic ecology through the loss of a small amount of ephemeral habitat. However, he has accepted that the habitat is of relatively low conservation value, the communities within it are tolerant of disturbance events and water quality impacts and that this loss is therefore acceptable.

The proposed Aldoga Aluminium Smelter is to be located in the upper Larcom Creek Catchment. The Coordinator-General has accepted that watercourses in the area are ephemeral, water quality is variable, that aquatic communities are sparse and not of conservation significance and that impacts on aquatic flora and fauna will be mitigated by the implementation of normal best practice stormwater management principles.

The Gladstone Steel Plant Project will be located in the vicinity of upper Larcom Creek and its headwater tributaries. The area is not considered to be sensitive in terms of aquatic ecosystems, and no aquatic ecology or water resource values were identified for the site during environmental database searches.

The Coke and Power project is within the Fitzroy catchment (Stanwell site). As it is in a different drainage basin there is no potential for the Arrow LNG Plant to contribute cumulatively to local impacts associated with the Coke and Power Project.

The Boyne Island Aluminium Smelter is situated close to the coast and does not impact on freshwater aquatic ecosystems or surface water resources, although there are some potential influences on marine and estuarine systems.

Arrow LNG Plant Contribution to Cumulative Impacts of Resource Development Projects

The project will contribute marginally to the loss of relatively low value ephemeral aquatic habitat in conjunction with the Gladstone Nickel Project. However, this loss will not affect listed species, the passage of aquatic species or ecological processes of conservation interest; hence the contribution to this cumulative impact is considered negligible.

8.1.4 Infrastructure Projects

The three infrastructure projects considered during the cumulative impacts assessment are the Gladstone-Fitzroy Pipeline, Moura Link- Aldonga Railway and the Hummock Hill Island Community Project.

The portion of the Gladstone-Fitzroy Pipeline that is within the freshwater aquatic ecology study area has been approved by the Coordinator-General with no conditions applicable to aquatic ecosystems, indicating that the watercourses within the study area are of relatively low quality or ecological value and that normal best practice for pipeline construction is expected to protect the existing values.

The Moura Link - Aldonga Railway project has been accepted by the coordinator general with no special conditions relevant to aquatic ecosystems. This project is within the Calliope River Catchment, of which Larcom Creek is also a tributary. This system discharges into Port Curtis, which is listed as a wetland of national significance. However the Moura Link – Aldonga Rail Project is not expected to impact on aquatic ecosystems in the Calliope River or in Port Curtis.

The Hummock Hill Island Community Project is located southeast of the study area and is not expected to influence freshwater aquatic ecosystems, although the project will affect marine and estuarine systems.

Arrow LNG Plant Contribution to Cumulative Impacts of Infrastructure Projects

The combined impacts of the three major infrastructure projects in the region are expected to have negligible impact on aquatic ecosystems. The contribution of the project to these impacts is also expected to be negligible.

8.2 Summary of Cumulative Impact Assessment

None of the projects considered during the cumulative impacts assessment are expected to significantly impact on freshwater aquatic ecosystems, communities or processes. The

overall effect of all projects is also expected to be minimal and spread across a number of small watercourses within or adjacent to the study area. This outcome is in part due to the environmental controls placed on each of these projects, but is largely due to the paucity of permanent freshwater systems and lack of freshwater aquatic communities, habitat or processes of high conservation value.

As outlined during the impact assessment for the Arrow LNG Plant, this project is not expected to have significant impacts on freshwater aquatic ecosystems, water quality or aquatic resources, hence its contribution to the cumulative impacts of key projects can also be expected to be negligible.

9 Inspection and Monitoring

This assessment has indicated that freshwater aquatic ecosystem values within the study area for the Arrow LNG Plant are very sparse in terms of the availability and quality of aquatic habitat present. As a result, environmental databases and baseline field surveys performed for a number of other projects have not identified any freshwater aquatic species listed as being of conservation significance.

Further, project activities that will occur in the mainland portion of the study area are expected to have minimal impact on the existing freshwater aquatic communities, habitat or processes.

Due to the low conservation value and minimal impacts of the project, specific monitoring or inspection of aquatic ecosystems in this part of the study area is not considered necessary. An approved environmental management plan will be prepared prior to commencement of works and will reflect the generic and specific mitigation strategies outlined herein. Audits of compliance with this plan will be adequate to protect the freshwater aquatic systems within the mainland portion of the study area.

On Curtis Island, freshwater aquatic habitat is sparse and not of high conservation value. The lower reaches of the single ephemeral stream system at the LNG Plant site will be diverted to direct flows around the LNG Plant. These systems will no longer be natural watercourses, and monitoring and/or inspection of freshwater aquatic ecosystems is considered unnecessary.

10 Conclusions

- Aquatic ecosystems within the study area and the freshwater aquatic ecology study area are sparse and generally ephemeral in nature, although a small number of remnant pools do occur. The quality of aquatic habitat is generally low, with most streams dry for much of the year, and typically with minimal variability of habitat type or structural integrity.
- Database searches indicate that aquatic species of conservation significance have been previously recorded in the area and site inspections confirmed the area is unlikely to support communities or species of conservation significance.
- Aquatic communities, habitat and processes within the study area are likely to be tolerant to a degree of disturbance. The level of disturbance anticipated as a result of the project is unlikely to significantly impact on these values except on Curtis Island, where the natural freshwater aquatic systems will be replaced by the LNG plant.
- The lower reaches of the ephemeral watercourse that flow through the LNG Plant site, will be diverted around the plant. This will not impact on the ecology of the upper reaches, but will render the lower reaches man-made, hence no monitoring or ongoing inspection of aquatic ecosystem values are required in this part of the project footprint. This disturbance is unavoidable and permanent, although the freshwater habitat that will be lost is not of high value, does not support significant aquatic species and represents a small proportion of similar habitat that exists locally.
- Specific environmental controls that would be required for protection of the existing aquatic values are minimal.
- The contribution of the project to cumulative impacts with other major development projects in the region is also considered to be low with regards to aquatic ecosystems. This is in part due to the nature of the project and the proposed approach to construction and operation, but is also largely due to the paucity of freshwater aquatic values and the tolerance of those values that do exist in the study area to disturbance events.
- Due to the low conservation value of aquatic systems in the study area and the generally short-term impacts associated with project activities, no specific inspection or monitoring protocols are suggested. Preparation and auditing against an approved environmental management plan that includes the generic and specific mitigations described herein will be sufficient to protect freshwater aquatic environments.

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Appendix A – Arrow LNG Plant ToR for Aquatic Ecology Values

The following table summarises the terms of reference for the Shell Australia LNG Project (now Arrow LNG Plant) prepared by DERM that are relevant to freshwater aquatic ecosystems. Cross references to appropriate sections within this document are provided.

Terms of reference		Aquateco Consulting Pty Ltd	
Section	**EIS requirement**	**Technical Study Name**	**Technical specialist report section**
3.3.4.1 Description of freshwater aquatic flora and fauna	Fish species, mammals, reptiles, amphibians and aquatic invertebrates occurring in the waterways within the project area, including any feral and exotic fauna species.	Aquateco Consulting Pty Ltd	Section 4
	Aquatic (waterway) macrophytes including native and exotic/weed species.	Aquateco Consulting Pty Ltd	Section 4
	Wetlands listed by DERM as areas of national, state or regional significance, and their values and importance.	Aquateco Consulting Pty Ltd	None present
	A description of terrestrial species that are ecologically associated with wetlands or waterways and are likely to be affected by the project.	Aquateco Consulting Pty Ltd	Refer to Ecosure (2011)
	Aquatic habitats, substrates and stream types.	Aquateco Consulting Pty Ltd	Sections 4.1, 4.3
	A description of mitigation measures to minimise aquatic habitat modification and associated impacts on aquatic flora and fauna. These would also include, where relevant, MNES identified under the EPBC Act. The MNES are to be discussed in section 8.	Aquateco Consulting Pty Ltd	Section 6 – no MNES present
3.3.4.2 Potential impacts and mitigation measures	Measures to minimise wildlife injury and mortality during construction and operation.	Aquateco Consulting Pty Ltd	Section 5.1.7 and 6
	Details of the methodologies that would be used to avoid injuries to native fauna as a result of the project's construction and operational works, and if accidental injuries should occur the methodologies to assess and handle injuries.	Aquateco Consulting Pty Ltd	Section 5.1.7 and 6
	Details of measures to be used to maintain fish passage in streams that would be affected.	Aquateco Consulting Pty Ltd	Sections 5.1.1, 5.1.2, 5.1.4, 5.1.5
	Potential impacts on groundwater dependant ecosystems, with options to avoid or mitigate these impacts, and details of proposed monitoring for each identified	Aquateco Consulting Pty Ltd	Sections 5.1.8, 6 and 9

	groundwater dependant ecosystems.		
	Review of control measures to prevent increases in local populations and spread of biting insect species of pest and health significance associated with construction activities and disposal of construction wastes.	Aquateco Consulting Pty Ltd	Sections 5.1.9 and 6
	Description of mitigation measures to prevent the creation of new mosquito and biting midge breeding sites, particularly during construction.	Aquateco Consulting Pty Ltd	Sections 5.1.9 and 6
	Description of the potential for and mitigation measures to prevent the introduction, transfer or facilitation of exotic, non-indigenous and noxious plants and water borne insect pests.	Aquateco Consulting Pty Ltd	Sections 5.1.5 and 6

Appendix B – Wildlife Online Database Search Results

The following is a list of species that utilise freshwater aquatic ecosystems to some extent during their life history, and shown as being present or previously being present within the study area. (C=common, NT=near threatened. Exotic species are shaded in grey).

Kingdom	Species	Common Name	Status
Amphibia	*Rhinella marina*	cane toad	
	Litoria fallax	eastern sedgefrog	C
	Litoria nasuta	striped rocketfrog	C
	Litoria rothii	northern laughing treefrog	C
	Litoria rubella	ruddy treefrog	C
	Litoria inermis	bumpy rocketfrog	C
	Litoria dentata	bleating treefrog	C
	Litoria caerulea	common green treefrog	C
	Litoria gracilenta	graceful treefrog	C
	Cyclorana alboguttata	greenstripe frog	C
	Litoria latopalmata	broad palmed rocketfrog	C
	Litoria wilcoxii	eastern stony creek frog	C
	Limnodynastes peronii	striped marshfrog	C
	Platyplectrum ornatum	ornate burrowing frog	C
	Limnodynastes tasmaniensis	spotted grassfrog	C
	Limnodynastes terraereginae	scarlet sided pobblebonk	C
	Limnodynastes fletcheri	barking frog	C
	Limnodynastes salmini	salmon striped frog	C
	Uperoleia fusca	dusky gungan	C
	Uperoleia rugosa	chubby gungan	C
	Crinia deserticola	chirping froglet	C
	Pseudophryne major	great brown broodfrog	C
	Pseudophryne raveni	copper backed broodfrog	C
birds	*Haliaeetus leucogaster*	white-bellied sea-eagle	C
	Pandion cristatus	eastern osprey	C
	Ceyx azureus	azure kingfisher	C
	Anas castanea	chestnut teal	C
	Anas gracilis	grey teal	C
	Cygnus atratus	black swan	C
	Anas rhynchotis	Australasian shoveler	C
	Anas superciliosa	Pacific black duck	C
	Nettapus coromandelianus	cotton pygmy-goose	NT

Dendrocygna arcuata	wandering whistling-duck	C
Dendrocygna eytoni	plumed whistling-duck	C
Chenonetta jubata	Australian wood duck	C
Aythya australis	hardhead	C
Tadorna radjah	radjah shelduck	NT
Anhinga novaehollandiae	Australasian darter	C
Anseranas semipalmata	magpie goose	C
Ardea ibis	cattle egret	C
Egretta sacra	eastern reef egret	C
Ardea intermedia	intermediate egret	C
Butorides striata	striated heron	C
Ixobrychus flavicollis	black bittern	C
Egretta novaehollandiae	white-faced heron	C
Nycticorax caledonicus	Nankeen night-heron	C
Ixobrychus dubius	Australian little bittern	C
Egretta garzetta	little egret	C
Ardea pacifica	white-necked heron	C
Ardea modesta	eastern great egret	C
Ephippiorhynchus asiaticus	black-necked stork	NT
Grus rubicunda	brolga	C
Todiramphus sanctus	sacred kingfisher	C
Todiramphus chloris	collared kingfisher	C
Irediparra gallinacea	comb-crested jacana	C
Pelecanus conspicillatus	Australian pelican	C
Phalacrocorax carbo	great cormorant	C
Microcarbo melanoleucos	little pied cormorant	C
Phalacrocorax varius	pied cormorant	C
Phalacrocorax sulcirostris	little black cormorant	C
Poliocephalus poliocephalus	hoary-headed grebe	C
Tachybaptus novaehollandiae	Australasian grebe	C
Lewinia pectoralis	Lewin's rail	NT
Gallinula tenebrosa	dusky moorhen	C
Porphyrio porphyrio	purple swamphen	C
Tribonyx ventralis	black-tailed native-hen	C
Recurvirostra novaehollandiae	red-necked avocet	C
Platalea regia	royal spoonbill	C
Platalea flavipes	yellow-billed spoonbill	C
Threskiornis molucca	Australian white ibis	C
Threskiornis spinicollis	straw-necked ibis	C
Plegadis falcinellus	glossy ibis	C

fish	*Ambassis agassizii*	Agassiz's glassfish	
	Anguilla reinhardtii	longfin eel	
	Glossamia aprion	mouth almighty	
	Craterocephalus stercusmuscarum	flyspecked hardyhead	
	Lates calcarifer	barramundi	
	Nematalosa erebi	bony bream	
	Hypseleotris galii	firetail gudgeon	
	Hypseleotris compressa	empire gudgeon	
	Hypseleotris species 1	Midgley's carp gudgeon	
	Gobiomorphus australis	striped gudgeon	
	Mogurnda adspersa	purplespotted gudgeon	
	Arrhamphus sclerolepis	snubnose garfish	
	Kuhlia rupestris	jungle perch	
	Lutjanus argentimaculatus	mangrove jack	
	Megalops cyprinoides	oxeye herring	
	Melanotaenia splendida splendida	eastern rainbowfish	
	Monodactylus argenteus	diamondfish	
	Mugil cephalus	sea mullet	
	Poecilia reticulata	guppy	
	Gambusia holbrooki	mosquitofish	
	Pseudomugil signifer	Pacific blue eye	
	Scatophagus argus	spotted scat	
	Selenotoca multifasciata	striped scat	
	Terapon jarbua	crescent grunter	
	Amniataba percoides	barred grunter	
	Leiopotherapon unicolor	spangled perch	
mammals	*Hydromys chrysogaster*	water rat	C
reptiles	*Chelodina longicollis*	eastern snake-necked turtle	C
	Elseya albagula	southern snapping turtle	C
	Emydura sp.	freshwater turtle sp	
	Emydura macquarii krefftii	Krefft's river turtle	C
	Wollumbinia latisternum	saw-shelled turtle	C
	Tropidonophis mairii	freshwater snake	C
plants	*Salvinia molesta*	salvinia	
	Sphagneticola trilobata	Singapore daisy	
	Nymphoides indica	water snowflake	C
	Ludwigia perennis	glandular ludwigia	C
	Ludwigia octovalvis	willow primrose	C

Ludwigia peploides subsp. montevidensis	water primrose	C
Persicaria decipiens	slender knotweed	C
Salix nigra	black willow	
Nelumbo nucifera	pink waterlily	C
Nymphaea violacea	native waterlily	C
Nymphaea caerulea	blue waterlily	
Nymphaea gigantea	giant waterlily	C
Crinum flaccidum	Murray lily	C
Proiphys cunninghamii	Moreton Bay lily	C
Crinum pedunculatum	river lily	C
Spirodela punctata	thin duckweed	C
Typhonium brownii	black arum lily	C
Schoenoplectus erectus	sharpscale bulrush	
Rhynchospora corymbosa		C
Fimbristylis dichotoma	common fringe-rush	C
Schoenoplectus lateriflorus	bulrush	C
Eleocharis cylindrostachys	drooping spike rush	C
Eleocharis philippinensis	spike rush	C
Eleocharis geniculata	spike rush	C
Eleocharis equisetina	spike rush	C
Cyperus alopecuroides	Foxtrail flatsedge	C
Abildgaardia vaginata		C
Cyperus scariosus	sedge	C
Cyperus exaltatus	tall flatsedge	C
Cyperus difformis	rice sedge	C
Cyperus concinnus	trim flatsedge	C
Baumea rubiginosa	soft twigrush	C
Baumea articulata	jointed twigrush	C
Fuirena ciliaris	annual fuirena	C
Cyperus squarrosus	bearded flatsedge	C
Cyperus leiocaulon	common leaf rush	C
Cyperus cyperoides	sedge	C
Abildgaardia ovata		C
Schoenus sparteus		C
Schoenus falcatus		C
Isolepis fluitans	floating club rush	C
Eleocharis dulcis	spike rush	C
Cyperus trinervis	flat sedge	C
Schoenus brevifolius	bog rush	C
Lepironia articulata		C

Cyperus polystachyos	bunchy sedge	C
Cyperus involucratus	sedge	
Fimbristylis nutans		C
Cyperus tetracarpus	umbrella sedge	C
Cyperus perangustus	sedge	C
Schoenus apogon	bog rush	C
Vallisneria	eel grass	C
Hydrilla verticillata	hydrilla	C
Ottelia ovalifolia	swamp lily	C
Tricoryne elatior	yellow autumn lily	C
Juncus continuus	common rush	C
Juncus polyanthemus	common rush	C
Juncus psammophilus	common rush	C
Triglochin procerum	water ribbons	C
Laxmannia gracilis	slender wire lily	C
Najas tenuifolia	water nymph	C
Philydrum lanuginosum	frogsmouth	C
Phragmites australis	common reed	C
Arundinella nepalensis	reedgrass	C
Paspalum distichum	water couch	C
Panicum paludosum	swamp panic	C
Urochloa mutica	para grass	
Polypogon monspeliensis	annual beardgrass	
Echinochloa crus-galli	barnyard grass	
Eichhornia crassipes	water hyacinth	
Potamogeton crispus	curly pondweed	C
Potamogeton octandrus	pond weed	C
Potamogeton pectinatus	fennel pondweed	C
Typha orientalis	broad-leaved cumbungi	C
Typha domingensis	narrow-leaved cumbungi	C

Appendix C – EPBC Report for Arrow LNG Plant

Australian Government
Department of Sustainability, Environment, Water, Population and Communities

Protected Matters Search Tool

EPBC Act Protected Matters Report: Coordinates

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

You may wish to print this report for reference before moving to other pages or websites.

Information about the EPBC Act including significance guidelines, forms and application process details can be found at http://www.environment.gov.au/epbc/assessmentsapprovals/index.html

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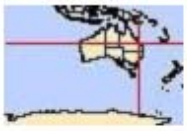

Summary

Details

Matters of NES
Other matters protected by the EPBC Act
Extra Information

Caveat

Acknowledgements

Coordinates
Buffer: 1Km

Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance - see http://www.environment.gov.au/epbc/assessmentsapprovals/guidelines/index.html.

World Heritage Properties:	1
National Heritage Places:	1
Wetlands of International Significance (Ramsar Wetlands):	None
Great Barrier Reef Marine Park:	Relevant
Commonwealth Marine Areas:	Relevant
Threatened Ecological Communitites:	4
Threatened Species:	45
Migratory Species:	54

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place and the heritage values of a place on the Register of the National Estate. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage/index.html

Please note that the current dataset on Commonwealth land is not complete. Further information on Commonwealth land would need to be obtained from relevant sources including Commonwealth agencies, local agencies, and land tenure maps.

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species. Information on EPBC Act permit requirements and application forms can be found at http://www.environment.gov.au/epbc/permits/index.html.

Commonwealth Lands:	1
Commonwealth Heritage Places:	1
Listed Marine Species:	98

Whales and Other Cetaceans:	12
Critical Habitats:	None
Commonwealth Reserves:	None

Report Summary for Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

Place on the RNE:	11
State and Territory Reserves:	16
Regional Forest Agreements:	None
Invasive Species:	14
Nationally Important Wetlands:	5

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	Status
Great Barrier Reef QLD	Declared property

National Heritage Places [Resource Information]

Name	Status
Natural	
Great Barrier Reef QLD	Listed place

Great Barrier Reef Marine Park [Resource Information]

Zone Type	Zone Name	IUCN
Habitat Protection	HP-23-5363	VI
Conservation Park	CP-23-4108	IV
Habitat Protection	HP-23-5362	VI
General Use	GU-21-6016	VI
Conservation Park	CP-23-4109	IV
Marine National Park	MNP-23-1167	II
Conservation Park	CP-23-4107	IV
Habitat Protection	HP-23-5367	VI
Habitat Protection	HP-23-5369	VI

Commonwealth Marine Areas [Resource Information]

Approval may be required for a proposed activity that is likely to have a significant impact on the environment in a Commonwealth Marine Area, when the action is outside the Commonwealth Marine Area, or the environment anywhere when the action is taken within the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

EEZ and Territorial Sea

Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened

ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Name	Status	Type of Presence
Littoral Rainforest and Coastal Vine Thickets of Eastern Australia	Critically Endangered	Community likely to occur within area
Brigalow (Acacia harpophylla dominant and co-dominant)	Endangered	Community known to occur within area
Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions	Endangered	Community likely to occur within area
Weeping Myall Woodlands	Endangered	Community likely to occur within area

Threatened Species [Resource Information]

Name	Status	Type of Presence
BIRDS		
Epthianura crocea macgregori		
Yellow Chat (Dawson) [67090]	Critically Endangered	Species or species habitat known to occur within area
Erythrotriorchis radiatus		
Red Goshawk [942]	Vulnerable	Species or species habitat likely to occur within area
Geophaps scripta scripta		
Squatter Pigeon (southern) [64440]	Vulnerable	Species or species habitat likely to occur within area
Macronectes giganteus		
Southern Giant-Petrel [1060]	Endangered	Species or species habitat may occur within area
Neochmia ruficauda ruficauda		
Star Finch (eastern), Star Finch (southern) [26027]	Endangered	Species or species habitat likely to occur within area
Pterodroma neglecta neglecta		
Kermadec Petrel (western) [64450]	Vulnerable	Species or species habitat may occur within area
Rostratula australis		
Australian Painted Snipe [77037]	Vulnerable	Species or species habitat may occur within area
Turnix melanogaster		
Black-breasted Button-quail [923]	Vulnerable	Species or species habitat likely to occur within area
MAMMALS		
Balaenoptera musculus		
Blue Whale [36]	Endangered	Species or species habitat may occur within area
Chalinolobus dwyeri		
Large-eared Pied Bat, Large Pied Bat [183]	Vulnerable	Species or species habitat may occur within area
Dasyurus hallucatus		
Northern Quoll [331]	Endangered	Species or species habitat known to occur within area
Megaptera novaeangliae		
Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Nyctophilus timoriensis (South-eastern form)		

Greater Long-eared Bat, South-eastern Long-eared Bat [66888]	Vulnerable	Species or species habitat may occur within area
Pteropus poliocephalus Grey-headed Flying-fox [186]	Vulnerable	Species or species habitat may occur within area
Xeromys myoides Water Mouse, False Water Rat [66]	Vulnerable	Species or species habitat likely to occur within area
OTHER		
Cycas megacarpa [55794]	Endangered	Species or species habitat known to occur within area
Cycas ophiolitica [55797]	Endangered	Species or species habitat known to occur within area
PLANTS		
Atalaya collina [55417]	Endangered	Species or species habitat likely to occur within area
Bosistoa selwynii Heart-leaved Bosistoa [13702]	Vulnerable	Species or species habitat likely to occur within area
Bosistoa transversa Three-leaved Bosistoa [16091]	Vulnerable	Species or species habitat likely to occur within area
Bulbophyllum globuliforme Miniature Moss-orchid [6649]	Vulnerable	Species or species habitat likely to occur within area
Corymbia xanthope [64021]	Vulnerable	Species or species habitat likely to occur within area
Cossinia australiana Cossinia [3066]	Endangered	Species or species habitat likely to occur within area
Cupaniopsis shirleyana Wedge-leaf Tuckeroo [3205]	Vulnerable	Species or species habitat likely to occur within area
Eucalyptus raveretiana Black Ironbox [16344]	Vulnerable	Species or species habitat likely to occur within area
Leucopogon cuspidatus [9739]	Vulnerable	Species or species habitat likely to occur within area
Parsonsia larcomensis [64587]	Vulnerable	Species or species habitat likely to occur within area
Pimelea leptospermoides [20849]	Vulnerable	Species or species habitat likely to occur within area
Pultenaea setulosa [2705]	Vulnerable	Species or species habitat likely to occur within area
Quassia bidwillii		

Quassia [10094]	Vulnerable	Species or species habitat likely to occur within area
Taeniophyllum muelleri Minute Orchid, Ribbon-root Orchid [10771]	Vulnerable	Species or species habitat may occur within area
REPTILES		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Delma torquata Collared Delma [1656]	Vulnerable	Species or species habitat likely to occur within area
Denisonia maculata Ornamental Snake [1193]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Egernia rugosa Yakka Skink [1420]	Vulnerable	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Furina dunmalli Dunmall's Snake [59254]	Vulnerable	Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Paradelma orientalis Brigalow Scaly-foot [59134]	Vulnerable	Species or species habitat likely to occur within area
Rheodytes leukops Fitzroy River Turtle, Fitzroy Tortoise, Fitzroy Turtle [1761]	Vulnerable	Species or species habitat may occur within area
SHARKS		
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat may occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Migratory Species		**[Resource Information]**
Name	Status	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat may occur within area
Ardea alba Great Egret, White Egret		Species or species habitat may occur within area

[59541]		
Ardea ibis		
Cattle Egret [59542]		Breeding likely to occur within area
Macronectes giganteus		
Southern Giant-Petrel [1060]	Endangered	Species or species habitat may occur within area
Sterna albifrons		
Little Tern [813]		Species or species habitat may occur within area
Migratory Marine Species		
Balaenoptera edeni		
Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Species or species habitat may occur within area
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus porosus		
Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Dugong dugon		
Dugong [28]		Species or species habitat likely to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Lepidochelys olivacea		
Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat likely to occur within area
Megaptera novaeangliae		
Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella brevirostris		
Irrawaddy Dolphin [45]		Species or species habitat may occur within area
Orcinus orca		
Killer Whale, Orca [46]		Species or species habitat may occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sousa chinensis		
Indo-Pacific Humpback Dolphin [50]		Species or species habitat may occur within area
Migratory Terrestrial Species		
Haliaeetus leucogaster		
White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area
Hirundapus caudacutus		
White-throated Needletail [682]		Species or species habitat may occur within area
Hirundo rustica		

Barn Swallow [662] Merops ornatus	Species or species habitat may occur within area
Rainbow Bee-eater [670] Monarcha melanopsis	Species or species habitat may occur within area
Black-faced Monarch [609] Monarcha trivirgatus	Breeding may occur within area
Spectacled Monarch [610] Myiagra cyanoleuca	Breeding likely to occur within area
Satin Flycatcher [612]	Species or species habitat likely to occur within area
Rhipidura rufifrons Rufous Fantail [592]	Breeding may occur within area
Migratory Wetlands Species	
Actitis hypoleucos Common Sandpiper [59309]	Roosting known to occur within area
Ardea alba Great Egret, White Egret [59541]	Species or species habitat may occur within area
Ardea ibis Cattle Egret [59542]	Breeding likely to occur within area
Arenaria interpres Ruddy Turnstone [872]	Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]	Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Roosting known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Roosting known to occur within area
Calidris ruficollis Red-necked Stint [860]	Roosting known to occur within area
Calidris tenuirostris Great Knot [862]	Roosting known to occur within area
Charadrius bicinctus Double-banded Plover [895]	Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Roosting known to occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]	Roosting may occur within area
Heteroscelus brevipes Grey-tailed Tattler [59311]	Roosting known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]	Roosting known to occur within area
Limosa lapponica Bar-tailed Godwit [844]	Roosting known to occur within area
Limosa limosa Black-tailed Godwit [845]	Roosting known to occur within area
Nettapus coromandelianus albipennis	

Australian Cotton Pygmy-goose [25979]	Species or species habitat may occur within area
Numenius madagascariensis	
Eastern Curlew [847]	Roosting known to occur within area
Numenius minutus	
Little Curlew, Little Whimbrel [848]	Roosting likely to occur within area
Numenius phaeopus	
Whimbrel [849]	Roosting known to occur within area
Pluvialis fulva	
Pacific Golden Plover [25545]	Roosting known to occur within area
Pluvialis squatarola	
Grey Plover [865]	Roosting known to occur within area
Rostratula benghalensis s. lat.	
Painted Snipe [889]	Species or species habitat may occur within area
Tringa stagnatilis	
Marsh Sandpiper, Little Greenshank [833]	Roosting known to occur within area
Xenus cinereus	
Terek Sandpiper [59300]	Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Defence - GLADSTONE ARES DEPOT

Commonwealth Heritage Places [Resource Information]

Name	Status
Natural	
Great Barrier Reef Region (Commonwealth) QLD	Indicative Place

Listed Marine Species [Resource Information]

Name	Status	Type of Presence
Birds		
Actitis hypoleucos		
Common Sandpiper [59309]		Roosting known to occur within area
Anseranas semipalmata		
Magpie Goose [978]		Species or species habitat may occur within area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat may occur within area
Ardea alba		
Great Egret, White Egret [59541]		Species or species habitat may occur within area
Ardea ibis		
Cattle Egret [59542]		Breeding likely to occur within area
Arenaria interpres		
Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata		

Sharp-tailed Sandpiper [874] Calidris canutus		Roosting known to occur within area
Red Knot, Knot [855] Calidris ferruginea		Roosting known to occur within area
Curlew Sandpiper [856] Calidris ruficollis		Roosting known to occur within area
Red-necked Stint [860] Calidris tenuirostris		Roosting known to occur within area
Great Knot [862] Charadrius bicinctus		Roosting known to occur within area
Double-banded Plover [895] Charadrius leschenaultii		Roosting known to occur within area
Greater Sand Plover, Large Sand Plover [877] Charadrius mongolus		Roosting known to occur within area
Lesser Sand Plover, Mongolian Plover [879] Charadrius ruficapillus		Roosting known to occur within area
Red-capped Plover [881] Gallinago hardwickii		Roosting known to occur within area
Latham's Snipe, Japanese Snipe [863] Gallinago megala		Roosting may occur within area
Swinhoe's Snipe [864] Gallinago stenura		Roosting likely to occur within area
Pin-tailed Snipe [841] Haliaeetus leucogaster		Roosting likely to occur within area
White-bellied Sea-Eagle [943] Heteroscelus brevipes		Species or species habitat likely to occur within area
Grey-tailed Tattler [59311] Himantopus himantopus		Roosting known to occur within area
Black-winged Stilt [870] Hirundapus caudacutus		Roosting known to occur within area
White-throated Needletail [682] Hirundo rustica		Species or species habitat may occur within area
Barn Swallow [662] Limicola falcinellus		Species or species habitat may occur within area
Broad-billed Sandpiper [842] Limosa lapponica		Roosting known to occur within area
Bar-tailed Godwit [844] Limosa limosa		Roosting known to occur within area
Black-tailed Godwit [845] Macronectes giganteus		Roosting known to occur within area
Southern Giant-Petrel [1060] Merops ornatus	Endangered	Species or species habitat may occur within area
Rainbow Bee-eater [670] Monarcha melanopsis		Species or species habitat may occur within area
Black-faced Monarch [609] Monarcha trivirgatus		Breeding may occur within area
Spectacled Monarch [610] Myiagra cyanoleuca		Breeding likely to occur within area

Satin Flycatcher [612]	Species or species habitat likely to occur within area
Nettapus coromandelianus albipennis	
Australian Cotton Pygmy-goose [25979]	Species or species habitat may occur within area
Numenius madagascariensis	
Eastern Curlew [847]	Roosting known to occur within area
Numenius minutus	
Little Curlew, Little Whimbrel [848]	Roosting likely to occur within area
Numenius phaeopus	
Whimbrel [849]	Roosting known to occur within area
Pluvialis fulva	
Pacific Golden Plover [25545]	Roosting known to occur within area
Pluvialis squatarola	
Grey Plover [865]	Roosting known to occur within area
Recurvirostra novaehollandiae	
Red-necked Avocet [871]	Roosting known to occur within area
Rhipidura rufifrons	
Rufous Fantail [592]	Breeding may occur within area
Rostratula benghalensis s. lat.	
Painted Snipe [889]	Species or species habitat may occur within area
Sterna albifrons	
Little Tern [813]	Species or species habitat may occur within area
Tringa stagnatilis	
Marsh Sandpiper, Little Greenshank [833]	Roosting known to occur within area
Xenus cinereus	
Terek Sandpiper [59300]	Roosting known to occur within area
Fish	
Acentronura tentaculata	
Shortpouch Pygmy Pipehorse [66187]	Species or species habitat may occur within area
Campichthys tryoni	
Tryon's Pipefish [66193]	Species or species habitat may occur within area
Choeroichthys brachysoma	
Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]	Species or species habitat may occur within area
Corythoichthys amplexus	
Fijian Banded Pipefish, Brown-banded Pipefish [66199]	Species or species habitat may occur within area
Corythoichthys flavofasciatus	
Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]	Species or species habitat may occur within area
Corythoichthys haematopterus	
Reef-top Pipefish [66201]	Species or species habitat may occur within area
Corythoichthys intestinalis	
Australian Messmate Pipefish, Banded Pipefish [66202]	Species or species habitat may occur within area
Corythoichthys ocellatus	
Orange-spotted Pipefish, Ocellated Pipefish [66203]	Species or species habitat may occur within area

Corythoichthys paxtoni Paxton's Pipefish [66204]	Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]	Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]	Species or species habitat may occur within area
Festucalex cinctus Girdled Pipefish [66214]	Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]	Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]	Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]	Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]	Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]	Species or species habitat may occur within area
Hippichthys cyanospilos Blue-speckled Pipefish, Blue-spotted Pipefish [66228]	Species or species habitat may occur within area
Hippichthys heptagonus Madura Pipefish, Reticulated Freshwater Pipefish [66229]	Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]	Species or species habitat may occur within area
Hippocampus bargibanti Pygmy Seahorse [66721]	Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]	Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]	Species or species habitat may occur within area
Hippocampus zebra Zebra Seahorse [66241]	Species or species habitat may occur within area
Lissocampus runa Javelin Pipefish [66251]	Species or species habitat may occur within area
Microgнathus andersonii Anderson's Pipefish, Shortnose Pipefish [66253]	Species or species habitat may occur within area
Microgнathus brevirostris thorntail Pipefish, Thorn-tailed Pipefish [66254]	Species or species habitat may occur within area
Nannocampus pictus Painted Pipefish, Reef Pipefish [66263]	Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's	Species or species habitat may occur within area