APPENDIX 8

ARROW LNG PLANT

Supplementary Report
- Technical Study of Marine Ecology (Port Curtis)

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SPECIALISTS IN ENVIRONMENTAL, SOCIAL AND SAFETY PERFORMANCE

TECHNICAL STUDY OF MARINE ECOLOGY (PORT CURTIS) FOR THE SUPPLEMENTARY REPORT TO THE ARROW LNG PLANT ENVIRONMENTAL IMPACT STATEMENT

PREPARED FOR ARROW CSG (AUSTRALIA) PTY LTD (ARROW ENERGY)

TECHNICAL STUDY OF MARINE ECOLOGY (PORT CURTIS) FOR THE SUPPLEMENTARY REPORT TO THE ARROW LNG PLANT ENVIRONMENTAL IMPACT STATEMENT

Prepared for Arrow CSG (Australia) Pty Ltd (Arrow Energy)

December 2012

CR 7033_22_v1

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EXECUTIVE SUMMARY

This technical study summarises the findings of supplementary work undertaken by Coffey Environments on behalf of Arrow CSG (Australia) Pty Ltd (Arrow Energy) to validate impacts and evaluate any changes to the worst-case impact scenario assessed in the Environmental Impact Statement (EIS). Specifically, the study focuses on assessing the impact on the marine ecology of the Port Curtis area following front-end engineering design (FEED) derived changes to the infrastructure and dredging footprints of the two main components of the Arrow LNG Plant; and changes to the current marine logistics and transport system. The study also provides mitigation and management measures to reduce impact on key environmental values, along with residual and cumulative impacts; and reviews ancillary information and public submissions made to the EIS during the review process.

Loss of Habitats from Changes to Marine Facilities

Of all five marine habitats assessed, revised disturbance areas have decreased for mangroves (5.80 ha to 5.10 ha), saltpan (58.20 ha to 55.01 ha) and reef and rock substrates (0.40 ha to 0.14 ha), but has increased for the intertidal zone (5.31 ha to 5.64 ha). By contrast, no seagrass beds are proposed to be removed. There is no proposed additional clearing of mangroves, saltpan vegetation or reef and rock substrate areas around any of the four main project sites following the changes in project description. Consequently, the ecological values of these marine habitats will be minimally affected since the extent of disturbance through clearings following proposed changes in project description is less than 1% of the respective available habitats for mangrove, intertidal zone, and rock and reef substrate in the Port Curtis area.

Indirect Impacts from Sediment Plumes

Simulations run by BMT WBM for the EIS appropriately covered spatial extent of sediment plumes originating from dredging operations at Calliope River, the LNG jetty off North China Bay and Boatshed Point. However, following FEED-based changes in project description dredge volumes of in-situ material have increased from 120,000 m^3 to 131,000 m^3 at the LNG jetty site, and from 50,000 m^3 to 313,000 m^3 and the MOF site at Boatshed Point. The substantial increase in dredge volume at Boatshed Point from the EIS will result in the longer duration of effective dredging operations, i.e., from approximately 4.2 days in the EIS to approximately 26 days based on the same medium-sized cutter suction dredge (CSD) capable of a 500 m^3 h^{-1} production rate.

Based on BMT WBM model outputs, the spatial extent of the sediment plume generated at the LNG jetty, including sediment deposition rates in areas adjacent to the point source, will not differ from that described in the EIS. Similarly, simulation outputs using the original 50,000 m^3 dredge volume to be removed at Boatshed Point remain valid for predicting the extent of the sediment dredge plume for any tidal condition for the revised 313,000 m^3 volume. Thus, considering model outputs, the significance of impact (pre-mitigation) due to sediment plumes over the two relatively small seagrass beds to the east of Boatshed Point continues to be assessed as **minor** as in the EIS. The **minor** impact significance is further highlighted by the fact that the combined area of two seagrass beds to the east of Boatshed Point (7.4 ha) accounts for 2.2% of the total area of seagrasses estimated to be present within Port Curtis (3403.8 ha).

Changes to Marine Logistics and Transport

There has been a significant reduction in the numbers of high speed people-moving cat movements from 1140 per month (EIS) to 480 per month. However, factors such as vessel size,

speed, travelling routes and passenger capacity remain unchanged. Revised figures following changes to the transport system indicates that Arrow Energy's percentage contribution to vessel movements by approximately ten percent from that reported in the EIS, however anecdotal evidence indicates that actual harbour traffic rates are higher than previously estimated which indicates that Arrow Energy's percentage contribution to harbour traffic would be even lower.

Review of Ancillary Information and Responses to Public Submissions

Maintenance dredging will be undertaken by the GPC as part of a port service agreement, and will be required to maintain the access channel to launch site 1 in Calliope River, the Arrow LNG swing basin, and the access channel to the Boatshed Point MOF and associated swing basin. Modelling of silt deposition rates suggest that there is a clear potential for fine sediment siltation in sub-sections of the LNG swing basin in North China Bay following dredging, due to the low-energy hydrodynamic regime characteristic of the area. Potential impacts can be addressed through the development of a maintenance dredging management plan that considers the appropriate water and sediment monitoring data, particularly at sites adjacent to areas with sensitive receptors such as the seagrass beds to the east of Boatshed Point.

Responses to public submissions made to the EIS includes the spatial and temporal occurrence of megafauna in the Calliope River and adjacent areas; information on megafauna-vessel interaction, including a review of avoidance, mitigation and management measures; and impacts of noise from relocated pile driving activities to Boatshed Point.

The entrance channel to Calliope River is frequented by marine turtles, as well as dugong and dolphins. A total of 55 sightings of marine turtles, 10 of dugongs and 26 of dolphins were reported for the period June-October 2012, with a greater incidence of sightings of megafauna (44) in August.

The reduction in the numbers of high speed people-moving cat movements within Port Curtis will reduce but not eliminate the risk of megafauna-vessel interaction. Thus, the pre-mitigation risk was assessed as **moderate** as in the EIS, with a residual risk of **minor** after implementation of mitigation measures including speed restrictions and propeller guards.

The significance of impact (pre-mitigation) to marine fauna from pile driving and vessel sources was reviewed and assessed as **moderate** for fishes, marine turtles, dugong and dolphins, and as **minor** for other fauna. Protection from risk of injury to fauna suddenly being exposed to harmful levels of sound was provided by mitigation measures that include prior observation, soft start-up procedures and bubble curtains to attenuate sounds and discourage individuals from coming too close to pile driving areas. Following implementation of these measures, risk significance was assessed as **minor**. Further movements studies of megafauna in the Calliope River are proposed in order to better inform the implementation of mitigation measures at this location.

1. INTRODUCTION

Arrow CSG (Australia) Pty Ltd (Arrow Energy) proposes to develop a liquefied natural gas (LNG) plant on Curtis Island off the central Queensland coast, near Gladstone. The project, known as the Arrow LNG Plant ('the project'), is a component of the larger Arrow LNG Project which incorporates upstream coal seam gas field developments and transmission gas pipelines.

An environmental impact statement (EIS) has been prepared for Arrow Energy by Coffey Environments under Part 4 of the *State Development and Public Works Organisation Act 1971* (Qld) (SDPWO Act) and s. 133 of the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act). The EIS identified and assessed the potential impacts of the project works (design, construction and operations) as well as project infrastructure on the marine and estuarine ecology values of areas within Port Curtis. The findings of the marine and estuarine ecology study, completed by Coffey Environments (Coffey Environments, 2011) in 2011, are discussed in Chapter 19 and the technical study report is presented in Appendix 12 of the EIS (Coffey Environments, 2012a).

Since the EIS was finalised and exhibited in April 2012, Arrow Energy has revised the project description, and has subsequently proposed a number of changes that could affect the areas of disturbance and the conclusions of the impact assessment presented in the EIS. In addition, a number of matters were identified in the EIS, along with some comments relating to marine ecology that were lodged as submissions during the public exhibition period.

This technical study summarises the findings of supplementary work undertaken by Coffey Environments on behalf of Arrow Energy to validate impacts and evaluate any changes to the worst-case impact scenario assessed in the original EIS, following changes to the proposed facilities in Port Curtis. Specifically, the study focuses on assessing the impacts on the marine ecology of Port Curtis following changes to the footprint of the materials offloading facility (MOF) at Boatshed Point and the LNG jetty and dredging works associated with both of these facilities. In addition, the study assesses the impact of changes to marine logistics and transport systems. It also reviews ancillary information and responds to public submissions made on the EIS. The extent to which predicted and residual impacts from these changes may alter the conclusions listed in the marine and estuarine ecology impact assessment (Coffey Environments, 2011) and EIS (Coffey Environments, 2012a) is also assessed. Potential impacts on the ecology of Calliope River as a result of project related dredging are addressed in a separate technical report, Technical Study of Estuarine Ecology (Calliope River) (Coffey Environments, 2012b).

This technical study is to be appended to the Supplementary Report to the Arrow LNG Plant EIS.

2. PROJECT DESCRIPTION CHANGES AND STUDY OBJECTIVES

The study was undertaken to review the impact on the marine ecology of Port Curtis following changes to the project description; to review ancillary information identified in the EIS; and to address public submissions made to the EIS of direct relevance to marine ecology. The objective of this technical study was to assess these changes and to validate the impact assessment on the ecology of Port Curtis that was completed for the EIS.

Details of changes to the project description, ancillary information and a summary of relevant public submissions on the EIS are provided below along with specific objectives of this study.

Changes in project description involving flaring and its effect on marine turtles have been addressed in the marine ecology (turtles) technical report by Pendoley Environmental (2012). Changes to the ecology of the Calliope River from dredging works are addressed in the estuarine ecology technical study prepared by Coffey Environments (2012).

2.1 Project Description Changes

The main changes to the project description from that which was presented in the EIS and that are relevant to marine ecology comprise modifications to the footprints of marine facilities and associated dredging works in Port Curtis, and changes to marine logistics and transport. Details of changes to the project description are provided below. The revised project area and proposed facilities are shown on Figure 1.

2.1.1 Changes to Marine Facilities

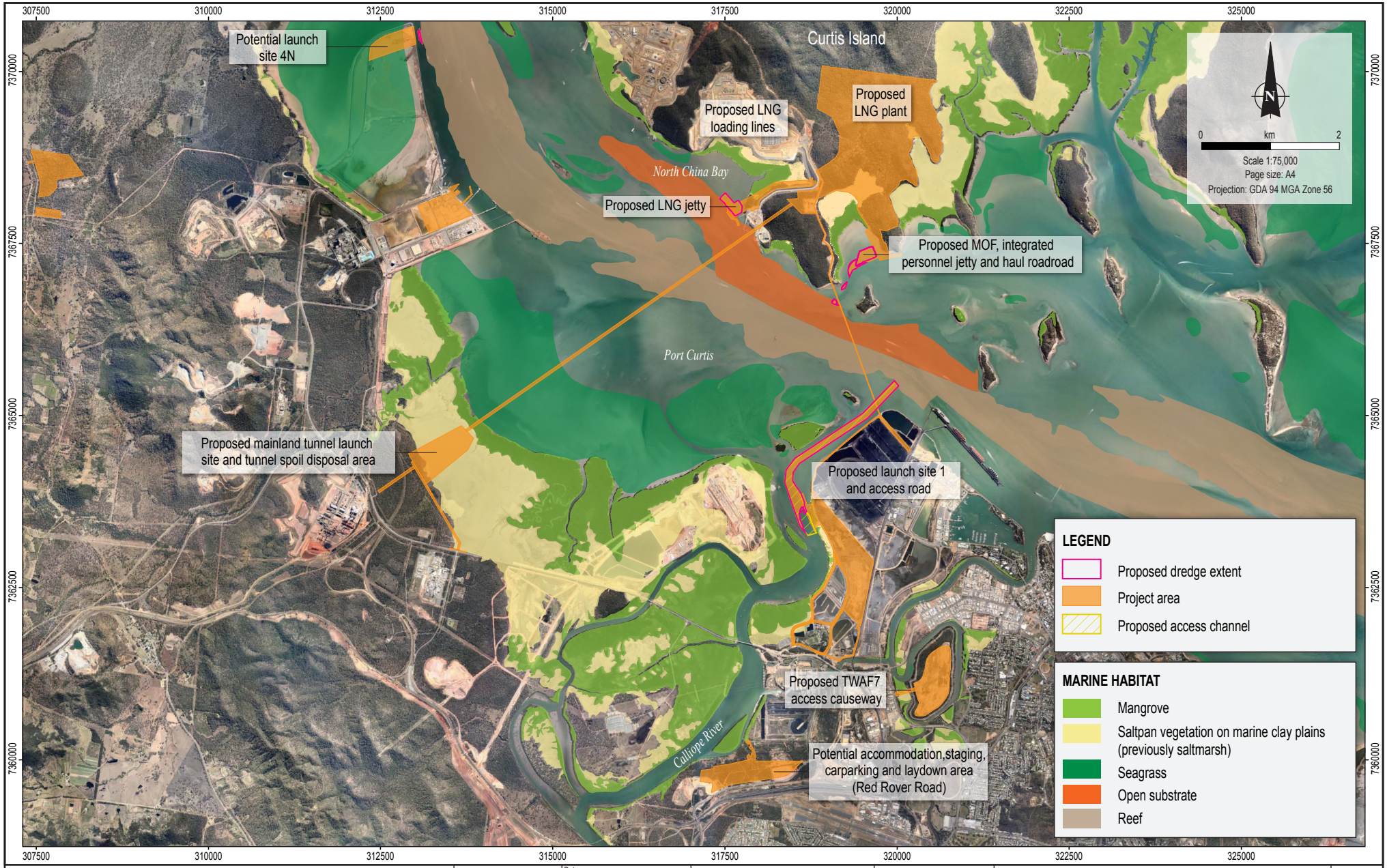
This section describes the proposed changes to the marine facilities and associated dredging works in Port Curtis from those described in the EIS.

The main changes to marine facilities in Port Curtis are described as follows:

- The footprint of the MOF at Boatshed Point on southern Curtis Island has been revised and includes a swing basin and a ferry passenger terminal (Figure 2). The MOF has been reconfigured to accommodate larger LNG Plant modules and the larger vessels (80 to 220 m) that will transport these modules.
- The footprint of the LNG jetty in North China Bay has been revised (Figure 3).
- The footprint of the launch site 1 and haul road in the Calliope River have been revised, and includes the removal of 2.01 ha of mangroves (Figure 4).
- The Hamilton Point South MOF and passenger jetty has been discontinued as an option.

The work required to complete the redesigned Boatshed Point MOF includes clearing of mangroves and saltpan to construct the facility, and establish a ferry terminal as well as dredging to create a swing basin. Dredging is also required to remove two isolated high seabed points along the access channel to the MOF.

Specific changes to the MOF footprint include the provision of an additional link span berth; a change from piled concrete decks to a sheet piled earth-filled structure; and the relocation of the personnel berth as well as the lift-on lift-off (LOLO) jetty from the southern tip of Boatshed Point to the western side of the point to the north and south of the MOF quay, respectively (see Figure 2).



Source:
Proposed LNG plant layout, dredging, access channel extent and associated marine infrastructure from Arrow Energy.
Project area from Coffey Environments.
Marine Habitat: Seagrass from DEEDI (2002), Open substrate and reef from DPI QFS (2002). Mangroves and saltpan from Ecosure (groundtruthed where available, DERM RE v6.1 data otherwise).
Imagery from Nearmap (captured 7 August 2012).

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Date: 12.12.2012
MXD: 7033CC_16_GIS072_v1_1
File Name: 7033CC_MNE_F001_GIS_VS

Arrow Energy

Arrow LNG Plant

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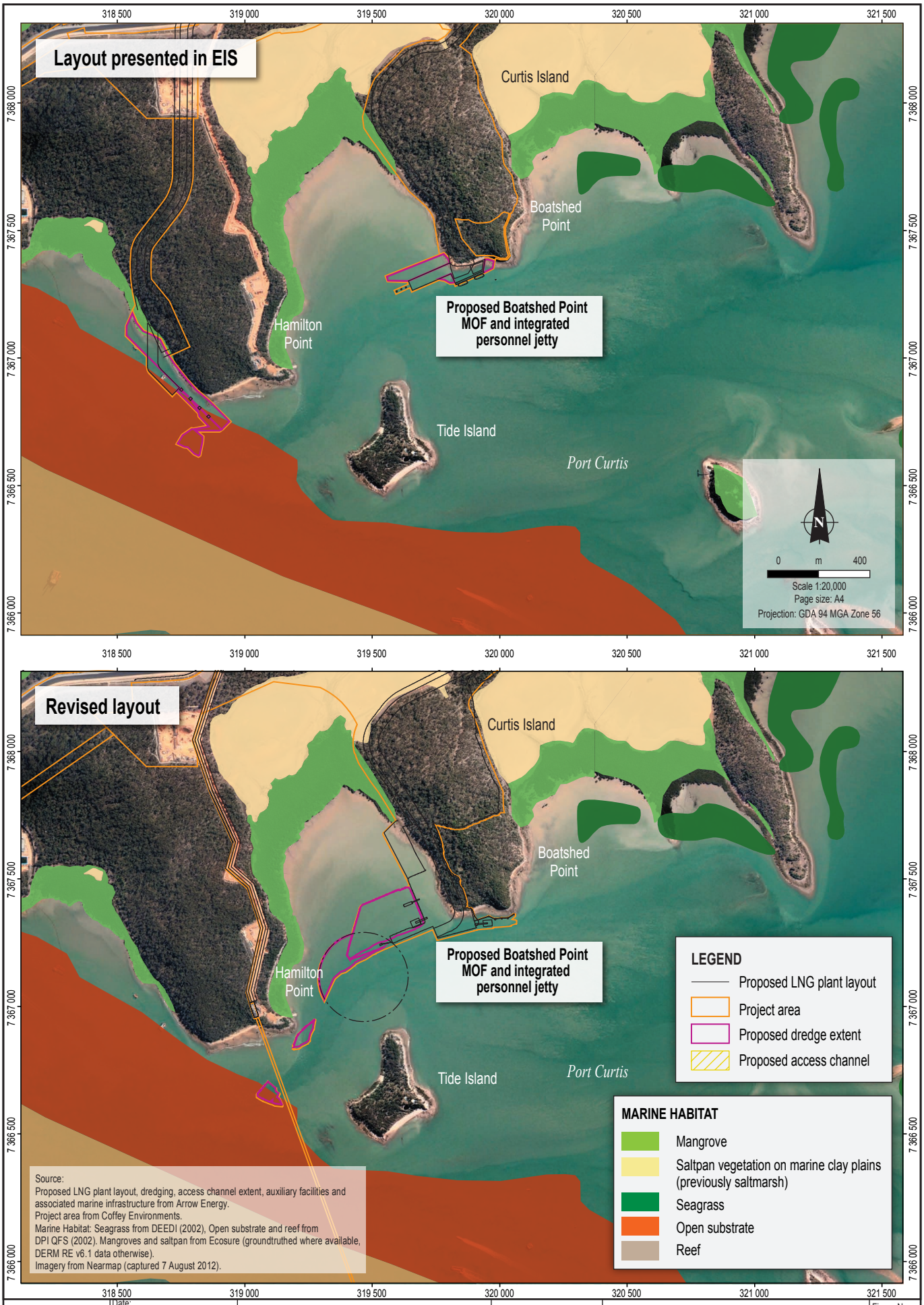
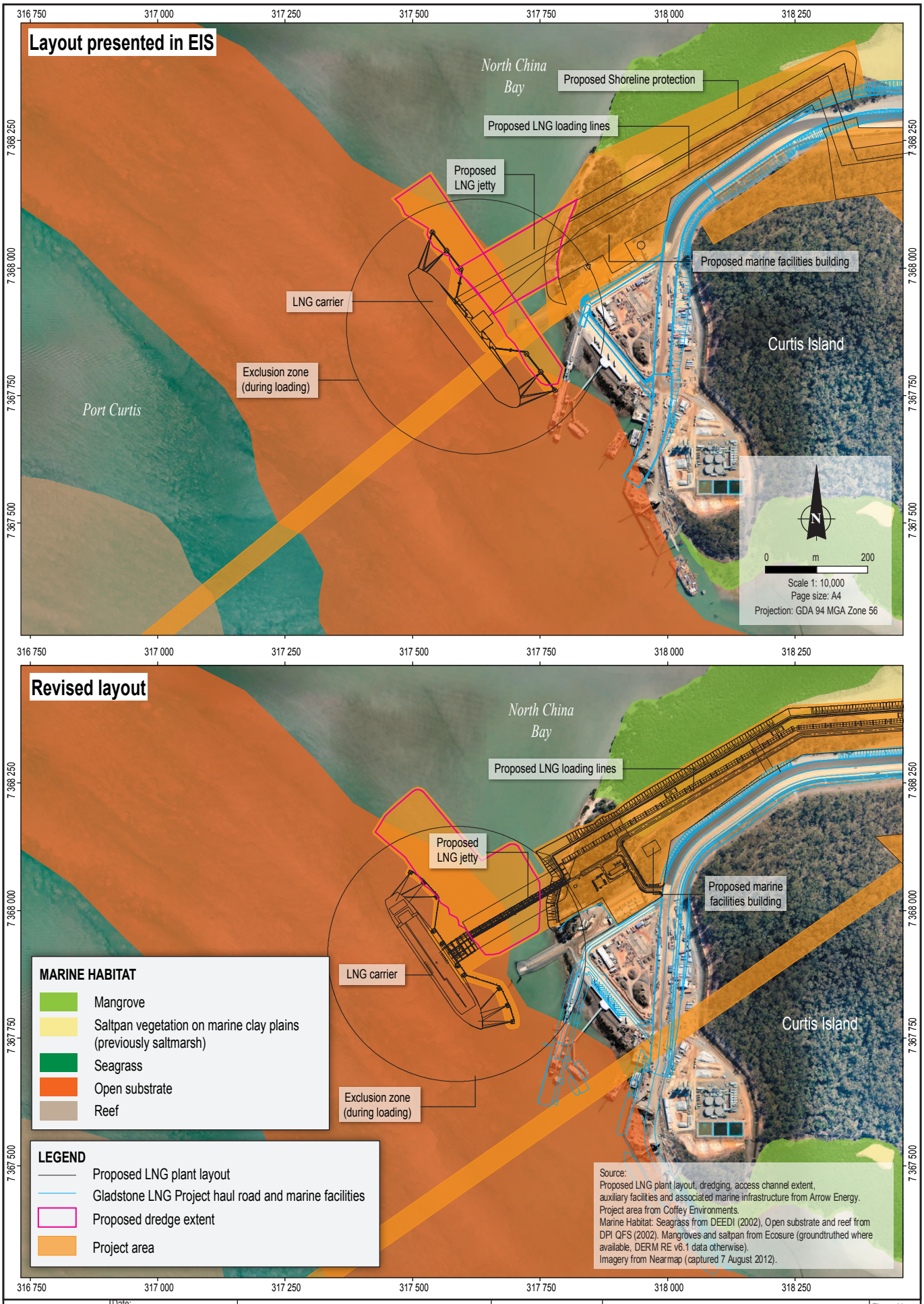
Main areas of the Arrow LNG Plant in Port Curtis

Figure No: 1

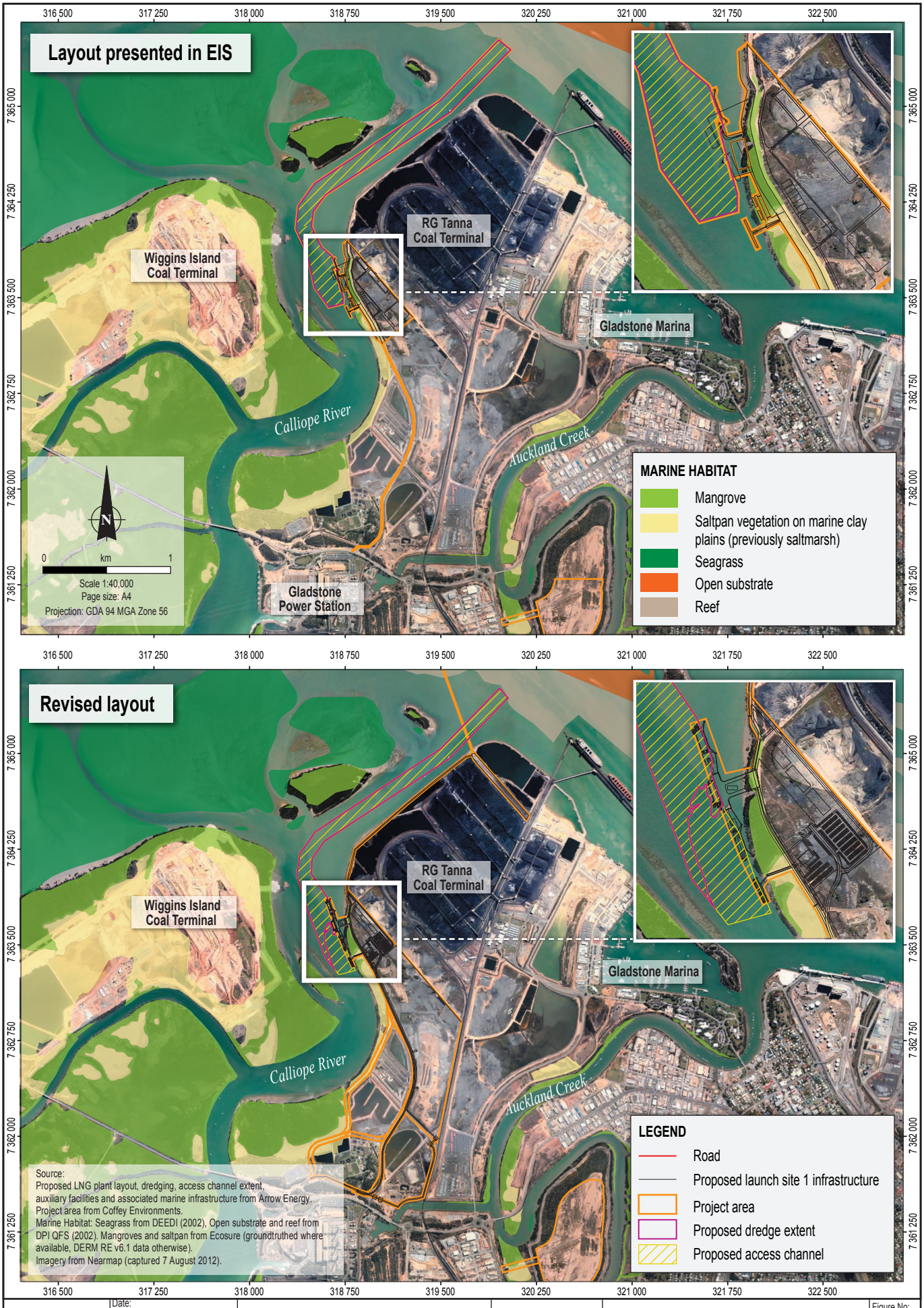


coffey environments	Date: 13.12.2012 MXT: 7033CC_16_GIS037_v1_1 File Name: 7033CC_MNE_F002_GIS_GL	Arrow Energy Arrow LNG Plant	arrow energy go further	Changes to Boatshed Point MOF layout and dredge extent

Figure No: 2



coffey environments	Date: 13.12.2012 MXT: 7033CC_MNE_GIS012_v1_1 File Name: 7033_MNE_F003_GIS_VS	Arrow Energy Arrow LNG Plant	arrow energy go further	Changes to LNG jetty layout and dredge extent	Figure No: 3



coffey environments	Date: 12.12.2012 MXT: 7033CC_16_GIS077_v1_1 File Name: 7033CC_MNE_F004_GIS_VS	Arrow Energy Arrow LNG Plant	arrow energy go further	Changes to launch site 1 layout and dredge extent	Figure No: 4

2.1.2 Dredging

Proposed dredging footprints and volumes to be removed from project areas following changes to the project description, with comparison to dredge footprints and volumes presented in EIS are provided in Table 1.

Table 1 Details of proposed footprints and volumes to be dredged for the construction and operation of Arrow LNG Plant Project facilities in Port Curtis

Component	Layout Reported in EIS		Revised Layout	
	Footprint (ha)	Volume (m^3)	Footprint (ha)	Volume (m^3)
Boatshed Point MOF and integrated passenger jetty	1.3	50,000	–	148,000
Boatshed Point access channel and swing basin	Option not presented		–	165,000
Total Boatshed Point MOF and associated components	**1.3**	**50,000**	**7.0**	**313,000**
Launch site 1 – Calliope River	36.7	900,000	30.2	900,000
LNG Jetty – North China Bay	4.5	120,000	4.9	131,000
Launch site 4N	0.4	2,500	0.4	2,500
Total all components	**42.9**	**1,072,500**	**42.5**	**1,346,500**

The total revised area to be dredged at Boatshed Point (dredge site 3) is estimated at 7.0 ha. This includes 4.5 ha for the ferry terminal, 1.7 ha for the swing basin and 0.4 ha for each of the two high seabed points along the access channel. The increase in total dredged volume at Boatshed Point (from 50,000 to 313,000 m^3) reflects the requirement to build the MOF and integrated passenger jetty, a swing basin and the access channel to the MOF, and combined represent the anticipated worst case.

The total area to be dredged for the construction of the LNG jetty in North China Bay (dredge site 5) has been revised from 4.5 to 4.9 ha (an increase of 0.4 ha). The estimated dredging volume has increased from 120,000 m^3 to 131,000 m^3.

The total revised area to be dredged at the launch site 1 in the Calliope River has decreased from 36.7 ha to 30.2 ha, while the estimated dredging volumes are expected to remain unchanged at 900,000 m^3. The area and volume of material expected to be dredged at the launch site 4N remains unchanged at 0.4 ha and 2,500 m^3, respectively.

All dredging scheduled for the project area is planned to be conducted using a medium-sized cutter suction dredge (CSD) or a backhoe dredge. The assumed in-situ production rate of the medium-sized CSD is approximately 500 m^3 h^{-1}, while that of the backhoe is lower so it would need to operate for longer periods. Assuming that dredging is to be carried out continuously 24 hours a day, 7 days a week during the construction phase, dredging of in-situ material at Boatshed Point (313,000 m^3) is expected to take around 26 days using the medium-sized CSD. Continuous round the clock dredging represents the most conservative assumption (in the event that dredging is conducted in days and evenings only the overall duration will extend but tidal flushing during down times will assist with sediment plume dispersal).

2.2 Changes to Marine Logistics and Transport

This section describes the proposed changes in the types and estimated number and frequency of marine vessel movements that were described in the EIS.

Six types of marine vessels will be used for activities associated with the construction and operations of the project. These comprise ferries, barges, LPG ships, and LNG carriers and escort tugs as well as RO-RO/LOLO/RoPax/LCT vessels to transport modules and equipment. The changes to the estimated number, type and frequency of marine vessels required to support the revised project description are provided in Table 2. The proposed changes to ferry movements for mainland residents during the construction phase are provided in Table 3.

Ferries licensed to carry up 150 passengers are expected to transport project construction personnel between Gladstone Marina and temporary facilities at Hamilton Point on Curtis Island, ahead of the establishment of the Boatshed Point MOF. Upon completion of the MOF, larger ferries licensed to carry up to 250 passengers are expected to operate up to 16 single movements per day. These are provisionally scheduled for between 05:30 am and 17:35 pm.

The number of Fast Cat ferry movements has reduced from the 1140 movements per months assessed in the EIS to 480 per month. The expected RoPax ferry movements remain unchanged at 540 per month. RoPax and high speed people carrier vessels and proposed speeds and passenger capacities are the same as those assessed in the EIS. There has been no change to the expected frequency of other project-related vessels (e.g., LNG carriers, LPG vessels, barges, escort tugs, dredges and support vessels).

Table 2 Estimated type, number and frequency of marine vessels for the Arrow LNG Plant Project

Type	Description	Number of Vessels EIS/Revised	Frequency Reported in the EIS	Revised Frequency[1]
Ferry (Construction)	High-speed (Fast Cat) people carriers with a capacity of 200 to 250 people.	3/4	1680 single ferry trips per month comprising: • 2 fast cats making 20 single trips each per day (estimated 1,140 per month). • 18single RoPax ferries per day (estimated 540 per month).	1020 single ferry trips per month comprising: • 16 fast cat single movements per day (estimated 480 single trips per month). • 18 single RoPax ferries per day (estimated 540 per month).
	RoPax ferry.	1/1		
Ferry (Operation)[4]	High-speed people carriers (Fast Cats) with a capacity of 200 to 250 people.	NA/2	NA.	12 (total both Fast Cats) single trips per day (estimated 360 single trips per month).
Barge	70x20 m barge (2,000 t).	1/1	60 to 70 per year.	60 to 70 per year.
LNG carrier	Membrane design 145,000 m^3 nominal capacity.	1/4 to 5	240 return trips per year.	240 return trips per year.
LPG vessel	–	1/1	1 return trip in the first year.	1 return trip in the first year.

Table 2 Estimated type, number and frequency of marine vessels for the Arrow LNG Plant Project (cont'd)

Type	Description	Number of Vessels EIS/Revised	Frequency Reported in the EIS	Revised Frequency[1]
LNG escort tug	70 to 80 t bollard pull tugs.	4/4	9602 per year.	3840 per year[2].
Cutter suction dredging vessel	Medium-sized CSD (rate = 500 m^3 h-1).	1/1	To be confirmed[3].	To be confirmed[3].
Support vessel	_	1/1	To be confirmed[3].	To be confirmed[3].
Backhoe dredging barge	_	1/1	To be confirmed[3].	To be confirmed[3].
Backhoe support tugs	_	2/2	To be confirmed[3].	To be confirmed[3].

[1] Based on four LNG trains operating.

[2] Assuming four tugs (two active and two on standby) per LNG carrier per one-way trip, the total number of tug movements is significantly less than the 9602 movements assessed in the EIS but the number of dumb barge movements (which may be included in the 9602) will only be determined after completion of detailed engineering design.

[3] Frequency of dredge vessels (including tugs and support vessels) will be included in the dredge management plan. Frequency of dredge vessels will be a function of volume to be dredged (as discussed in 2.1) and number of vessels available.

Table 3 Proposed changes to ferry movements for mainland workforce during the construction and operations

	Amount of Mainland Residents to be Transported	No. of Ferries (250 pax)	Total One Way Ferry Movements (per day)	Total One Way Ferry Movements (per month)
Movements reported in the EIS (construction)	1000 to 1500	3	56: approx. 40 fast cat and 20 RoPax.	1140 (fast cat). 540 (RoPax).
Revised Movements (construction)	1000 to 1500	4	34: 16 fast cat and 18 RoPax.	480 (fast cat). 540 (RoPax).
Movements reported in the EIS (operations)	Not reported in the EIS.			
Revised movements (operations)[1]	375	2	20: 12 fast cat and 8 RoPax.	360 (fast cat). 240 (RoPax).

[1] During major maintenance works such as shutdown, workforce numbers and accordingly ferry movements will be as for construction.

2.3 Review of Ancillary Information

Further information has been gathered to identify the potential impact of maintenance dredging required for the project area. This matter is addressed in this technical study.

2.4 Response to Public Submissions

A number of key matters were identified subsequent to the finalisation and exhibition of the EIS. These include the spatial and temporal use of the Calliope River and adjacent areas by marine

megafauna (e.g., turtles, dugongs, dolphins, whales), potential vessel strikes on turtle and dugong populations, and impacts of underwater noise from pile driving activities on these and other fauna. These issues are individually addressed in this study.

2.5 Study Objectives

The main objectives of this technical study are to assess the impact on the marine ecology of Port Curtis following changes to the project description, including changes to marine facilities, logistics and transport; review ancillary information; and address specific relevant submissions made on the EIS.

The specific objectives addressed in this study regarding changes to the infrastructure design and dredging footprint of the project's marine facilities are as follows:

- Evaluate impacts to marine habitats in Port Curtis as a result of changes to the project description concerning infrastructure, including the spatial extent to which marine habitats would need to be further cleared as a result of project description changes.
- Evaluate the extent to which ecological values of mangroves and other marine habitats may be altered as a result of proposed clearing.
- Evaluate revised results of modelling of coastal processes likely to result from the additional dredging works planned for the project area, and assess to what extent model outputs are likely to alter the original assessment of marine habitats at and around the project area.
- Identify locations for confirmatory field studies of the ecological values of sites where limited or no information exists, and the new areas of impact resulting from changes in the project design.

The specific objectives addressed in this technical study concerning changes in the marine logistics and transport system in the Port Curtis area are as follows:

- Describe changes to ferry movements and other vessels (i.e., barges, LNG escort tugs and module carriers, and LPG ships) planned for the project in relation to potential cumulative impacts.
- Assess to what extent the significance of impact has changed as a result of increased ferry movements in the area.

The specific objectives addressed in this technical study concerning the review on ancillary information and responses to relevant submissions made on the EIS are as follows:

- Review potential impacts of dredging required to maintain operational continuity of the project marine facilities in Port Curtis.
- Investigate the spatial and temporal use of the Calliope River and adjacent areas by marine megafauna (e.g., turtles, dugongs, dolphins, whales) to facilitate an informed decision on potential impacts of dredging and use of the proposed access channel.
- Assess new information (based on locally available data) on potential vessel strikes in the project area on turtle and dugong populations, including a review of avoidance, mitigation and management measures as well as consideration of cumulative impact due to changes in the project description.
- Assess impacts of noise from pile driving activities around Boatshed Point.

3. LEGISLATIVE CONTEXT

All specific Commonwealth and state legislation, regulations and policies related to protecting the values of the marine and estuarine environments within the project area, including guidelines for the protection of internationally recognised areas, were addressed in detail in the EIS (Coffey Environments, 2012a).

Offset legislation at a state level are unchanged since the Arrow LNG Plant EIS was finalised. Offsets remain governed by the Queensland Government Environmental Offsets Policy, June 2008 (EPA, 2008). The offsets policy was under review in November 2012. The State Government has released the Ecological Equivalence Methodology Guideline (DERM, 2011) in 2011. The guideline is intended to inform requirements for ecological offset required under the Policy for Vegetation Management Offsets and Queensland Biodiversity Offsets Policy.

Offsets concerned with the removal of marine habitats for the construction of the LNG plant and associated infrastructure will be included in an environmental offset strategic management plan to be submitted prior to the commencement of construction in 2014.

4. METHODS

The methods used in this technical study consisted of a desktop review of existing and new information, the completion of field observations in conjunction with field works undertaken by Central Queensland University (CQU). This information was then used to identify and assess the ecological impacts following changes to the project description, and the subsequent comparison to those specified in the EIS (Coffey Environments, 2012a).

4.1 Available Data

The desktop study included a review of the following reports and information:

- Coastal processes, marine water quality and hydrodynamic modelling information provided by BMT WBM (BMT WBM, 2011 and 2012) that included simulations of spatial extent of turbidity plumes from different dredging sources associated with project works within Port Curtis.
- LIDAR mapping data from DNRM (DERM, 2011).
- Reports of marine megafauna sightings (turtles, dugong and dolphins) by Coffey Geotechnics (June to October, 2012).
- Field surveys undertaken in Port Curtis by CQU in May 2010 (Phase I) and February 2011 (Phase II) (Alquezar, 2011), and more recently in August 2012 (Wilson, 2012). The 2012 CQU field survey was carried out concurrently with field sampling in the Calliope River, and included collection of samples for water quality analyses, assessment of mangrove communities, sampling of fishes and macro-invertebrates.

4.2 Study Approach

This section describes the approach adopted to meet the specific objectives listed for this technical study, based on the changes to the project description that were identified as having a potential impact on the key marine habitats and associated fauna of Port Curtis. The following clarifications have been applied to marine habitat types:

- The habitat classified as ‘saltmarsh’ in the EIS has been renamed ‘saltpan’ in this technical study as there are no clear boundaries between saltmarsh vegetation and bare saltpan, and both habitats are present in Port Curtis.
- The habitat classified as ‘benthic zone and intertidal mudflats’ in the EIS has been re-named ‘intertidal zone’. This zone includes those areas that are below the mean high water mark and which are alternately submerged and exposed, such as mudflats.
- The habitat that comprises the entirely submerged zone, and is deeper than the mean lower low water mark is referred to as the ‘subtidal zone’. This habitat includes all habitats found in the benthic environment, such as seagrass beds as well as reef and rock substrate.

4.2.1 Disturbance to Marine Habitats

Marine habitats that will be directly or indirectly disturbed during the project’s construction phase, i.e., totally removed or temporarily disrupted, comprise mangroves, saltpan, intertidal zone, and reef and rock substrate. No seagrass beds will be directly disturbed during the construction of the LNG jetty, Boatshed Point MOF or vessel terminals. This assessment of disturbance of seagrass is based on information presented in a 2002 DEEDI database. The extent of habitat clearing from

the construction of LNG plant and associated infrastructure, and of the launch site 1 in Calliope River are shown in Figure 5 and Figure 6.

A geographical dataset defining the total project area of disturbance within Port Curtis was created by Coffey Environments and was based on project layouts supplied by Arrow (AutoCAD files). The revised dataset follows changes in the project description that occurred as a result of FEED, and includes all land and marine-based infrastructure, as well as areas to be dredged, whether these are associated with infrastructure or access channels. Revised footprints of areas to be dredged during the construction of the Boatshed Point MOF and LNG jetty in North China Bay as presented in Table 1 were projected on specific maps. The areas of disturbance (7.0 ha and 4.9 ha, respectively) and revised volumes of material to be dredged (313,000 m^3 and 131,000 m^3) respectively were estimated using GIS.

The updated total mangrove and saltpan areas to be removed following changes in the project description were estimated using GIS and were based on the ground-truthed regional ecosystem 2011 dataset provided by Ecosure, and the regional ecosystem dataset (v6.1 2011) provided by DERM. The revised areas of intertidal zone and reef and rock substrates to be removed were estimated using GIS and based on 2002 datasets provided by Department of Primary Industry (DPI) Queensland Fisheries Service (QFS).

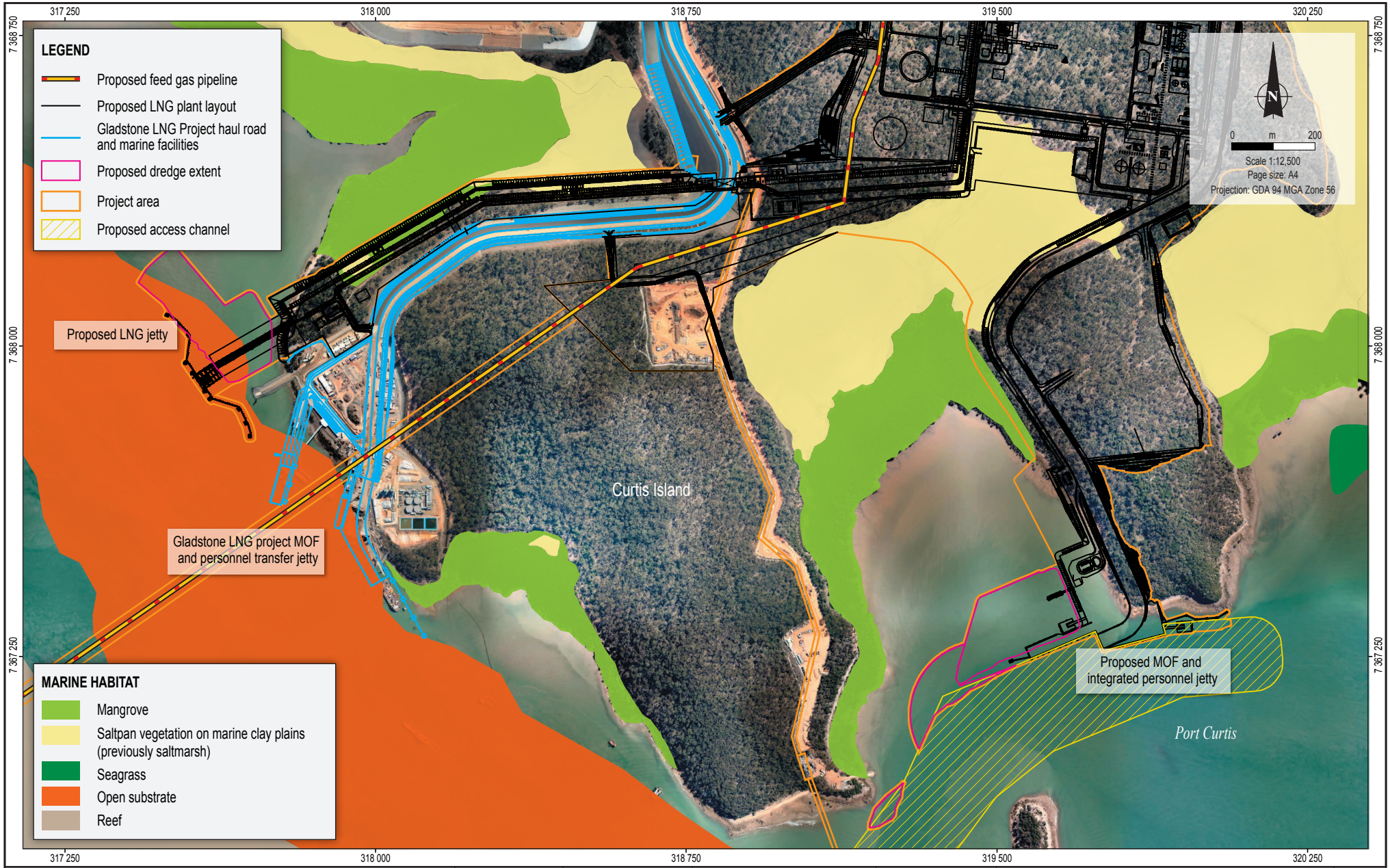
4.2.2 Marine Fauna

Six major fauna groups were discussed in detail in the EIS: plankton, benthic macro-invertebrates, shellfish, fishes, reptiles and marine mammals. However, greater emphasis was placed on marine megafauna, i.e., reptiles and mammals. Reptiles discussed included six of the world's seven species of marine turtles and the sole species of saltwater crocodile. Marine mammals discussed included dugong and several cetaceans, including eight dolphin and five whale species.

Of the several dolphin species known to occur in the Port Curtis region, the Australian snubfin dolphin (*Orcaella heinsohni*) and the Indo-Pacific humpback dolphin (*Sousa chinensis*), are listed as a 'near threatened' under the IUCN Red List (IUCN, 2012) and NC Act, as 'migratory' under the EPBC Act, and are regarded as being of most concern. The snubfin dolphin has only recently been recognised as a separate species from the Irrawaddy dolphin, *O. brevirostris* (Parra et al., 2005). Further information on the ecology of these species, including their spatial and temporal use of Port Curtis and the Calliope River, are included in this report, along with discussion on the impacts from the project works and information on proposed mitigation and management measures, and residual impacts.

Four direct and indirect impacts were identified in the EIS (Coffey Environments, 2012a) as likely to affect the fauna values during all phases of the project, and were addressed accordingly. These impacts include: loss and disturbance of habitat from dredging; smothering from increased turbidity and sedimentation derived from dredging; vessel interaction (mostly propeller strikes) from increased vessel traffic; and underwater noise from pile driving during construction.

Occurrence of megafauna in the Port Curtis area, including Calliope River, was extensively discussed in the EIS (Coffey Environments, 2012a). Following changes to the project description, sightings of marine turtles, dugong and dolphins within the project area were updated using information collected during field work conducted by CQU in August 2012 (Wilson, 2012), and Coffey Geotechnics between 21 June to 25 October 2012. Locations of sightings were plotted on GIS maps, and are based on records obtained from vessels that were underway at the time of



Source:
Proposed LNG plant layout, dredging, access channel extent and associated marine infrastructure from Arrow Energy.
Project area from Coffey Environments.
Marine Habitat: Seagrass from DEEDI (2002), Open substrate and reef from DPI QFS (2002). Mangroves and saltpan from Ecosure (groundtruthed where available, DERM RE v6.1 data otherwise).
Imagery from Nearmap (captured 7 August 2012).

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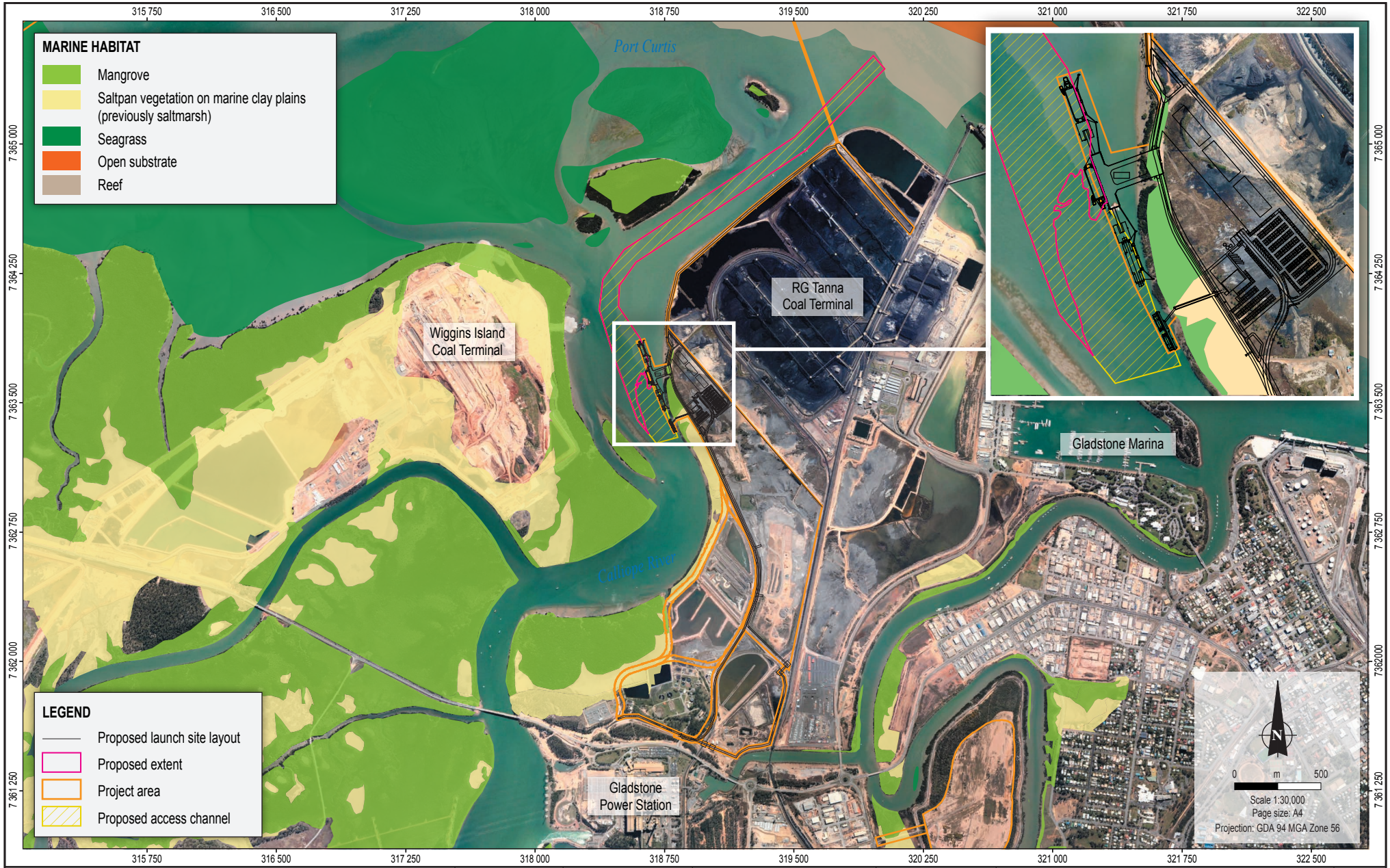
Arrow Energy

Arrow LNG Plant

arrow energy go further

Extent of habitat clearing from construction of LNG plant and associated infrastructure

Figure No: 5



Source:
Proposed LNG plant layout, dredging, access channel extent, auxiliary facilities and associated marine infrastructure from Arrow Energy. Project area from Coffey Environments.
Marine Habitat: Seagrass from DEEDI (2002), Open substrate and reef from DPI QFS (2002). Mangroves and saltpan from Ecosure (groundtruthed where available, DERM RE v6.1 data otherwise).
Imagery from Nearmap (captured 7 August 2012).

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File Name: 7033CC_MNE_F006_GIS_VS

Arrow Energy

Arrow LNG Plant

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Extent of habitat clearing from construction of launch site 1 in Calliope River

Figure No: 6

observation and stationary drilling platforms at locations throughout Port Curtis. Sightings recorded correspond to fauna type (e.g., dolphins) as identifications to genus or species level could not be completed with certainty.

Information on occurrence of megafauna in the project area was complemented with information recorded in DSEWPaC and EHP databases. In addition, observations recorded in February to April 2011 and June 2011 during vessel and aerial surveys completed for the Western Basin Dredging and Disposal Project EIS (GPC, 2011) were considered. Information on the occurrence and distribution of snubfin and humpback dolphins in Port Curtis was obtained from local surveys conducted between January 2006 and September 2008 (URS, 2009). Updated sightings of megafuna were mapped for the areas around Boatshed Point (Figure 8), the Gladstone Marina and the mouth of the Calliope River (Figure 7).

4.2.3 Vessel Interactions

Proposed changes to marine logistics and transportation will change the potential for interaction between vessels and marine megafauna, i.e., vessel strikes. The direct impact of vessel strikes on marine megafauna (specifically turtles, dugong and cetaceans) was assessed following the approach applied in the EIS (Coffey Environments, 2012a), considering the frequency of the vessel movements, the likelihood of the animals being in the path of the vessel and the ability of the species to detect and take avoiding action. Table 3 outlines the predicted vessel frequency for the project.

Updated information on occurrence of megafauna in Port Curtis provided by the team from Coffey Geotechnics reflects predominantly opportunistic reports of locations of sighting by the observers.

4.2.4 Underwater Noise

The impact of underwater noise on marine fauna was assessed following the approach applied in the EIS (Coffey Environments, 2012a). Pile driving activities were identified as the main source of underwater noise known to affect the project area. To a lesser extent, increased vessel traffic was also identified as a source of underwater noise. The required pile driving activities within the project area have not changed from those described in the EIS and still include the construction of the proposed MOF at Boatshed Point and LNG jetty in North China Bay, and the launch site 1 in the Calliope River.

The same criteria used in the EIS were applied in this study. The assessment considers the possibility for fauna to avoid the noise (possible avoidance) and the possible injury levels that could be sustained (possible injury levels). Sound exposure levels (SEL) which indicate the distance from piling activities at which turtles and dugongs could potentially be adversely impacted were taken to be 55 m and 22 m respectively. The distances for potential avoidance were taken to be 1,500 m for marine turtles and 205 m for dugong.

In the EIS, it was assumed that sound levels would drop below 150 dB re 1 µPa (decibels for standard water conditions) within a radius of 350 m from the noise source (threshold response radius). This is below the level of 160 dB re 1 µPa specified in the EPBC Policy Statement 2.1 that addresses interactions between offshore seismic explorations and whales (DEWHA, 2008). The assumed level is not necessarily below levels where behavioural responses may be expected from exposed marine animals. A 350 m noise projection boundary was applied by the GLNG Project (L. Huson and Associates Pty Ltd, 2009) for works in Port Curtis, and has been applied in this technical study to pile driving activities required for construction of project infrastructure in

Source:
Marine life sighting from Coffey Geotechnics (indicative observations from field work locations only).
Proposed dredging and access channel extent from Arrow Energy.
Project area from Coffey Environments.
Imagery from Nearmap (captured 7 August 2012).

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Sightings of marine megafauna in Gladstone Marina and Calliope River

Figure No: 7

Source:
Marine life sighting from Coffey Geotechnics (indicative observations from field work locations only).
Proposed dredging and access channel extent from Arrow Energy.
Project area from Coffey Environments.
Imagery from Nearmap (captured 7 August 2012).

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MXD: 7033CC_16_GIS066_v1_1
File Name: 7033CC_MNE_F008_GIS_GL

Arrow Energy

Arrow LNG Plant

arrow energy go further

Sightings of marine megafauna around Boatshed Point and Hamilton Point

Figure No: 8

Port Curtis and the Calliope River. The 350 m noise projection limit was superimposed on pile driving sources and individually mapped for the LNG jetty in North China Bay (Figure 9), the MOF at Boatshed Point (Figure 10) and the launch site 1 in the Calliope River (Figure 11). This was completed to determine whether any feeding habitats for turtles and dugongs were located within areas where the SEL was anticipated to be greater than 150 dB re 1 µPa.

4.3 Impact Assessment Approach

The assessment approach adopted in this technical study follows that used in the original marine and estuarine ecology impact assessment (Coffey Environments, 2011a). Environmental values are established. The sensitivity of the environmental value being impacted in the context of existing environment and the magnitude of the impact on the value are assessed. Sensitivity and magnitude criteria are discussed below in sections 4.3.2 and 4.3.3. The interaction between sensitivity of an environmental value and magnitude of impact determines the significance of an impact. This is expressed in a matrix that takes into account factors such as geographical extent, duration and severity of impacts, and any formal status or sensitivity of each receptor. The matrix is presented in section 4.3.5.

The assessment draws on information on the existing environment presented in the marine and estuarine ecology impact assessment (Coffey Environments, 2011a), the results of field surveys undertaken by CQU in 2010/2011 (Alquezar, 2011) and 2012 (Wilson, 2012), and information available from pertinent literature and databases.

The assessment of sensitivity of environmentally sensitive areas as well as estuarine flora and fauna of Port Curtis is based on regulations by the Environmental Protection Act 1994, the EPBC Act 1999, the Nature Conservation Act 1992, and information relevant to the conservational status of a species provided primarily from the IUCN Red List of Threatened Species (IUCN, 2012). This list provides categories of conservation status as Extinct; Extinct in the Wild; Critically Endangered; Endangered; Vulnerable; Near Threatened; Least Concern; or Not Evaluated (i.e., when it has not yet been evaluated against the criteria).

Where applicable, proposed engineering design features to be implemented to limit the impacts of the project are assumed to have been implemented prior to completion of the assessment. However, if impacts are unavoidable, mitigation and management measures are proposed to reduce each impact. The assessment of significance for residual impacts is applied following the assignment of mitigation measures, assuming that all avoidance and mitigation measures are successful.

4.3.1 Identification of Impacts

The identification of impacts that may occur as a result of the revised project activities, follows the same approach adopted in the EIS (Coffey Environments, 2012a), and includes identification of direct, indirect and cumulative impacts. In the case of marine habitat loss and disturbance, impacts deemed likely to affect environmental values were classified as either direct (i.e., dredging and clearing) or indirect (i.e., smothering by sediment plumes).

Direct and Indirect Impacts

Direct impacts in the marine and/or estuarine environment include those that affect or disturb the environmental values directly, whereas indirect impacts are those that occur as a subsequent result of the project or activities related to the project. The removal of mangrove areas resulting in the loss of habitat once occupied by specific faunal communities is considered a direct impact.

Source:
Proposed LNG plant layout, dredging, access channel extent and associated marine infrastructure from Arrow Energy.
Project area from Coffey Environments. Underwater noise projection contour from Katestone.
Marine Habitat: Seagrass from DEEDI (2002), Open substrate and reef from DPI QFS (2002). Mangroves and saltpan from Ecosure (groundtruthed where available, DERM RE v6.1 data otherwise).
Imagery from Nearmap (captured 7 August 2012).

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Arrow Energy

Arrow LNG Plant

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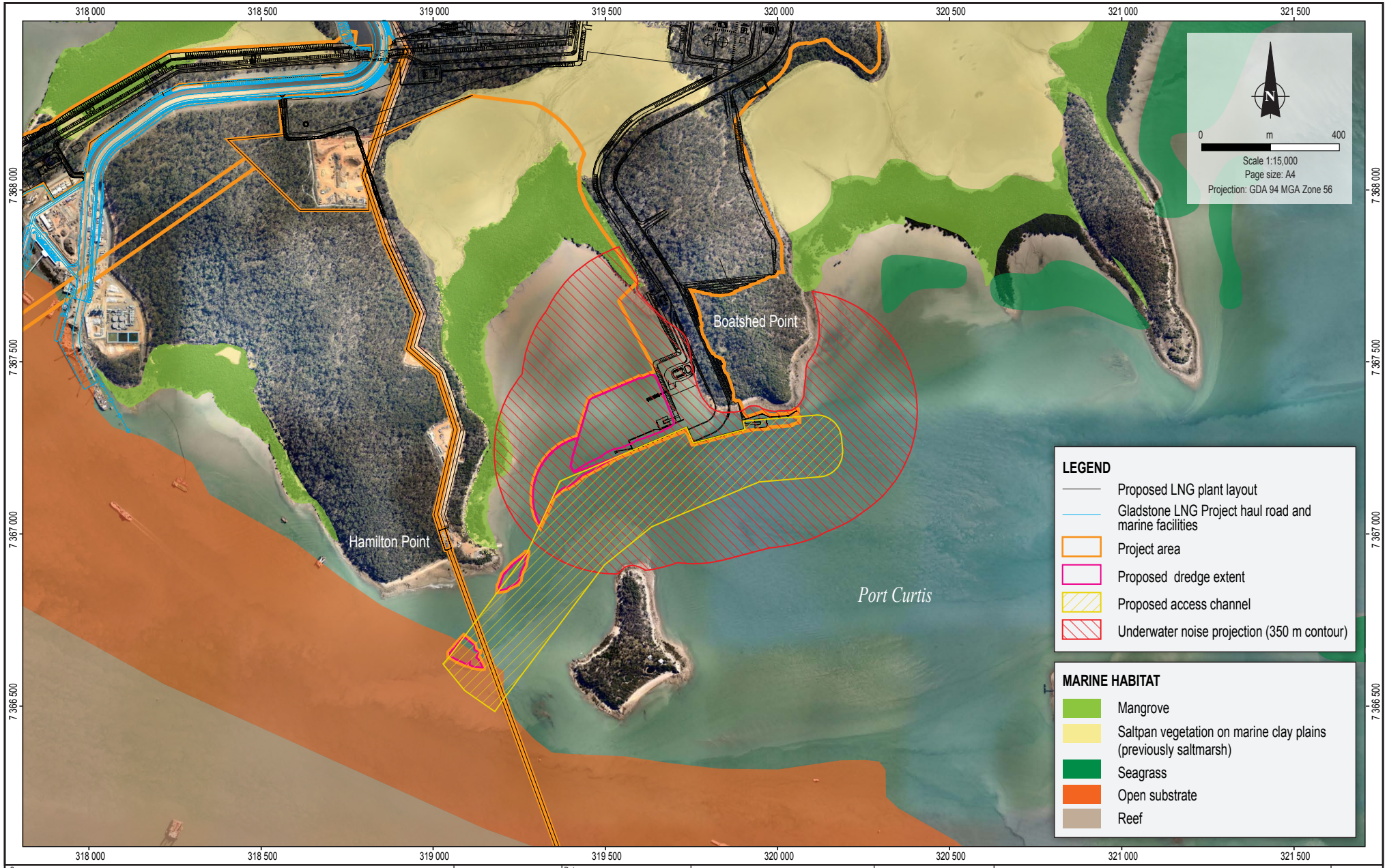
Underwater noise projection from pile driving in North China Bay

Figure No: 9



Source:
Proposed LNG plant layout, dredging, access channel extent, auxiliary facilities and associated marine infrastructure from Arrow Energy. Project area and underwater noise projection contour from Coffey Environments.
Marine Habitat: Seagrass from DEEDI (2002), Open substrate and reef from DPI QFS (2002). Mangroves and saltpan from Ecosure (groundtruthed where available, DERM RE v6.1 data otherwise).
Imagery from Nearmap (captured 7 August 2012).

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File Name: 7033CC_MNE_F010_GIS_VS

Arrow Energy

Arrow LNG Plant

arrow energy go further

Underwater noise projection from pile driving at Boatshed Point

Figure No: 10

Source:
Proposed LNG plant layout, dredging, access channel extent, auxiliary facilities and associated marine infrastructure from Arrow Energy. Project area and underwater noise projection contour from Coffey Environments.
Marine Habitat: Seagrass from DEEDI (2002), Open substrate and reef from DPI QFS (2002). Mangroves and saltpan from Ecosure (groundtruthed where available, DERM RE v6.1 data otherwise).
Imagery from Nearmap (captured 7 August 2012).

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Date: 06.12.2012
MXD: 7033CC_MNE_GIS010_v1_1
File Name: 7033CC_MNE_F011_GIS_VS

Arrow Energy

Arrow LNG Plant

arrow energy go further

Underwater noise projection from pile driving at launch site 1

Figure No: 11

The increased turbidity in the surrounding marine habitats as a result of the clearing can be regarded as an indirect impact. Indirect impacts are harder to predict as they may not become immediately evident in the marine environment. Examples include localised, short to long-term changes to water quality and/or sedimentation. Assessment of such impacts may rely on modelling of dispersion and/or dilution processes. Impacts may be positive as well as negative; a positive example includes the installation of marine infrastructure, which will result in the creation of new habitat suitable for colonisation by marine or estuarine fauna and flora.

In this technical study, direct and indirect impacts resulting from the project apply to:

- Marine habitats to be cleared and/or removed for the purpose of building the Boatshed Point MOF and LNG plant in North China Bay.
- Dredging of areas associated with the construction of the Boatshed Point MOF, including two high points along the access channel, a swing basin and the passenger terminal.
- Dredging of the area associated with the construction of the LNG jetty in North China Bay.

The worst-case impacts to the marine and estuarine habitats in Port Curtis were determined by comparing existing habitat distribution with areas expected to be affected by direct and indirect disturbances. The impacts were subsequently compared to those previously described in the EIS (Coffey Environments, 2012a). Once areas of direct and indirect impact were identified, the worst case impact for each habitat was selected and carried through the impact assessment.

Residual Impacts

Residual impacts are the potential impacts remaining after the application of any design responses and mitigation and management measures. The extent to which potential impacts have been reduced is determined by undertaking an assessment of the significance of the residual impacts. If the proposed mitigation measures or design responses are ineffective in reducing the significance of the residual impacts, additional or new measures or responses need to be developed. In the event that environmentally sensitive areas are severely impacted by the project, and mitigation and management measures only provide a partial recovery, offset strategies are proposed to compensate for the loss.

Cumulative Impacts

Cumulative impacts include those arising from other projects and the actions of third parties and are based on analogous examples on the influence that a project or the actions of third parties may have on environmental values. For example, in the marine environment this might apply to the development of other projects with incremental impacts on resources or habitats, or to changes in the pattern of fishing activities. In such context, it is relevant that the three other LNG proponents in the project area are further advanced in their approvals and construction processes and as such cumulative impacts from construction may be lessened as similar activities may not be occurring concurrently with the Arrow works.

4.3.2 Sensitivity of an Environmental Value

The sensitivity of an environmental value is based on nationally and internationally accepted conservation values, and is determined through desktop studies and field investigations that place the existing environment or baseline conditions of the environmental value into its holistic context. The criteria applied to sensitivity are shown in Table 4. If the environmental value has a conservation status under the IUCN, Commonwealth and/or state government, then it prevails over other recognised listings or importance, and it will determine its sensitivity. If there is no conservation status, then the listing or importance will determine its sensitivity. The sensitivity of

an environmental value (see below) is generally fixed at a particular moment in time, although it can change over time with changes in project phases (Table 4). However, sensitivity of values adopted for marine habitats in the EIS were maintained during this study.

Table 4 Sensitivity of an environmental value

Sensitivity	Definition
Very High	• An environmental value that is listed as 'critically endangered' under the IUCN and Commonwealth government or 'international' under state government. • An environmental value that has international listing or importance.
High	• An environmental value that is listed as 'endangered' under the IUCN, Commonwealth or state governments. • An environmental value that has national importance. • An environmental value of essential (local) commercial/recreational requirement or importance in maintaining ecological integrity (even if not otherwise listed).
Medium	• An environmental value that is listed as 'vulnerable' or 'rare' under the IUCN, Commonwealth or state governments. • An environmental value that has state importance. • An environmental value of common or frequent recreational/commercial importance locally.
Low	• An environmental value that is listed as 'near threatened' under the IUCN or 'conservation dependent' under the Commonwealth government or 'least concern' under the state government. • An environmental value that has regional importance. • An environmental value of occasional recreational/commercial importance locally.
Very Low	• An environmental value that is common and is not listed under the IUCN, Commonwealth or state governments. • An environmental value with local importance. • An environmental value of no reported recreational/ commercial importance locally.

4.3.3 Magnitude of Impact

The magnitude of an impact considers severity, geographical extent, duration or probability of an impact. The criteria for assessment of magnitude are presented in Table 5. Selected criteria have been adopted from the Commonwealth government's '*Matters of National Environmental Significance, Significant Impact Guidelines 1.1 Environment Protection and Biodiversity Conservation Act 1999*' (DEWHA, 2009) and the IUCN 'Red List Categories and Criteria' (IUCN, 2012). The magnitude of an impact can change. That is it can be avoided or reduced through implementation of management or mitigation measures.

Table 5 Magnitude of an impact

Magnitude	Definition
Very High	• Widespread and severe impacts, over large geographical areas which may be irreversible or long lasting and are very likely to happen. • Reduce the extent of an ecological community substantially (e.g., by 90%). • Destroy habitat necessary for an ecological community's survival. • Result in persistent and major adverse changes to an ecological community's life cycle, including breeding, feeding and migration.
High	• Regional impacts which may be long lasting and are likely to happen. • Reduce the extent of an ecological community by ~50%. • Modify habitat necessary for an ecological community's survival. • Result in major adverse changes to an ecological community's life cycle, including breeding, feeding and migration.

Table 5 Magnitude of an impact (cont'd)

Magnitude	Definition
Medium	• Localised impacts which may be long lasting and are likely to happen. • Reduce the extent of an ecological community by ~25%. • Fragment habitat necessary for an ecological community's survival. • Result in moderate adverse changes to an ecological community's life cycle, including breeding, feeding and migration.
Low	• Localised impacts which may be short lived and likely to happen. • Reduce the extent of an ecological community by <10%. • Disturb habitat necessary for an ecological community's survival. • Result in minor adverse changes to an ecological community's life cycle, including breeding, feeding and migration.
Very Low	• Impact undetectable or insignificant. • Extent and population of ecological community stable. • Habitat necessary for an ecological community's survival not expected to be impacted. • The life cycle of an ecological community, including breeding, feeding and migration not expected to be impacted.

4.3.4 Significance Assessment

The significance of an impact involves an assessment of the sensitivity of an environmental value against the magnitude of potential impacts on that value, and it can be rated between negligible and major. An environmental value is described as "a quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety" (EPA, 1994 (Qld)). The significance of an environmental value is derived from its sensitivity, whether it is as a consequence of threatening processes or as a consequence of its conservation status or intrinsic value. The magnitude of impact on an environmental value, on the other hand, is an assessment of the geographical extent, duration severity and likelihood of the impact on that environmental value.

The significance of an impact is assessed pre- and post- mitigation to determine the need for mitigation and how effective the proposed mitigation is in reducing the potential effects of the proposed development. The result of the post-mitigation assessment of significance of the impact comprises the residual impact of the project.

Predicting significance of an impact is partly objective and partly subjective in that it relies significantly on the professional judgement of specialists as well as scientific evidence. However, it is guided by criteria or definitions, and the environmental impact assessment sets out the basis of the judgements so that others can understand the rationale underpinning such assessment.

4.3.5 Assessment of Significance

The level of significance of an impact is determined through Table 6 below.

Table 6 Matrix of significance of impact

		Sensitivity of Environmental Value				
		Very High	**High**	**Medium**	**Low**	**Very Low**
Magnitude of impact	**Very High**	Major	Major	Major	Moderate	Negligible
	High	Major	Moderate	Moderate	Minor	Negligible
	Medium	Moderate	Moderate	Minor	Minor	Negligible
	Low	Moderate	Minor	Minor	Minor	Negligible
	Very Low	Negligible	Negligible	Negligible	Negligible	Negligible

- **Major significance**. Impact that is assessed as either high or very high, and which has the potential to cause irreversible, long lasting or widespread harm to an environmental value that has been listed as vulnerable, endangered or critically endangered. The values are unique and, if lost, cannot be replaced or relocated. An impact that is likely to be a key factor in the decision-making process and raise considerable stakeholder concern.
- **Moderate significance**. An impact that has the potential to cause actual environmental harm. Typically, such impacts are likely to be important at a regional or district scale, and require the application of specific environmental controls to be managed. This level of impact will influence decision-making, particularly when combined with other similar effects.
- **Minor significance**. An impact that is assessed as low, medium or high in magnitude, and which has the potential to cause temporal harm to an environmental values that has been listed as near threatened, vulnerable or endangered. Typically, its effect would be important at a local scale and, when combined with other impacts, could have a more material effect. It is likely to have negligible influence on decision-making, but could raise awareness and concern about possible cumulative effects from a range of minor impacts.
- **Negligible significance**. An impact that will result in no noticeable environmental change or effects, and which would not influence the decision-making process.

5. ASSESSMENT OF IMPACTS AND RISKS

The assessment of impacts and risks to marine and estuarine ecological values included a review of direct and indirect impacts to marine habitats, and marine fauna from the project.

5.1 Impacts to Marine Habitats

The revised project is expected to cause direct or indirect impacts to the five key marine habitats present in the project area. Specific changes to the project description comprise revised disturbance areas for mangroves, saltpans, intertidal zone, and reef and rock substrate. No direct disturbance is expected to affect seagrass beds. The extent of disturbance on the key marine and estuarine habitats of Port Curtis presented in the EIS, and revised for the supplementary assessment are detailed in Table 7.

Table 7 Extent of disturbance of marine habitats reported in EIS and revised

Habitat	Total Area of Disturbance Reported in EIS (ha)	Revised Location of Disturbance	Breakdown of Areas of Disturbance (ha)[1]	Revised Total Area of Disturbance (ha)
Mangroves	5.80	Launch site 1 and haul road – Calliope River.	2.01	Base case – 4.70 Alternative case – 5.10
		LNG jetty.	1.69	
		Curtis Island infrastructure: Boatshed Point MOF, integrated personnel jetty and haul road and loading lines leading to LNG jetty.	0.79	
		TWAF7 access causeway.	0.21	
		Laydown and staging area.	0.61	
Saltpans[1]	58.20	Tunnel (Curtis Island link) launch site.	32.5	Base case – 55.01 Alternative case – 54.49
		Curtis Island infrastructure: Boatshed Point MOF, integrated personnel jetty and haul road and loading lines leading to LNG jetty.	15.60	
		Launch site 1 and haul road – Calliope River.	4.50	
		LNG jetty.	1.89	
		TWAF7 access causeway.	0.52	
Seagrass beds[2]	0	Launch site 4N.	0	Alternative case – 0.00
Reef and rock substrate	0.30	Launch site 4N.	0.14	Alternative case – 0.14
Intertidal zone	5.31	LNG jetty.	3.72	Both cases – 5.64
		Boatshed Point access channel and dredge footprint.	1.92	

[1] Areas calculated for saltpan vegetation in the SREIS are based on Ecosure's ground-truthed regional ecosystem 2011 data set and DERM regional ecosystem v6.1 2011 data set.

[2] Areas calculated for seagrass in the EIS and SREIS are based on the full 2002 data set sourced from the DEEDI.

Given that specific changes are relatively minor and comprise a reduction in disturbance area in all except the intertidal zone, the significance of direct impacts on marine habitats from clearing (pre-mitigation) remains unchanged from that reported in the EIS (Table 8). However, the significance of indirect (pre-mitigation) impacts on marine habitats adjacent to or nearby Boatshed Point are likely to change given the substantially larger volume of in-situ material to be dredged compared to that reported in the EIS (i.e., 50,000 m^3 vs. 313,000 m^3) (Figure 2). The direct and indirect impacts to marine and estuarine habitats are addressed separately below.

Table 8 Pre-mitigation significance of direct and indirect impacts on marine and estuarine habitats from clearing and dredging

Value	Sensitivity	Impact	Revised Area of Disturbance (ha)	Magnitude/ Significance EIS	Revised Magnitude/ Significance
Mangroves	Medium	Direct: loss and disturbance of marine and estuarine habitat (clearing).	4.7 base case, 5.1 ha alternative case	Low/ Minor	Low/ Minor
		Indirect: turbidity plumes from dredging.	Nil	Low/ Minor	Low/ Minor
Saltpan vegetation	Medium	Direct: loss and disturbance of marine and estuarine habitat (clearing).	55.01 base case, 54.49 alternative case	Medium/ Minor	Medium/ Minor
Seagrass beds	High	Direct: loss and disturbance of marine and estuarine habitat (clearing).	Nil	Very Low/ Negligible	Very Low/ Negligible
		Indirect: turbidity plumes from dredging.	Nil	Low/ Minor	Low/Minor
Intertidal zone	High	Direct: loss and disturbance of marine and estuarine habitat (clearing).	5.64 both cases	Low/ Minor	Low/ Minor
		Indirect: turbidity plumes from dredging.	Nil	Medium/ Moderate	Medium/ Moderate
Reef and rock substrate	Medium	Direct: loss and disturbance of marine and estuarine habitat (clearing).	0.14 alternative case	Low/ Minor	Low/ Minor
		Indirect: turbidity plumes from dredging.	Nil	Low/ Minor	Low/ Minor

5.1.1 Direct Loss of Marine Habitats

The key direct impacts identified to affect marine habitats constitute loss and disturbance of habitats from clearing or removal works. Direct impacts on mangroves, saltpan, intertidal zone and reef and rock substrate were addressed in the EIS (Coffey Environments, 2012a), and are re-assessed herein following changes in project description.

Revised disturbance areas have decreased for mangroves (5.80 ha to 5.10 ha (alternative case presented as most conservative case)), saltpan (58.20 ha to 55.01 ha) and reef and rock substrates (0.40 ha to 0.14 ha), but has increased for the intertidal zone (5.31 ha to 5.64 ha).

Mangroves

The maximum direct loss of mangroves following changes to project description has been re-assessed to be 5.10 ha, corresponding to a reduction in 0.70 ha from the estimated 5.80 ha specified in the EIS.

Of the revised area of mangroves proposed to be removed during the project, 1.69 ha is to be cleared from the footprint of the LNG jetty in North China Bay and 0.69 ha for the Boatshed Point MOF, whereas 2.01 ha will be removed ahead of the construction of the launch site 1 and haul road in the Calliope River (see Figure 6).

The overall impact of removing 5.80 ha of mangroves was considered as of **low** magnitude and of **minor** significance in the EIS. Given that the total mangrove area to be disturbed is smaller than that in the EIS, the direct impact continues to be of **low** magnitude and **minor** significance based on the small area of impact in absolute and percentage terms, and the consequent localised area of effects.

The impact arising from the removal of 2.01 ha of mangroves for the construction of the launch site 1 and haul road in the Calliope River has been addressed in the estuarine ecology technical study (Coffey Environments, 2012b).

Saltpan

The maximum direct loss of saltpan following changes to project description has been re-assessed to be 55.01 ha, corresponding to a reduction in 3.19 ha from the estimated 58.20 ha specified in the EIS. Nearly all of the area to be removed is attributed to the construction of the Curtis Island infrastructure as well as the launch site 1 and haul road in Calliope River.

The overall impact of removing 58.20 ha of saltpan was considered as being of **medium** magnitude and of **minor** significance in the EIS, based on the small area of impact in absolute and percentage terms, and the consequent localised area of effects. Given that the total saltpan area to be disturbed is smaller than that reported in the EIS, the direct impact continues to be of **medium** magnitude and of **minor** significance based on the overall small area of impact on a regional scale both in absolute and percentage terms. Areas of saltpan to be cleared at Arrow project sites are predominantly areas of bare claypan which result from micro-topographic variation dependent on salinity and elevation. Actual saltpan vegetation to be cleared at the mainland tunnel launch site comprises elevated alluvial rises which occupy a relatively small proportion of the marine plain. The estimated area of vegetated alluvial rises is 0.3 ha of the total area of disturbance of 35 ha of saltpan at this site.

Intertidal Zone

The maximum direct loss of intertidal zone following changes to project description has been re-assessed to be 5.64 ha corresponding to an increase in 0.34 ha from the estimated 5.3 ha reported in the EIS. This area is to be removed during construction of the LNG jetty in North China Bay and the access channel to Boatshed Point.

The overall impact of removing 5.30 ha of intertidal zone was considered as of **low** magnitude and of **minor** significance in the EIS. Given the small increase in area to be disturbed from that specified in the EIS, the direct impact continues to be of **low** magnitude and **minor** significance

based on the overall small area of impact in absolute and percentage terms, and the large extent of these habitats in the Port Curtis region.

Reef and Rock Substrate

The maximum direct loss of reef and rock substrate following changes to project description has been re-assessed at 0.14 ha, corresponding to a reduction in 0.16 ha from the estimated 0.30 ha reported in the EIS. All the area of reef and rock substrate is to be removed from launch site 4N.

The overall impact of removing 0.30 ha of rock and reef substrate was considered as of **low** magnitude and of **minor** significance in the EIS. Therefore, the direct impact from removing almost half of the area following changes to the project description continues to be of **low** magnitude and **minor** significance, based on the small area of impact in absolute and percentage terms.

5.1.2 Indirect Impacts

The main indirect impacts identified as likely to affect marine habitats would be caused by increased sedimentation and turbidity plumes from dredging works. The main refinement to the project description that is of significance to indirect impacts is the change to the volume of dredging material scheduled to be removed. Following the removal of the Hamilton Point MOF option, dredging is now scheduled to be conducted at four sites: LNG jetty, Boatshed Point MOF and associated components, launch site 1 in the Calliope River, and launch site 4N.

Key considerations and findings of two studies on coastal processes and dredging operations completed by BMT WBM for the project are directly relevant to the assessment undertaken in this technical study (BMT WBM, 2011; 2012). These are summarised below.

- Dredging operations are planned to be completed using a medium-sized cutter suction dredge (CSD) or a backhoe dredge; the latter produces less turbid plume material than the CSD.
- The CSD is capable of dredging at an in-situ production rate of approximately 500 $m^3 h^{-1}$.
- The backhoe dredge has a lower production rate compared to the medium-sized CSD so would need to operate for longer periods; however, the overall impact of the two dredging methods is considered to be largely comparable.
- The seabed and intertidal areas of Port Curtis comprise a mixture of sediments that include gravels, sands and fine silt/clay materials. Over shallow areas, these materials can become re-suspended by tidal currents and locally-generated wind-waves.
- Tidal currents are the dominant natural re-suspension mechanism within the Port Curtis.
- Dredging results in additional re-suspension of seabed material and the formation of plumes of suspended sediment through a number of potential sources and/or mechanisms. The spatial and temporal extent of these plume sources depends on the characteristics of the sediment, dredge type and duration of dredging operations.
- Two of the primary sources of potential environmental impacts caused by dredging activities are the increased turbidity associated with the dredge plume, and the additional sediment deposition associated with settling of the dredge plume material.
- The project area can be regarded as a high energy environment, with strong tidal flows dominating local hydrodynamics.

- Turbidity increases with depth in the water column, most likely due to bottom sediment re-suspension from higher velocities.
- Plumes from dredging activity will cause increased turbidity in the immediate vicinity of the dredging operation at each of the project sites.
- Sediment concentrations in areas close to the sources are highest during neap tides when velocities and dispersion are lowest. By contrast, sediment concentrations further away from the source are typically highest during spring tides when tidal currents are strong enough to facilitate the transport of suspended sediments to those locations.
- Hydrodynamic modelling of sediment plumes from the proposed Boatshed Point MOF based on a dredge volume of 50,000 m^3 showed a rapid dispersion of the plume due to the high-energy environment in that area, with elevated TSS levels contained to a small footprint within 350 m of the dredge plume source. However, the substantially larger dredge volume proposed for Boatshed Point following the FEED (313,000 m^3) will require a longer dredging program using the medium-sized CSD (approximately 26 days), so the time of exposure to elevated turbidity as well as total deposition thickness at sensitive sites will be proportionally greater; dredging operations are assumed to be carried out around the clock.
- The extent of sediment deposition in the vicinity of the seagrass beds adjacent to Garden Island has been estimated between <0.01 and 0.02 mm per day. The continued operation of a medium-sized CSD for the predicted 26 days would thus result in a deposition of 0.26 to 0.52 mm of sediments. Taking into account modelling uncertainties, 0.52mm is predicted as the upper limit of deposition.
- Direction of flood currents along Boatshed Point is mostly to the west/south-west, whereas ebb currents are mostly to the north-east. Thus, sediment particles can be transported in opposite directions from the dredge point source.
- Numerical modelling of the initial EIS scenario considering a dredge volume of 50,000 m^3 showed that above-background TSS levels exceeded for 10% of the time were below 30 mg/L within 350 m of Boatshed Point, and that high velocity currents in that area cause rapid plume dispersion; 15 mg/L corresponds to the highest TSS quantity accepted in the Queensland Water Quality Guidelines for enclosed coastal waters as those in Port Curtis (DERM, 2009).

Habitats Other than Seagrass Beds

Indirect impacts of dredging on mangroves, saltpan, seagrass beds, reef and rock substrate, and intertidal zone were addressed in the EIS (Coffey Environments, 2012a). These were re-assessed with consideration to the revised dredging requirements. Seagrass beds are addressed separately given the high sensitivity of these areas (see below).

Across all main project areas, the impact and significance of indirect impact due to increased turbidity levels and sedimentation (pre-mitigation) was assessed in the EIS as **low** and **minor** for mangroves, seagrass beds and reef and rock substrate, as **medium** and **minor** for saltpan, and as **medium** and **moderate** for the intertidal zone. These were based on output models run by BMT WBM (BMT WBM, 2011) showing areas of maximum and 10% exceedence plume concentrations, and where rapid plume dispersion from the dredging source was assumed due to the high velocity currents in the area.

Seagrass Beds near Boatshed Point

Two seagrass bed areas are present approximately 400 m to the east of Boatshed Point, next to Garden Island, and occupy a combined area of 7.4 ha (see Figure 2). Although the proposed

volume of dredged material has increased from 50,000 m^3 to 313,000 m^3, model predictions of the spatial extent of the sediment plume generated at Boatshed Point by BMT WBM (BMT WBM, 2012) have not changed from the worst-case assessment reported in the EIS (Coffey Environments, 2012a), and thus remain valid for any tidal condition. Such conclusion is based on the facts that the proposed dredging technique or equipment has not changed (CSD), and that the larger volume of sediment released following the longer dredging campaign is unlikely to result in a greater overall impact due to the tendency of sediments to settle out, mix with natural suspended sediment and/or disperse during the neap tide periods.

Modelling of sediment plumes also predicted that the increase in the volume of material dredged for the construction of the Boatshed Point MOF will result in a proportionally longer exposure to sediment deposition that may cause disturbance to nearby habitats (BMT WBM, 2012). However, the total amount of sediments predicted to be deposited over the seagrass beds to the east of Boatshed Point following the continued 26-day effective dredging operation using the medium-sized CSD is very small (0.26 to 0.52 mm), and well below the deposition levels tolerated by seagrasses. In this context, a number of experimental and field studies have shown seagrasses to be highly resilient to sediment deposition, and having a number of adaptive mechanisms to tolerate smothering and survive burial. One of such studies was able to demonstrate that seagrasses are capable of surviving sediment deposition rates of 2-13 cm yr^{-1} through their vertical stem or rhizome growth (Vermaat et al., 1997), with horizontal rhizome growth comprising yet another adaptation that assists survival following burial. In general, seagrasses help to increase sedimentation rates and reduce re-suspension rates by trapping and stabilising sediments around the plants, thereby reducing turbidity and promoting further growth by reducing light attenuation in the water column (de Boer, 2007).

Based on the predicted spatial extent of the sediment plume generated at Boatshed Point, and the thin sediment layer expected to be deposited over the duration of the dredging campaign, the magnitude and significance of impact (pre-mitigation) due to sediment plumes over the two small seagrass beds to the east of the point continues to be assessed as **low** and **minor**, respectively, as reported in the EIS. The assessment of this impact as of **minor** significance is also supported by the fact that the combined area of these two seagrass beds (7.4 ha) represents 2.2% of the total of 3,403.8 ha of seagrasses estimated to be present within Port Curtis.

5.2 Impacts to Marine Fauna

The main direct impacts identified as being likely to affect marine fauna values comprise habitat disturbance from clearing, vessel interactions and underwater noise. Vessel interaction and underwater noise were addressed in the EIS (Coffey Environments, 2012a), and are re-assessed herein following changes to the project description. The main indirect impact identified as being likely affect fauna values is sedimentation and turbidity plumes from dredging works, and it was also assessed in the EIS.

A component of this technical study involved investigating the spatial and temporal use of the Port Curtis by marine megafauna (turtles, dugongs, dolphins), particularly in the Calliope River and adjacent areas. Sighting information supports an informed decision on potential impacts of dredging and use of the proposed channel.

5.2.1 Sightings of Megafauna

Numbers of sightings of megafauna within Port Curtis presented below are based on opportunistic observations recorded by a team from Coffey Geotechnics during unrelated geotechnical work. Sighting data is summarised in Table 9. Sightings comprise at least one animal, and

identifications were only made to group level. Areas of Port Curtis where sightings were reported are shown on Figure 7 and Figure 8, and include:

- Boatshed Point and Tide Island.
- Hamilton Point.
- Gladstone Marina and mouth of Auckland Inlet.
- Calliope River mouth to the area opposite the Gladstone Sewage Treatment Plant.

Table 9 Sightings of marine megafauna recorded by Coffey Geotechnics - June to October 2012

Group	Month					Total Type
	June	July	August	September	October	
Marine turtles	4	7	35	43	0	89
Dugong	3	4	3	1	0	11
Dolphins	-	22	8	51	4	85
Total sightings	7	33	46	95	4	**185**

Turtles

Six of the world's seven existing species of marine turtles are known to occur in Port Curtis. Three of these, namely green, flatback and loggerhead turtles, are known to nest in the Great Barrier Reef Marine Park and World Heritage Area, including areas south of the proposed LNG plant site and marine facilities. Species status and general ecology of all six marine turtles was addressed in detail in the EIS (Coffey Environments, 2012a); all six species were assigned **medium** to **high** sensitivity values depending on species. The potential impacts from project lighting are reported in separate specialist study (Pendoley, 2012).

Marine turtles are frequently sighted in Port Curtis areas scheduled for the construction of project infrastructure (see Figure 7 and Figure 8). Nearly 90 sightings have been recorded along the entrance to Calliope River and around Boatshed Point between June and October 2012, with a higher incidence during September (see Table 9). Identification of turtles to species level has not been possible. Sightings do not provide information as to turtle activity, numbers or swimming direction.

A total of 370 marine turtle strandings have been recorded in the Gladstone region (Rodds Bay Peninsula to Sandy Point, north of Yeppoon) between 1 January 2011 and 30 September 2012, with 292 verified mortalities (DEHP, 2011). The term 'stranding' generally applies to marine mammals (e.g., cetaceans and pinnipeds) rather than turtles, and can be defined as the situation when marine mammals either come ashore alive under unusual circumstances, are injured close to shore, or wash ashore dead, whether individually or in groups. In general, strandings of marine megafauna in the Gladstone region have increased significantly since recording began on 1 January 2011. Of the 292 turtle mortalities, 45 were identified as resulting from natural causes, 40 from interactions with vessels, 15 from fisheries-related activities, 2 from dredging operations, and the remaining 190 from unidentified causes.

Dugong

Species status and general ecology of dugong populations in Port Curtis was addressed in detail in the EIS (Coffey Environments, 2012a). Dugongs are listed as a protected migratory species under the EPBC Act and as a vulnerable species by IUCN (IUCN, 2012) and the Nature Conservation Act and, accordingly, assigned a **medium** sensitivity value within the project area.

Sightings of dugongs are infrequent within Port Curtis, and only 11 were recorded between June and October 2012 (see Table 9). All live dugongs sighted during that period have been sighted along the entrance channel to Calliope River. None were observed around Boatshed Point. There is abundant anecdotal evidence of dugong activity in waters around the Gladstone Power Station in the Calliope River. The dugongs are believed to be attracted to the warm water discharged via a subsurface outlet from the power station. There are also abundant seagrass beds in relatively close proximity (see Figure 4).

A total of 19 dugong strandings have been recorded in the Gladstone region between 1 January 2011 and 30 September 2012 (DEHP, 2011). Of the 19 dugongs, one was released alive, three were mortalities believed to have resulted from vessel interactions, disease and net entanglement, and 15 were mortalities from unidentified causes.

Cetaceans

A total of 13 species of cetaceans (porpoises, dolphins and whales) are likely to occur in waters of Port Curtis region and were addressed in detail in the EIS (Coffey Environments, 2012a). Ten of the species are listed as either ‘least concern’, ‘near threatened’ or ‘endangered’ under the IUCN Red List (IUCN, 2012), while the remaining three are regarded as ‘data deficient’.

The EIS focused on two species of dolphins, i.e., the Australian snubfin dolphin and the Indo-Pacific humpback dolphin. Both species occur in tropical and subtropical coastal and estuarine waters of Queensland, Northern Territory and Western Australia (Heithaus et al., 2002; Ross, 2006), and co-occur in areas with abundant resources and lower incidence of shared predators (Parra, 2006). Both species are considered as ‘near threatened’ under the IUCN Red List and are included in the EPBC list of migratory marine species, although they are not listed under the EPBC list of threatened fauna. Consequently, they were assigned a **medium** sensitivity value in the project area.

Snubfin dolphins generally inhabit shallow waters (1 to 2 m) closer to river mouths and seagrass beds. By contrast, humpback dolphins usually frequent deeper (2 to 5 m) water including dredged channels. Habitat segregation appears also to be related to the more aggressive nature of humpback dolphins, which may cause snubfin dolphins to prefer shallower waters (Parra, 2006). In terms of feeding behaviour, snubfin and humpback dolphins are opportunistic-generalist feeders, with humpback dolphins favouring a fish-dominant diet, and snubfin dolphins having a diet comprising of both fish and cephalapods (Parra and Jedensjö, 2009).

In Queensland both dolphin species are known to live in small, geographically isolated populations comprising relatively few adults; humpback dolphins have been observed in pods of up to 25 individuals whereas snubfin dolphins have been observed in pods of between 1 to 15 individuals, with a mean pod size of approximately 5 individuals (Bannister et al., 1996; Parra et al., 2005; Cagnazzi et al., 2011). Humpback dolphins may live more than 40 years (Bannister et al., 1996), whereas the maximum life span of snubfin dolphins has been estimated to be about 30 years (GBRMA, 2012).

Dolphins have been frequently sighted in the locations of proposed project infrastructure, particularly in the vicinity of the Gladstone marina and along the entrance to Calliope River (see Figure 7). A total of 85 sightings have been recorded around these areas between June and October 2012, with a significantly higher incidence during September (see Table 9). Identification of dolphins to species level has not been possible, and none of the sightings provides information as to their numbers, activity or swimming direction.

Surveys undertaken during February to April and June 2011 as part of the Western Basin Dredging and Disposal Project (GPC, 2011) recorded 124 and 57 dolphins, respectively, comprising humpback, snubfin and inshore bottlenose dolphins (*Tursiops aduncus*). Surveys were conducted both aerially and by boat. Humpback dolphins were the most frequently observed species, with 85 sightings documented having an average of 3.5 individuals per pod (GPC, 2011). Greater dolphin numbers were reported around Port Alma and Port Curtis during summer, with most pods sighted in the latter area. The surveys also reported sightings of 34 snubfin dolphins north of the Narrows around Port Alma and to the north of Curtis Island, with greater numbers during the June survey.

Visual and photo-identification surveys of snubfin and humpback dolphins in Port Curtis were conducted between January 2006 and September 2008 as part of a PhD research project (URS, 2009). Over the two year period, a total of 156 humpback dolphin pods were sighted, with pods averaging less than 4 individuals and a maximum of up to 15. However, no snubfin dolphins were observed during that period. The study suggests that approximately 65 humpback dolphins live in Port Curtis, though populations sizes from a 2-year mark-recapture analysis is deemed as inaccurate (URS, 2009).

Both the snubfin dolphin and humpback dolphin possess life-history traits that make them susceptible to several environmental pressures. These include slow growth rates, long life span, late maturation and low reproduction rates, philopatric behaviour (i.e., the behaviour of remaining in or returning to the individual's birthplace), low relative abundance, small pod sizes and small home ranges (GBRMPA, 2012). Both species are particularly vulnerable to human activities in coastal areas (Parra, 2005). Threatening processes associated with human activities in the Port Curtis region include: habitat degradation and loss due to increased coastal development, decline in water quality and productivity due to such factors as dredging activities, increase in underwater noise (impacting cetaceans that use echo-location), and boat strikes from increased boating activities (GBRMA, 2012).

The Gladstone Ports Corporation (GPC, 2011) employed abundance estimates of marine wildlife to determine the Potential Biological Removal, a method used to determine the maximum level of anthropogenic mortality that can occur in a population, while allowing the population to reach or maintain an optimal sustainable size (Wade, 1998). The mortality limits estimated for Australian snubfin and humpback dolphins within the Curtis Coast region indicate that a limit of less than 1 dolphin per subpopulation per year was unsustainable. Over a 4-month period in 2011, three humpback dolphin mortalities were recorded within Port Curtis, with at least one believed to be killed by vessel interaction (GPC, 2011). Between 2001 and 2010, prior to the commencement of the first LNG plant projects, 1 to 3 marine wildlife mortalities from boat strikes were recorded per year (D. Orgill, DNPRSR, 2012, pers. com.).

5.2.2 Direct Impacts

This sections reviews and re-assesses the key impacts likely to directly affect marine fauna in Port Curtis from the project, with consideration of the revised project description. The key direct impacts identified are habitat disturbance, vessel interactions and underwater noise.

Habitat Disturbance

The direct impact of habitat loss or disturbance on key marine fauna values for the Arrow LNG Plant Project was not assessed in the EIS (Coffey Environments, 2012a). The significance of direct impacts on marine fauna following the FEED process is assessed as **minor** to **moderate** depending on fauna group (Table 10) for two main reasons:

- The extent of proposed habitat loss is low and it does not affect seagrass beds.
- The extent of proposed habitat loss is highly localised and represents a lower source of risk compared with vessel interactions.

In addition to the above, the effect on marine fauna is considered generally un-measurable in practical terms. The precautionary principle is applied in determining impacts and recommending mitigations. Results from benthic survey work undertaken by a team from CQU during August 2012 suggests that dredging of the access channel to the Boatshed Point MOF, including dredging of the associated swing basin, is likely to result in the direct disturbance approximately 220 species of macro-invertebrates from 9 different phyla (Wilson, 2012). The most common organisms recorded across all sampled sites included the brittle stars (Phylum Echinodermata), gastropods (Phylum Mollusca) and polychaete worms (Phylum Annelida). The effect however will be localised and (with consideration of the aerial extent of this type of habitat within Port Curtis) this impact does not affect the **minor** to **moderate** significance rating.

Vessel Interactions

The magnitude of the impact of boat strike on marine mammals was assessed as **high** in the EIS, as any individuals killed or injured could affect the local populations and provoke increased public concern. The significance of this impact (pre-mitigation) was therefore **moderate** for dugong, marine turtles and cetaceans.

The risk of boat strike can be assumed to be primarily related to the frequency of marine vessels operating in the port and the speed at which those vessels travel. The revised project description indicates a net reduction in the number of vessel movements per day. The decrease in vessel movement frequency will decrease the risks and frequency of boat strike to marine fauna such as dugong, marine turtles and cetaceans. While the route between mainland and the integrated MOF personnel jetty at Boatshed Point does not traverse any seagrass beds, where species such as dugong or turtles may aggregate to feed, these and dolphin species are nevertheless expected to occur in or migrate past the vessel routes, including those around the Calliope River. The most significant component of the change in vessel movements is the reduction in the number of high speed people-moving ‘fast cat’ ferries from 1140 per month (EIS) to 480 per month. Where all other factors of vessel size, speed, travelling routes and passenger capacity remain the same, there is therefore a corresponding reduction in the likely numbers and frequencies of boat strike. The impact (pre-mitigation) will be no worse than previously assessed, and remains at **moderate** significance.

Underwater Noise

The magnitude of impact from underwater noise to marine fauna was assessed as **high** for pile driving, and as **medium** to **low** for other vessel sources. The corresponding significance ranged from **moderate** for fishes, marine turtles, dugong and dolphins to **minor** for other fauna.

The revised SEL contours for pile driving at Hamilton Point, Boatshed Point and the launch site 1 in the Calliope River are shown in Figure 9, Figure 10 and Figure 11, respectively. The 350 m contour does not intersect any seagrass beds, so underwater noise that would be considered likely to disturb marine fauna will not reach these habitat / foraging areas. The two seagrass beds present to the east of Boatshed Point are located approximately 20 m to 500 m outside of the 350 m contour and are, to some extent, shielded by Boatshed Point.

Although the seagrass beds are considered as a likely focus for feeding by dugongs and turtles, the anecdotal observational data indicates these animals could be present in most parts of Port

Curtis and any fauna moving around Port Curtis and up the Calliope River could potentially pass within 350 m of pile driving activities associated with the project.

The greatest risk of injury to marine fauna from underwater noise occurs if they are 'suddenly exposed' to high noise levels. However, there is a shortage of empirical data, particularly for dugongs and turtles, although the literature is generally consistent in describing a relatively narrow zone of potential injury risk. The zone of potential disturbance, i.e., the range for sounds that would be intense enough to cause disturbance or some form of behavioural shift, is much wider. The 350 m distance represents a conservative limit of potential injury, though sound levels beyond this distance may elicit some behavioural response or avoidance. As the three areas of pile driving are well separated, there is no overlap of the 350 m contours and limited risk of disturbance to feeding areas. Significance (pre-mitigation) remains as previously assessed. Further mitigation of the impacts of underwater noise may be achieved through the deployment of bubble curtains around pile driving activities. Bubble curtains serve to deter marine fauna from entering work areas (minimising the likelihood of exposure to surprise loud noises) and support the rapid attenuation of noise closer to the noise source.

The direct impacts due to habitat loss, vessel interaction and underwater noise, and indirect impacts are summarised below in Table 10.

Table 10 Significance of direct and indirect impacts on marine fauna values for the Arrow LNG Plant Project due to construction and vessel traffic

Value	Sensitivity	Impact	Magnitude/ Significance Reported in the EIS	Revised Magnitude/ Significance
Dugong	Medium	Direct: Vessel interaction.	High/Moderate	High/Moderate
		Direct: Underwater noise (pile driving).	High/Moderate	High/Moderate
		Direct: Habitat loss.	Not assessed	Low/Minor
		Indirect: Turbidity plumes from dredging.	Not assessed	Low/Minor
Marine turtles	Medium to High	Direct: Vessel interaction.	High/Moderate	High/Moderate
		Direct: Underwater noise (pile driving).	High/Moderate	High/Moderate
		Direct: Habitat loss.	Not assessed	Low/Minor
		Indirect: Turbidity plumes from dredging.	Not assessed	Low/Minor
Cetaceans	Medium	Direct: Vessel interaction.	High/Moderate	High/Moderate
		Direct: Underwater noise (pile driving).	High/Minor	High/Minor
		Direct: Habitat loss.	Not assessed	Low/Minor
		Indirect: Turbidity plumes from dredging.	Not assessed	Low/Minor

Table 10 Significance of direct and indirect impacts on marine fauna values for the Arrow LNG Plant Project due to construction and vessel traffic (cont'd)

Value	Sensitivity	Impact	Magnitude/ Significance Reported in the EIS	Revised Magnitude/ Significance
Invertebrates/ macrobenthos	Low	Direct: Underwater noise (pile driving).	High/Minor	High/Minor
		Direct: Habitat loss.	Not assessed	Medium/Minor
		Indirect: Turbidity plumes from dredging.	Not assessed	Medium/Minor
Plankton	Very low	Direct: Underwater noise (pile driving).	High/Negligible	High/Negligible
		Indirect: Turbidity plumes from dredging.	Not assessed	High/Negligible
Fish and shellfish	Medium	Direct: Underwater noise (pile driving).	High/Moderate	High/Moderate
		Direct: Habitat loss.	Not assessed	High/Moderate
		Indirect: Turbidity plumes from dredging.	Not assessed	High/Moderate

5.2.3 Indirect Impacts

The indirect impact of turbidity and sediment plumes from dredging on key marine fauna values for the Arrow LNG Plant Project was not assessed in the EIS (Coffey Environments, 2012a). The significance of indirect impacts on marine fauna following FEED is assessed as **minor** to **moderate** depending on fauna group (see Table 10). In the case of dugong, the sediment plume originating at Boatshed Point during dredging operations will have a low direct impact on sensitive receptors such as seagrass beds to the east of the area and accordingly the feeding areas of dugong will have limited impact. The main impact of turbidity and sediment loads over seagrass beds is light attenuation and burial through sediment deposition, both of which are factors well known to limit the growth and colonization of seagrass beds (de Boer, 2007). However, seagrasses possess a number of adaptations to enhance their likelihood of survival following burial, such as vertical and/or horizontal rhizome growth (Vermaat et al., 1997; de Boer, 2007). In general, any impact from sediment loads on seagrass beds will ultimately depend on factors such as amount of suspended sediment in the water column, particle size and sedimentation rates, as well as velocities of local tidal currents and distance between the dredging source and the receptor.

Simulations completed before changes in project description appropriately covered potential fate of sediment plumes originating from dredging operations at Calliope River, LNG jetty off North China Bay (i.e., Hamilton Point North) and Boatshed Point. The volume of in-situ material proposed to be dredged at the Calliope River site has remained unchanged from that specified in the EIS, i.e., 900,000 m^3. However, dredge volumes of in-situ material proposed for the construction and operation of the LNG jetty has increased by 11,000 m^3 from 120,000 m^3 to

131,000 m^3 whereas that planned for the Boatshed Point MOF has increased substantially from 50,000 m^3 to 313,000 m^3.

Simulation outputs from the LNG jetty site prior to increase in dredge volume associated with changes to the project description show that above-background TSS levels exceeded for 10% of the time are below 30 mg/L within 750 m of the dredge plume source. The adoption of a 30 mg/L criterion is arbitrary, and it is well above 5 mg/L TSS that is comparable to natural water column concentrations in the study area during neap tides (BMT WBM, 2011). Simulation runs before changes to the project description also indicate that the above-background TSS concentrations on the tidal flats to the north of Hamilton Point are significantly elevated for prolonged periods. These findings are unlikely to differ from those described in the EIS based on the initial dredge volume of 120,000 m^3. Therefore, the significance of indirect impact assessed in this technical study due to increased turbidity levels and sedimentation on mangrove areas to the north of the site proposed for the LNG jetty was assessed as **low** as in the EIS (Coffey Environments, 2012a).

Simulations run by BMT WBM for the EIS for the Boatshed Point site show that above-background TSS levels exceeded for 10% of the time are below 30 mg/L within 350 m of the dredge plume source, with plumes subjected to rapid dispersal by the high velocity currents in the area. Following FEED-based changes in project description, however, dredge volumes of in-situ material have increased from 50,000 m^3 to 313,000 m^3 and the MOF site at Boatshed Point. This substantial increase in dredge volume from the EIS will result in the longer duration of non-stop dredging operations, i.e., from approximately 4.2 days in the EIS to approximately 26 effective dredging days based on the same medium-sized cutter suction dredge (CSD) capable of a 500 m^3 h^{-1} production rate.

Based on BMT WBM modelling, simulation outputs using the original 50,000 m^3 dredge volume to be removed at Boatshed Point remain valid for predicting the extent of the sediment dredge plume for any tidal condition for the revised 313,000 m^3 volume (BMT WBM, 2012). Thus, considering model outputs, the significance of impact (pre-mitigation) due to sediment plumes over the two relatively small seagrass beds to the east of Boatshed Point was assessed as **minor** as in the EIS. The **minor** impact significance is further highlighted by the fact that the combined area of two seagrass beds to the east of Boatshed Point (7.4 ha) accounts for 2.2% of the total area of seagrasses estimated to be present within Port Curtis (3403.8 ha).

Turbidity and sediment plumes can affect benthic (flora and fauna at or associated with the seabed), pelagic (free swimming fauna in the water column) and planktonic (microscopic and/or macroscopic flora and fauna drifting with water currents) communities in a number of ways, though such effects in aquatic environments are generally considered difficult to quantify. In the Port Curtis area, however, it could be assumed that the effect from turbidity and sediment plumes on marine flora and fauna may be localized and generally short-lived, as a result of the rapid plume dispersion from the point source by the local high-velocity tidal currents (BMT WBM, 2012).

6. MANAGEMENT MEASURES

This section addresses the avoidance, mitigation, and management measures that are recommended to minimise impacts on the marine ecological values of Port Curtis.

6.1 Management and Mitigation Commitments

Eighteen key management and mitigation commitments were described in the EIS (Coffey Environments, 2012b) and are listed below. It is understood that these commitments will continue to be applied by Arrow as measures undertaken to minimise impacts on the marine ecology of Port Curtis through the development of the project. Additional measures arising from the changes in project description are listed in Section 6.2.2.

6.1.1 Commitments reported in the EIS

The original commitments to be implemented by Arrow Energy to manage impacts on the marine and estuarine ecological values of Port Curtis are listed in Table 11.

Table 11 Commitments relating to marine and estuarine ecology of Port Curtis

No.	Commitment
C19.01	Develop a construction management plan will be completed, which contains specific mitigation measures, performance indicators and management actions required to reduce impacts to the marine and estuarine ecological values.
C19.02	Establish a marine offsets strategy for the project to compensate for the loss of marine and estuarine habitat as a result of the project.
	Implement measures to reduce the impacts of light from the LNG plant and ancillary facilities including:
C17.16	• Shield/direct the light source onto work areas.
C17.17	• Use long-wavelength lights, including use of red, orange or yellow lights.
C17.18	• Lower the height of the light sources.
C17.19	• Avoid routine planned maintenance flaring at night during sensitive turtle-reproductive periods.
C15.02	Develop a dredge management plan that considers the appropriate water and sediment monitoring data (e.g., current WBDD Project data) and will include:
C15.03	• Requirements for monitoring of water quality.
C15.04	• Actions to be taken to minimise impacts of dredging on sensitive areas should water quality monitoring data show performance criteria are exceeded. Finalise specific actions in the dredge management plan.
C19.03	Comply with environmental and legal criteria of the Queensland Government environmental offsets policy as the overarching framework for a specific-issue offset policy.
C19.04	Contribute to the development of a Port of Gladstone shipping activity strategy and management plan. Comply with applicable speed limits for the Port of Gladstone-Rodds Bay Zone B dugong protection area, as detailed in the management plan.
C19.05	Where feasible install propeller guards (or equivalent) on high-speed vessels to reduce the impact of injury in the event of vessel strikes.
C19.06	Implement soft-start procedures where a sequential build-up of warning pulses will be carried out prior to commencement of full-power pile-driving activities.
C19.07	Undertake fauna observations prior to and during pile-driving and dredging activities to check for the presence of marine turtles, dugongs and cetaceans. Should fauna be spotted within the area of the works, implement procedures to minimise impact, such as reverting to soft-start piling or stopping temporarily to allow animals to move away from the area.

Table 11 Commitments relating to marine and estuarine ecology of Port Curtis (cont'd)

No.	Commitment
C19.08	Keep dredging activities within the identified dredge footprint area.
C19.09	Where practical maintain a fauna-spotting function during dredging activities. Do not commence dredging if turtles, crocodiles and/or marine mammals are spotted within the area of dredging, and stop temporarily if fauna is spotted within the area of the dredge head. In both cases, resumption of dredging must wait until fauna has moved away.
C19.10	Project vessels servicing the LNG plant that originate from overseas ports must comply with Commonwealth and local government ballast water management systems and implement Australian Quarantine and Inspection Service hull hygiene measures.
C19.11	All project vessels must comply with all applicable maritime law, especially when passing through the GBRMP. Project vessels will traverse the marine park via designated navigation routes with pilotage as required within port boundaries.

6.1.2 Recommended Additional Commitments

In addition to the existing commitments that will minimise impacts on the marine ecology of Port Curtis, additional mitigations are recommended. These are discussed as follows.

- Evaluate the use of bubble curtains for each method of piling, and deploy where they are demonstrated to be effective in aiding the rapid attenuation of underwater noise and deterring marine fauna from approaching, or remaining at, pile driving sites.
- Establish a system for the recording of opportunistic observation of marine megafauna (turtles, crocodiles, dugong and cetaceans) spotted during marine operations such as dredging, pile driving and marine transport including where these activities occur within the Calliope River.

In addition to commitments made in the EIS and recommended above, specific measures applying to the environmental values affected by project description changes are summarised below.

6.1.3 Habitat Disturbance

There are no practicable methods to mitigate the loss of marine and estuarine habitats that will result from the removal of habitat areas within the project footprint. The direct net loss of habitats from project's footprint is to be addressed the offsets proposal specified under mitigation measures C19.02 and 19.03.

Indirect impacts on sensitive habitats, primarily from the dredging related plumes, are addressed by mitigation measures C15.02, C15.03 and C15.04.

6.1.4 Marine Fauna

No mitigation measures are specifically applicable to addressing the impacts to marine fauna from the direct /indirect loss of habitats. The impact significance assessments are low in all cases. The implementation of water quality monitoring in accordance with commitment C15.04 will facilitate management of dredging operations in a manner that is reactive to excessive turbidity. The offset strategies C19.02 and 19.03 compensate for impacts to these environmental values.

6.1.5 Vessel Interactions

The mitigation measures proposed in the EIS reflect the necessity for a holistic approach to mitigating the risk to marine fauna posed by vessel strikes. Reduced speed, fixed navigational routes and vigilance to the presence of marine turtles, dugongs and cetaceans are the most effective mitigation against potential vessel strikes. Additional measures, such as propeller

guards, propulsion systems and changes in hull design, can reduce the severity of injury from accidental collision. These measures will only be effective if they are implemented as part of an overall management strategy for the Port of Gladstone, as detailed in mitigation measures C19.04 and C19.05.

Restricting vessel speed will be the most effective mitigation limiting the impact of vessel interactions with marine megafauna. The establishment of a system to record opportunistic observations of megafauna during marine operations will support development of greater understanding of the spatial and temporal use of Port Curtis and the Calliope River by megafauna. Information gained through recording opportunistic observations of marine megafauna may influence future mitigations associated with avoiding vessel interactions.

6.1.6 Underwater Noise

Mitigation measures C19.05, C19.06 and C19.07 address impacts from underwater noise from pile driving.

Further observation of the use of the Calliope River, Boatshed Point and North China Bay by marine megafauna will facilitate the reactive management of pile driving operations, e.g., avoidance of star-tup when marine fauna are spotted. Soft start procedures will allow marine fauna to move away from work areas before they are exposed to surprising loud noises. The deployment of bubble curtains around pile driving operations will deter marine fauna from entering work areas and will ensure rapid attenuation of noise away from the source.

The noise characteristics from project-related vessels such as ferries, dredges, tugs, supply vessels and LNG carriers are likely to be similar to other port shipping. Port shipping is already extensive and the continued observance of marine fauna in the Port indicates a degree of resilience to boating noise. There are no practical mechanisms for reduction of noise from these vessels.

Apart from ferries, most vessels are slow moving and the noise generated from such vessels can be detected and avoided by animals before any physical injury from sound occurs. Sound propagation characteristics from dredging modelled by SVT Engineering Consultants (2010) engaged by Queensland Curtis Liquefied Natural Gas (QCLNG) Project showed noise levels to be much lower than those produced by pile driving. It is not practical or necessary for an observation program to be implemented other than that proposed to mitigate impacts from pile driving.

6.1.7 Dredging

Impacts of dredging related plumes are addressed by mitigation measures C15.02, C15.03 and C15.04, and fauna interactions by measures C19.07, C19.08 and C19.09.

6.2 Residual Impacts

A summary of residual impacts after the application of the mitigation measures is presented in Table 12. In all cases except those associated with turbidity impacts on seagrass beds, the residual impacts are no greater than those assessed in the EIS (Coffey Environments, 2012a). This is logical as the net area of habitat loss is lower and the number of vessel movements has reduced. In the case of underwater noise, no change is expected but the proposed additional mitigation measures will further limit the impacts.

In those specific cases where no assessment was previously made because of low impacts, significances remain **low** or **minor** and are considered as ‘no change’.

In terms of dredging, the significance of impact at Boatshed Point post-mitigation is assessed as **minor**, i.e., no changes in worst-case scenario assessed in the EIS. This assessment is predominantly based on the modelling outputs prepared by BMT WBM that indicates that the spatial extent of the potential dredge plume generated at Boatshed Point following the proposed dredging of 313,000 m^3 (BMT WBM, 2011 and 2012) will be no greater than that associated with the dredging of 50,000 m^3 assessed in the EIS despite the longer dredging duration.

Table 12 Post-mitigation magnitude and significance of direct and indirect impacts on marine habitats and fauna values for the Arrow LNG Plant Project due to construction and vessel traffic

Value	Sensitivity	Impact	Residual Impacts from EIS		Mitigation Following FEED	Residual Impact Following FEED		Change to Worst Case Scenario?
			Magnitude	Significance		Magnitude	Significance	
Mangroves	Medium	Direct: Loss and disturbance of marine and estuarine habitat (clearing)	Very low	Negligible	Establish a marine offsets strategy for the project to compensate for the loss of marine and estuarine habitat as a result of the project [C19.02]. Comply with environmental and legal criteria of the Queensland Government environmental offsets policy as the overarching framework for a specific-issue offset policy [C19.03].	Very low	Negligible	No
		Indirect: Turbidity plumes from dredging	Very low	Negligible	Develop a dredge management plan that considers the appropriate water and sediment monitoring data (e.g., current WBDD Project data) and will include [C15.02]: • Requirements for monitoring of water quality [C15.03]. • Actions to be taken to minimise impacts of dredging on sensitive areas should water quality monitoring data show performance criteria are exceeded. Finalise specific actions in the dredge management plan [C15.04].	Very low	Negligible	No
Saltpan vegetation	Medium	Direct: Loss and disturbance of marine and estuarine habitat (clearing)	Very low	Negligible	Establish a marine offsets strategy for the project to compensate for the loss of marine and estuarine habitat as a result of the project [C19.02]. Comply with environmental and legal criteria of the Queensland Government environmental offsets policy as the overarching framework for a specific-issue offset policy [C19.03].	Very low	Negligible	No

Table 12 Post-mitigation magnitude and significance of direct and indirect impacts on marine habitats and fauna values for the Arrow LNG Plant Project due to construction and vessel traffic (cont'd)

Value	Sensitivity	Impact	Residual Impacts from EIS		Mitigation Following FEED	Residual Impact Following FEED		Change to Worst Case Scenario?
			Magnitude	Significance		Magnitude	Significance	
Seagrass beds	High	Direct: Loss and disturbance of marine and estuarine habitat (clearing)	Very low	Negligible	Establish a marine offsets strategy for the project to compensate for the loss of marine and estuarine habitat as a result of the project [C19.02]. Comply with environmental and legal criteria of the Queensland Government environmental offsets policy as the overarching framework for a specific-issue offset policy [C19.03]	Very low	Negligible	No
		Indirect: Turbidity plumes from dredging	Low	Minor	Develop a dredge management plan that considers the appropriate water and sediment monitoring data (e.g., current WBDD Project data) and will include [C15.02]: • Requirements for monitoring of water quality [C15.03]. • Actions to be taken to minimise impacts of dredging on sensitive areas should water quality monitoring data show performance criteria are exceeded. Finalise specific actions in the dredge management plan [C15.04]. Keep dredging activities within the identified dredge footprint area [C19.08].	Low	Minor	No
Intertidal zone	High	Direct: Loss and disturbance of marine and estuarine habitat (clearing)	Low	Minor	Establish a marine offsets strategy for the project to compensate for the loss of marine and estuarine habitat as a result of the project [C19.02]. Comply with environmental and legal criteria of the Queensland Government environmental offsets policy as the overarching framework for a specific-issue offset policy [C19.03]	Low	Minor	No

Table 12 Post-mitigation magnitude and significance of direct and indirect impacts on marine habitats and fauna values for the Arrow LNG Plant Project due to construction and vessel traffic (cont'd)

Value	Sensitivity	Impact	Residual Impacts from EIS		Mitigation Following FEED	Residual Impact Following FEED		Change to Worst Case Scenario?
			Magnitude	Significance		Magnitude	Significance	
		Indirect: Turbidity plumes from dredging.	Very Low	Negligible	Develop a dredge management plan that considers the appropriate water and sediment monitoring data (e.g., current WBDD Project data) and will include [C15.02]: • Requirements for monitoring of water quality [C15.03]. • Actions to be taken to minimise impacts of dredging on sensitive areas should water quality monitoring data show performance criteria are exceeded. Finalise specific actions in the dredge management plan [C15.04].	Very Low	Negligible	No
Reef and rock substrate	Medium	Direct: Loss and disturbance of marine and estuarine habitat (clearing)	Very low	Negligible	Establish a marine offsets strategy for the project to compensate for the loss of marine and estuarine habitat as a result of the project [C19.02]. Comply with environmental and legal criteria of the Queensland Government environmental offsets policy as the overarching framework for a specific-issue offset policy [C19.03]	Very low	Negligible	No
		Indirect: Turbidity plumes from dredging.	Very low	Negligible	Develop a dredge management plan that considers the appropriate water and sediment monitoring data (e.g., current WBDD Project data) and will include [C15.02]: • Requirements for monitoring of water quality [C15.03]. • Actions to be taken to minimise impacts of dredging on sensitive areas should water quality monitoring data show performance criteria are exceeded. Finalise specific actions in the dredge management plan [C15.04].	Very low	Negligible	No

Table 12 Post-mitigation magnitude and significance of direct and indirect impacts on marine habitats and fauna values for the Arrow LNG Plant Project due to construction and vessel traffic (cont'd)

Value	Sensitivity	Impact	Residual Impacts from EIS		Mitigation Following FEED	Residual Impact Following FEED		Change to Worst Case Scenario?
			Magnitude	Significance		Magnitude	Significance	
Dugong	Medium	Direct: Vessel interaction	High	Moderate	Contribute to the development of a Port of Gladstone shipping activity strategy and management plan. Comply with applicable speed limits for the Port of Gladstone-Rodds Bay Zone B dugong protection area, as detailed in the management plan [C19.04]. Where feasible install propeller guards (or equivalent) on high-speed vessels to reduce the impact of injury in the event of vessel strike [C19.05]. Establish a system for the recording of opportunistic observation of marine megafauna (turtles, crocodiles, dugong and cetaceans) spotted during marine operations such as dredging, pile driving and marine transport including where these activities occur within the Calliope River.	Low	Minor	Yes (improved)
		Direct: Underwater noise (pile driving)	Medium	Minor	Implement soft-start procedures where a sequential build-up of warning pulses will be carried out prior to commencement of full-power pile-driving activities [19.06]. Implementation of bubble curtain. Undertake fauna observations prior to and during pile-driving and dredging activities to check for the presence of marine turtles, dugongs and cetaceans. Should fauna be spotted within the area of the works, implement procedures to minimise impact, such as reverting to soft-start piling or stopping temporarily to allow animals to move away from the area [C19.09].	Low	Minor	No

Table 12 Post-mitigation magnitude and significance of direct and indirect impacts on marine habitats and fauna values for the Arrow LNG Plant Project due to construction and vessel traffic (cont'd)

Value	Sensitivity	Impact	Residual Impacts from EIS		Mitigation Following FEED	Residual Impact Following FEED		Change to Worst Case Scenario?
			Magnitude	Significance		Magnitude	Significance	
Dugong (cont'd)		Direct: Habitat loss	N/A	N/A	Establish a marine offsets strategy for the project to compensate for the loss of marine and estuarine habitat as a result of the project [C19.02]. Comply with environmental and legal criteria of the Queensland Government environmental offsets policy as the overarching framework for a specific-issue offset policy [C19.03].	Low	Negligible	N/A
		Indirect: Turbidity plumes from dredging	N/A	N/A	Develop a dredge management plan that considers the appropriate water and sediment monitoring data (e.g., current WBDD Project data) and will include [C15.02]: • Requirements for monitoring of water quality [C15.03]. • Actions to be taken to minimise impacts of dredging on sensitive areas should water quality monitoring data show performance criteria are exceeded. Finalise specific actions in the dredge management plan [C15.04].	Medium	Minor	N/A

Table 12 Post-mitigation magnitude and significance of direct and indirect impacts on marine habitats and fauna values for the Arrow LNG Plant Project due to construction and vessel traffic (cont'd)

Value	Sensitivity	Impact	Residual Impacts from EIS		Mitigation Following FEED	Residual Impact Following FEED		Change to Worst Case Scenario?
			Magnitude	Significance		Magnitude	Significance	
Marine turtles	Medium to High	Direct: Vessel interaction	High	Moderate	Contribute to the development of a Port of Gladstone shipping activity strategy and management plan. Comply with applicable speed limits for the Port of Gladstone-Rodds Bay Zone B dugong protection area, as detailed in the management plan [C19.04]. Where feasible install propeller guards (or equivalent) on high-speed vessels to reduce the impact of injury in the event of boat strike [C19.05]. Establish a system for the recording of opportunistic observation of marine megafauna (turtles, crocodiles, dugong and cetaceans) spotted during marine operations such as dredging, pile driving and marine transport including where these activities occur within the Calliope River.	Low	Minor	Yes (improved)
		Direct: Underwater noise (pile driving)	Medium	Moderate	Implement soft-start procedures where a sequential build-up of warning pulses will be carried out prior to commencement of full-power pile-driving activities [19.06]. Bubble curtain mitigation. Undertake fauna observations prior to and during pile-driving and dredging activities to check for the presence of marine turtles, dugongs and cetaceans. Should fauna be spotted within the area of the works, implement procedures to minimise impact, such as reverting to soft-start piling or stopping temporarily to allow animals to move away from the area [C19.09].	Low	Minor	Yes (improved)

Table 12 Post-mitigation magnitude and significance of direct and indirect impacts on marine habitats and fauna values for the Arrow LNG Plant Project due to construction and vessel traffic (cont'd)

Value	Sensitivity	Impact	Residual Impacts from EIS		Mitigation Following FEED	Residual Impact Following FEED		Change to Worst Case Scenario?
			Magnitude	Significance		Magnitude	Significance	
		Direct: Habitat loss	N/A	N/A	Establish a marine offsets strategy for the project to compensate for the loss of marine and estuarine habitat as a result of the project [C19.02]. Comply with environmental and legal criteria of the Queensland Government environmental offsets policy as the overarching framework for a specific-issue offset policy [C19.03].	Low	Negligible	N/A
		Indirect: Turbidity plumes from dredging.	N/A	N/A	Develop a dredge management plan that considers the appropriate water and sediment monitoring data (e.g., current WBDD Project data) and will include [C15.02]: • Requirements for monitoring of water quality [C15.03]. • Actions to be taken to minimise impacts of dredging on sensitive areas should water quality monitoring data show performance criteria are exceeded. Finalise specific actions in the dredge management plan [C15.04].	Medium	Minor / Moderate	N/A
Cetaceans	Medium	Direct: Vessel interaction	High	Moderate	Contribute to the development of a Port of Gladstone shipping activity strategy and management plan. Comply with applicable speed limits for the Port of Gladstone-Rodds Bay Zone B dugong protection area, as detailed in the management plan [C19.04]. Where feasible install propeller guards (or equivalent) on high-speed vessels to reduce the impact of injury in the event of vessel strike [C19.05].	Low	Minor	Yes (improved)

Table 12 Post-mitigation magnitude and significance of direct and indirect impacts on marine habitats and fauna values for the Arrow LNG Plant Project due to construction and vessel traffic (cont'd)

Value	Sensitivity	Impact	Residual Impacts from EIS		Mitigation Following FEED	Residual Impact Following FEED		Change to Worst Case Scenario?
			Magnitude	Significance		Magnitude	Significance	
	Medium	Direct: Vessel interaction	High	Moderate	Establish a system for the recording of opportunistic observation of marine megafauna (turtles, crocodiles, dugong and cetaceans) spotted during marine operations such as dredging, pile driving and marine transport including where these activities occur within the Calliope River.	Low	Minor	Yes (improved)
		Direct: Underwater noise (pile driving)	N/A	N/A	Implement soft-start procedures where a sequential build-up of warning pulses will be carried out prior to commencement of full-power pile-driving activities [19.06]. Implementation of bubble curtain Undertake fauna observations prior to and during pile-driving and dredging activities to check for the presence of marine turtles, dugongs and cetaceans. Should fauna be spotted within the area of the works, implement procedures to minimise impact, such as reverting to soft-start piling or stopping temporarily to allow animals to move away from the area [C19.09].	Low	Minor	N/A
		Direct: Habitat loss	N/A	N/A	Establish a marine offsets strategy for the project to compensate for the loss of marine and estuarine habitat as a result of the project [C19.02]. Comply with environmental and legal criteria of the Queensland Government environmental offsets policy as the overarching framework for a specific-issue offset policy [C19.03]	Low	Negligible	N/A

Table 12 Post-mitigation magnitude and significance of direct and indirect impacts on marine habitats and fauna values for the Arrow LNG Plant Project due to construction and vessel traffic (cont'd)

Value	Sensitivity	Impact	Residual Impacts from EIS		Mitigation Following FEED	Residual Impact Following FEED		Change to Worst Case Scenario?
			Magnitude	Significance		Magnitude	Significance	
Cetaceans (cont'd)		Indirect: Turbidity plumes from dredging.	N/A	N/A	Develop a dredge management plan that considers the appropriate water and sediment monitoring data (e.g., current WBDD Project data) and will include [C15.02]: • Requirements for monitoring of water quality [C15.03]. • Actions to be taken to minimise impacts of dredging on sensitive areas should water quality monitoring data show performance criteria are exceeded. Finalise specific actions in the dredge management plan [C15.04].	Medium	Minor	N/A
Invertebrates/ macrobenthos	Low	Direct: Underwater noise (pile driving)	Medium	Negligible	Implement soft-start procedures where a sequential build-up of warning pulses will be carried out prior to commencement of full-power pile-driving activities [19.06]. Implementation of bubble curtain	Low	Negligible	No
		Direct: Habitat loss	N/A	N/A	Establish a marine offsets strategy for the project to compensate for the loss of marine and estuarine habitat as a result of the project [C19.02]. Comply with environmental and legal criteria of the Queensland Government environmental offsets policy as the overarching framework for a specific-issue offset policy [C19.03]	Low	Negligible	N/A
		Indirect: Turbidity plumes from dredging.	N/A	N/A	Develop a dredge management plan that considers the appropriate water and sediment monitoring data (e.g., current WBDD Project data) and will include [C15.02]: • Requirements for monitoring of water quality [C15.03].	Medium	Negligible	N/A

Table 12 Post-mitigation magnitude and significance of direct and indirect impacts on marine habitats and fauna values for the Arrow LNG Plant Project due to construction and vessel traffic (cont'd)

Value	Sensitivity	Impact	Residual Impacts from EIS		Mitigation Following FEED	Residual Impact Following FEED		Change to Worst Case Scenario?
			Magnitude	Significance		Magnitude	Significance	
Invertebrates/ macrobenthos (cont'd)					• Actions to be taken to minimise impacts of dredging on sensitive areas should water quality monitoring data show performance criteria are exceeded. Finalise specific actions in the dredge management plan [C15.04].			
Plankton	Very low	Direct: Underwater noise (pile driving)	Medium	Negligible	Implement soft-start procedures where a sequential build-up of warning pulses will be carried out prior to commencement of full-power pile-driving activities [19.06]. Bubble curtain mitigation.	Low	Negligible	No
		Indirect: Turbidity plumes from dredging.	N/A	N/A	Develop a dredge management plan that considers the appropriate water and sediment monitoring data (e.g., current WBDD Project data) and will include [C15.02]: • Requirements for monitoring of water quality [C15.03]. • Actions to be taken to minimise impacts of dredging on sensitive areas should water quality monitoring data show performance criteria are exceeded. Finalise specific actions in the dredge management plan [C15.04].	Medium	Negligible	N/A

Table 12 Post-mitigation magnitude and significance of direct and indirect impacts on marine habitats and fauna values for the Arrow LNG Plant Project due to construction and vessel traffic (cont'd)

Value	Sensitivity	Impact	Residual Impacts from EIS		Mitigation Following FEED	Residual Impact Following FEED		Change to Worst Case Scenario?
			Magnitude	Significance		Magnitude	Significance	
Fish and shellfish	Medium	Direct: Underwater noise (pile driving)	Medium	Minor	Implement soft-start procedures where a sequential build-up of warning pulses will be carried out prior to commencement of full-power pile-driving activities [19.06]. Bubble curtain mitigation. Undertake fauna observations prior to and during pile-driving and dredging activities to check for the presence of marine turtles, dugongs and cetaceans. Should fauna be spotted within the area of the works, implement procedures to minimise impact, such as reverting to soft-start piling or stopping temporarily to allow animals to move away from the area [C19.09].	Low	Minor	No
		Direct: Habitat loss	N/A	N/A	Establish a marine offsets strategy for the project to compensate for the loss of marine and estuarine habitat as a result of the project [C19.02]. Comply with environmental and legal criteria of the Queensland Government environmental offsets policy as the overarching framework for a specific-issue offset policy [C19.03].	Low	Negligible	N/A
		Indirect: Turbidity plumes from dredging.	N/A	N/A	Develop a dredge management plan that considers the appropriate water and sediment monitoring data (e.g., current WBDD Project data) and will include [C15.02]: • Requirements for monitoring of water quality [C15.03]. • Actions to be taken to minimise impacts of dredging on sensitive areas should water quality monitoring data show performance criteria are exceeded. Finalise specific actions in the dredge management plan [C15.04].	Medium	Minor	N/A

7. CUMULATIVE IMPACTS

Following the changes to project description, revised assessments of cumulative impacts to the marine environment apply to:

- Direct habitat loss.
- Dredging (sediment plumes).
- Vessel interactions.
- Underwater noise.

7.1 Direct Habitat Loss

The percentage contribution to the total habitat loss estimated from the other LNG projects is provided in Table 13. The overall area of habitat disturbance after changes in project description has decreased for mangroves (5.80 ha to 5.1 ha), saltpan (58.20 ha to 55.01 ha) and reef and rock substrate (0.3 ha to 0.14 ha), but has slightly increased for the intertidal zone (5.31 ha to 5.64 ha). The overall cumulative area to be impacted by the total removal or disturbance of marine habitats following the works proposed for the Arrow LNG Plant project amounts to 0.5% of the total area of Port Curtis.

7.2 Dredging

It is anticipated that dredging associated with other LNG plant developments will be complete before the commencement of the project. This would mean that the short term impacts of concurrent dredging activities (i.e., increased persistent turbid plumes that could join up) will be unlikely to occur. Assessment of the impact of dredging indicates that the dynamic marine environment of Port Curtis ensures that impacts are predominantly short term. Project dredging activities that could take place concurrently with other dredging activities in Port Curtis are limited to Stage 2 of the Western Basin Dredging and Disposal (WBDD) Project dredging at Laird Point. The dredge management plan for the Arrow LNG Plant will consider the locations and timing of all dredging activities in Port Curtis (project and non-project). Subject to scheduling, additional modelling studies may be necessary to determine the likely extent of any dredge plume interaction and associated cumulative impacts.

7.3 Vessel Interactions

It was originally calculated in the EIS that the project would contribute 79.1% of total vessel movements within Port Curtis during construction, and 7.42% of total vessel movements during operation. This was based on Arrow's contribution of 1687 of a total of 2132 trips for construction and 17 of 229 trips for operation. Based on data provided in other proponents impact assessment, and the revised project description, Arrow's representative contribution to vessel movements reduces by approximately 10% for construction but an increase in the contribution to harbour traffic is reflected for operations.

To a great extent, the data used to complete the cumulative assessment in the EIS reflects potential understatement of actual harbour traffic. Arrow's project is of a similar size and scope to the other proponent's LNG developments. Arrow's refined vessel movements indicate an overall reduction during both construction and operations phases from those reported in the EIS. Accordingly Arrow's contribution to the cumulative impacts of vessel interactions is also anticipated to reduce from that reported in the EIS. Arrow's proposed vessel movements are well

Table 13 Estimated cumulative area of marine habitat to be directly or indirectly impacted

Project	Area of Environmental Habitat to be Directly or Indirectly Impacted (ha)												
	Mangroves*		Saltpan Vegetation*		Seagrass Beds		Reef and Rock Substrate		Intertidal Zone		Fish/Intertidal Habitat†		Total
	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	
Wiggins Island Coal											398		398
WBDD Project					258.8	1,406			643.2	4,010			6,318
Fishermans Landing	1.45		0.45		89.18				84.35	461.51	395	3,728	4,759.94
APLNG Project	2.4		31.7										34.1
GLNG Project	4.42	28.09	25.26	18.44		34							110.21
QCLNG Project		9.4			2.00								11.40
Gladstone LNG (Fishermans Landing)													
Hummock Hill	0.86		0.04										0.90
Subtotal	9.13	37.49	57.45	18.44	349.98	1,440	0	0	727.55	4,471.51	793	3728	11,632.60
Arrow LNG Plant (EIS)	5.8	0	58.2	0	0	0	0.30	<0.1	5.31	0			69.55
Arrow LNG Plant (after FEED)	5.10		55.01**		0		0.14		5.64				65.89
Cumulative Area (Total)	14.23	37.49	112.46	18.44	349.98	1,440	0.14	<0.1	733.19	4,471.51	793	3,728	11,698.54
Arrow LNG Plant (% of total area)	35.8	0.0	48.9	0.0	0.0	0.0	100.0	0.0	0.8	0.0	0.0	0.0	0.5

* Components of or regional ecosystems listed under the Vegetation Management Regulation. (Regional Ecosystems determined by DERM).

** Saltpan vegetation.

† Fish and intertidal habitats sourced from proponent documents are not separated into individual environmental values. Areas provided are assumed to be inclusive of mangroves, saltmarsh and seagrass beds.

8. CONCLUSIONS

This technical study summarises the findings of supplementary work undertaken by Coffey Environments on behalf of Arrow Energy to validate impacts and evaluate any changes to the worst-case impact scenario assessed in the Environmental Impact Statement (EIS) (Coffey Environments, 2012a). Specifically, the study focuses on assessing the impact on the marine ecology of the Port Curtis area following changes to the project description through the completion of FEED. The predominant changes relate to infrastructure and dredging footprints of the two main components of the Arrow LNG Plant project; and changes to the marine logistics and transport system. The study also reviews ancillary information and responds to public submissions made on the EIS during the review process.

The main findings of this study with reference to the study tasks listed in section 2.5 are summarised below.

8.1 Changes to Marine Facilities

1. *Evaluate impacts to marine habitats in the Port Curtis area as a result of changes to the project description concerning infrastructure, including the spatial extent to which marine habitats would need to be further cleared as a result of project description changes*

The intertidal zone comprises the only area of marine habitat proposed to be further cleared as a result of the changes to the project description following FEED. Total areas to be cleared for remaining marine habitats have decreased for mangroves, saltpan, and reef and rock substrate, whereas no seagrass beds are proposed to be removed.

The maximum direct loss of **intertidal zone** following changes to project description has been re-assessed to be 5.64 ha, corresponding to an increase in 0.34 ha from the estimated 5.31 ha specified in the EIS. This area is to be removed during construction of the LNG jetty in North China Bay and the access channel to Boatshed Point.

The maximum direct loss of **mangroves** following changes to project description has been re-assessed to be 5.10 ha, corresponding to a reduction in 0.70 ha from the estimated 5.80 ha specified in the EIS. Over half of the mangrove area to be removed is attributed to the construction of the LNG jetty in North China Bay as well as the launch site 1 and haul road in Calliope River.

The maximum direct loss of **saltpan** following changes to project description has been re-assessed to be 55.01 ha, corresponding to a reduction in 3.19 ha from the estimated 58.20 ha specified in the EIS. Nearly all of the area to be removed is attributed to the construction of the Curtis Island infrastructure as well as the launch site 1 and haul road in Calliope River.

The maximum direct loss of **reef and rock substrate** following changes to project description has been re-assessed to be 0.14 ha, corresponding to a reduction in 0.16 ha from the estimated 0.3 ha specified in the EIS. All the area of reef and rock substrate is to be removed from the launch site 4N.

2. *Evaluate the extent to which ecological values of mangroves and/or other marine habitats may be altered as a result of clearings.*

Ecological values of marine habitats will be minimally affected since the extent of disturbance through clearings following proposed changes in project description is less than 1% of the

respective available habitats for mangrove, intertidal zone, and rock and reef substrate; no seagrass beds will be directly removed. The overall revised area of intertidal zone to be removed (5.64 ha) represents less than 0.8% of the total intertidal zone estimated for the Arrow LNG Plant project in Port Curtis.

2.1. *If additional clearing of mangroves and other marine habitats is found to be significant, describe and assess the extent to which such changes are likely to affect macro-invertebrate and fish habitats and respective populations.*

There is no proposed additional clearing of areas of mangroves, saltpan or reef and rock substrate around any of the four main project sites following the FEED-based changes in project description. However, an additional 0.34 ha of intertidal zone has been scheduled for clearing around the LNG jetty in North China Bay and the access channel to Boatshed Point. Given the extensive nature of this marine habitat in Port Curtis, the magnitude of impact of direct loss of the additional 0.34 ha of intertidal zone continues to be **low** as specified in the EIS based on an original proposed loss of 5.64 ha. The removal of the total revised 5.64 ha of intertidal zone is therefore assessed as unlikely to affect habitats of juvenile and adult fishes except for localised, possible short-lived effects on flora and fauna which would be almost impossible to quantify.

The removal of the total revised 5.64 ha of intertidal zone is assessed as unlikely to affect local macro-invertebrate and fish assemblages except for localised, possible short-lived effects on flora and fauna which would be almost impossible to quantify.

2.2. *In the event that clearing of mangrove areas increases significantly as a result of changes to the project description, determine whether such clearing alters the magnitude of impact on mangrove values from the EIS rating (i.e., **low**) and therefore the significance of impact, and provide reasons for such change.*

The overall total mangrove area to be cleared as a result of the FEED-derived changes to the project description is set to decrease from 5.80 ha to 5.10 ha. Therefore, the magnitude of impact on mangrove values will remain as **low**, as assessed in the EIS (Coffey Environments, 2012a).

2.3. *In the event that clearing of saltpan vegetation areas increases significantly as a result of changes in project description, determine whether such clearing alters the magnitude of impact on the saltpan value from the EIS rating (i.e., **medium**) and therefore the significance of impact, and provide reasons for such change.*

The overall total saltpan area to be cleared as a result of the FEED-derived changes to the project description is set to decrease from 58.20 ha to 55.01 ha. Therefore, the magnitude of impact on saltpan value will remain regionally as **medium**, as assessed the EIS (Coffey Environments, 2012a).

3. Evaluate revised results of modelling runs of sediment plumes and coastal processes (BMT WBM, 2011 and BMT WBM, 2012) likely to result from the additional dredging works planned for the project area, and assess to what extent changes, if any, model outputs are likely to alter the original assessment of marine habitats at and around the project area.

Simulation outputs produced by BMT WBM investigated maximum and 10% exceedence plume concentrations from dredging operations using a medium-sized CSD at four project locations: Calliope River (site 1; locations A and B); Boatshed Point (site 3); Hamilton Point South (site 4); and Hamilton Point North (site 5; location of revised LNG plant and jetty). The plume resulting from dredging operations at launch site 4N (site 2) was not modelled given the very small dredge volume required (i.e., 2,500 m^3).

Simulations completed before changes in project description appropriately covered potential fate of sediment plumes originating from dredging operations at Calliope River, LNG jetty off North China Bay (i.e., Hamilton Point North) and Boatshed Point. The volume of in-situ material proposed to be dredged at the Calliope River site has remained unchanged from that specified in the EIS, i.e., 900,000 m^3. However, dredge volumes of in-situ material proposed for the construction and operation of the LNG jetty has increased by 11,000 m^3 from 120,000 m^3 to 131,000 m^3 whereas that planned for the Boatshed Point MOF has increased substantially from 50,000 m^3 to 313,000 m^3.

Simulation outputs from the LNG jetty site prior to increase in dredge volume associated with changes to the project description show that above-background TSS levels exceeded for 10% of the time are below 30 mg/L within 750 m of the dredge plume source. Simulation runs before changes to the project description also indicate that the above-background TSS concentrations on the tidal flats to the north of Hamilton Point are significantly elevated for prolonged periods. These findings are unlikely to differ from those described in the EIS based on the initial dredging volume of 120,000 m^3. Therefore, the significance of indirect impact assessed in this technical study due to increased turbidity levels and sedimentation on mangrove areas to the north of the site proposed for the LNG jetty was assessed as **low** as in the EIS (Coffey Environments, 2012a).

Simulations run by BMT WBM for the EIS for the Boatshed Point site show that above-background TSS levels exceeded for 10% of the time are below 30 mg/L within 350 m of the dredge plume source, with plumes subjected to rapid dispersal by the high velocity currents in the area. Following FEED-based changes in project description, however, dredge volumes of in-situ material have increased from 50,000 m^3 to 313,000 m^3 and the MOF site at Boatshed Point. This substantial increase in dredge volume from the EIS will result in the longer duration of non-stop dredging operations, i.e., from approximately 4.2 days in the EIS to 26 days based on the same medium-sized cutter suction dredge (CSD) capable of a 500 $m^3\ h^{-1}$ production rate.

Based on BMT WBM modelling, simulation outputs using the original 50,000 m^3 dredge volume to be removed at Boatshed Point remain valid for predicting the extent of the sediment dredge plume for any tidal condition for the revised 313,000 m^3 volume (BMT WBM, 2012). Thus, considering model outputs, the significance of impact (pre-mitigation) due to sediment plumes over the two relatively small seagrass beds to the east of Boatshed Point was assessed as **minor** as in the EIS. The **minor** impact significance is further highlighted by the fact that the combined area of two seagrass beds to the east of Boatshed Point (7.4 ha) accounts for 2.2% of the total area of seagrasses estimated to be present within Port Curtis (3403.8 ha).

4. *Identify locations for confirmatory field studies of the ecological values of sites where limited or no information exists, and the new areas of impact resulting from changes in the project design.*

Field surveys in the Arrow LNG project area have been conducted by teams from the Gladstone-based Central Queensland University (CQU) in May 2010 and February 2011 (Alquezar, 2011), and more recently on 21-30 August 2012 (Wilson, 2012). The latter surveys provided additional information on the mangrove communities and intertidal benthic ecology of the Calliope River, as well as infauna benthic ecology around the proposed LNG jetty site, the Boatshed Point MOF and associated swing basin and access channel, and the outfall site at the point (Wilson, 2012). Besides mangrove assessment and general field observations (e.g., marine turtles, dugongs and cetaceans), field sampling included macro-invertebrate and fish assemblages, benthic communities and sediment grain size analysis.

While the data collected for mangroves and benthic communities was generally adequate for the Calliope River and the area around Boatshed Point, additional data on fish diversity and abundance could be further obtained at the two sites by developing a sampling program that incorporates increased sampling effort both spatially and temporally. Identical sampling efforts for fish as well as benthic communities should be implemented around the Arrow LNG site as well as the areas immediately to the north of the Arrow LNG site and to the east of Boatshed Point. There are currently no data available on either benthic communities or fish assemblages for these areas as ecological sampling was omitted during surveys. Additional confirmatory studies are therefore recommended to be carried out at those areas, particularly areas of high sensitivity such as the seagrass beds to the east of Boatshed Point.

5. *Regarding changes in the marine logistics and transport system in the Port Curtis, describe changes to ferry movements and other vessels planned for the project in relation to potential cumulative impacts, and re-assess to what extent the significance of impact has changed as a result of increased ferry movements in the area.*

The review of changes to the marine logistics and transport system indicated a significant reduction in the numbers of high speed people-moving cat movements from 1140 per month (EIS) to 480 per month. However, factors such as vessel size, speed, travelling routes and passenger capacity remain unchanged.

The EIS estimated that the Arrow LNG Plant project would contribute 79.1% and 7.42% of total vessel movements within Port Curtis during construction and operations, respectively, based on Arrow's contribution of 1687 out of 2132 trips for construction and 17 out of 229 trips for operation. Revised figures following changes to the transport system indicates that Arrow's percentage contribution to vessel movements will reduce by approximately 10% during construction but increase during operations. Percentage contribution to vessel traffic is affected by the apparent understatement of vessel traffic for other projects. Overall Arrow's vessel movements reduce in comparison to those presented in the EIS so the percentage contribution of vessel interactions is also anticipated to reduce to that previously reported.

8.2 Review of Ancillary Information

The only ancillary information identified in the EIS and needed reviewing in relation to changes to the project description comprises potential impacts of maintenance dredging. This issue is addressed below.

Maintenance dredging will be undertaken by the GPC as part of a port service agreement, and will be required to maintain the access channel to launch site 1 in Calliope River, the Arrow LNG swing basin, and the access channel to the Boatshed Point MOF and associated swing basin. Modelling of silt deposition rates undertaken by BMT WBM suggest that there is a clear potential for fine sediment siltation in sub-sections of the LNG swing basin in North China Bay following dredging, due to the low-energy hydrodynamic regime characteristic of the area (BMT WBM, 2011).

Increased suspended fine sediments derived from maintenance dredging of the Arrow LNG swing basin are likely to be transported northwards with the prevailing tidal currents, and potentially impact intertidal mudflats and mangrove areas along the northern North China Bay. Potential impacts can be addressed through the development of a maintenance dredging management plan that considers the appropriate water and sediment monitoring data [C15.02], particularly at site adjacent to areas with sensitive receptors such as the seagrass beds to the east of Boatshed Point. Such plan will require developing a of water quality monitoring program [C15.03], including

trigger points as well as a definitive actions (e.g., temporary slowdown or stoppage of dredging) to minimise impacts of dredging on sensitive areas if water quality water triggers are exceeded following monitoring.

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10. ACRONYMNS AND GLOSSARY

10.1 Acronyms

dB re 1 µPa	decibel; measure of sound level underwater (re 1 µPa: water standard).
CSD	cutter suction dredge.
CUQ	Central University of Queensland (Gladstone).
DEEDI	Department of Employment, Economic Development and Innovation.
DEHP	Department of Environment and Heritage Protection.
DERM	Department of Environment and Resource Management.
DEWHA	Department of Environment, Water, Heritage and the Arts.
DPI	Department of Primary Industry.
DSEWPC	Department of Sustainability, Environment, Water, Population and Communities.
EIS	Environmental Impact Statement.
EPBC	Environment Protection and Biodiversity Conservation.
FEED	front end engineering design.
GBRMP	Great Barrier Reef Marine Park.
GBRMPA	Great Barrier Reef Marine Park Authority.
GBRWHA	Great Barrier Reef World Heritage Area.
GLNG	Gladstone Liquefied Natural Gas.
GPC	Gladstone Port Corporation.
IUCN	International Union for Conservation of Nature.
LCT	Landing craft type vessel.
LOLO	lift-on lift-off vessel.
LNG	Liquefied Natural Gas.
LPG	Liquefied Petroleum Gas.
$m^3 h^{-1}$	metres cubic per hour.
$Mg L^{-1}$	milligrams per litre.
MOF	Material Offloading Facility.
QCLNG	Queensland Curtis Liquefied Natural Gas.
QFS	Queensland Fisheries Service.
RORO	Roll on roll off vessel.

RoPAX	Roll on roll off passenger vessel.
SDPWO	State Development and Public Works Organisation.
TSS	Total Suspended Solids.
WBDD	Western Basin Dredging and Disposal.

10.2 Glossary

Benthic Pertaining to the seabed or river bed.

Benthic community Living organism (aquatic flora and fauna) attached to, living on, in or near the seabed or river bed; bottom-associated.

Benthic habitat The seabed or river bed zone inhabited by aquatic flora and fauna.

Ebb tide Outgoing or receding tide.

Flood tide Incoming tide.

Intertidal zone The shore zone between the highest and lowest tides; also referred to as the littoral zone; the alternately submerged/exposed zone below the mean higher high water mark.

Macrobenthos Those animals that are larger than a mesh opening of 0.5 mm; include clams, oysters, annelid worms, barnacles and amphipods.

Neap tide Tide of minimum amplitude occurring at the time of first and last quarter of the moon, when the difference between high and low water is less than at any other part of the month.

Pelagic Pertaining to the water column of the sea; organisms found in open coastal to oceanic waters (e.g., squid, fishes, turtles, marine mammals).

Planktonic Pertaining to plankton, i.e., living micro- to macroscopic plants and animals that are unable to maintain their position or distribution independent of the movement of water.

Spring tide Tide of maximum amplitude occurring at the time of full and new moon.

Subtidal zone The zone extending from the lower margin of the intertidal zone to the outer edge of the continental shelf at a depth of 200 m; also referred to as the sublittoral zone; the entirely submerged zone deeper than the mean lower low water mark.

Turbidity Degree of opaqueness of water column due to suspended matter.