8 MARINE ECOLOGY

8.1 RESPONSE TO SUBMISSIONS ON DRAFT EIS

Submissions relating to Queensland Curtis LNG (QCLNG) Project LNG Component marine ecology (and in particular draft environmental impact statement *Volume 5, Chapter 8: Marine Ecology Quality*, and *Appendix 5.9 - LNG Facility – Marine Water Quality Assessment*) as described and assessed in the draft EIS are summarised in *Table 5.8.1* below.

Table 5.8.1 Response to Submissions on Draft EIS

Issue Raised	QCLNG Response	Relevant Submission(s)
Submissions were made concerning possible environmental impacts associated with the cumulative impacts from multiple dredging operations.	Cumulative impacts of dredging operations is addressed in Gladstone Ports Corporation's (GPC) Western Basin Dredge Disposal Project (WBDD) environmental impact statement. The assessment of dredging currently proposed by QGC is addressed in *Volume 5, Chapter 8,* and *Volume 6.*	22, 24, 26, 30, 32, 33, 40
The risk and threat to the nesting and foraging turtle population is significant and lighting associated with construction may result in much higher predation than normal. Consideration must be given to keeping lighting to a minimum during nesting and hatching times.	The significance of impacts to turtles, including cumulative impacts, were discussed in draft EIS *Volume 5, Section 8.4.1.4.* Further discussion is included in this *Section 8.16* of this volume.	38
Further information relating to sewage treatment on Curtis Island should be provided; specifically, there should be: • greater emphasis on sewage effluent reduction and reuse on site • tertiary treatment for sewage effluent prior to discharge from the site • additional assessment of potential impacts arising from site effluent discharges, including cumulative impacts associated with discharges from other potential projects on Curtis Island • consideration of combining the sewage and reverse osmosis concentrate discharge streams • modelling of persistent contaminant concentrations.	QGC is investigating treating sewage effluent to a standard meeting the definition of tertiary treated sewage specified by sub-regulation 135 (3) of *The Great Barrier Reef Marine Park Regulations 1983 (Statutory Rules 1983 No. 262 as amended)* prior to discharge from the LNG Facility site. As the Project proceeds through detailed design, further consideration will be given to options other than discharge including irrigation within the boundary of the LNG Facility site. Further assessment of potential impacts arising from discharge of treated sewage and reverse osmosis (RO) brines is provided in *Volume 5, Section 8.7* of this supplementary EIS and *Appendix 5.9* of the draft EIS.	32

Issue Raised	QCLNG Response	Relevant Submission(s)
Further information should be provided on mitigation measures to address impacts arising from the increased volume of vessel traffic.	The numbers of ship and other vessel movements are described in the draft EIS. Additional comments are made below on revised vessel numbers arising from recently completed studies on recreational vessels and a more detailed analysis of commercial vessel movements; see *Section 8.4* of this volume. Impacts to fauna are discussed in *Sections 8.15-8.17* of this volume. Management measures for avoiding and minimising impact to fauna are described in *Volume 5, Section 8.4.1.2* of the draft EIS.	38
Long-term research and monitoring to assess the status of key marine species in the area should be carried out prior to consideration of the EIS by government.	The status of key marine species is discussed in the draft EIS *Volume 5*. Further information is provided in these *Sections 8.15-8.17* of this chapter.	26

8.2 SUMMARY OF ADDITIONAL INPUT TO BASELINE AND UPDATE OF IMPACTS

A summary of revisions to the Marine Ecology chapter, made subsequent to the draft EIS is provided in *Table 5.8.2* below. These revisions have been made as a result of the completion of additional reporting and modelling. This provides a summary of key changes only.

Table 5.8.2 Revisions to Marine Ecology

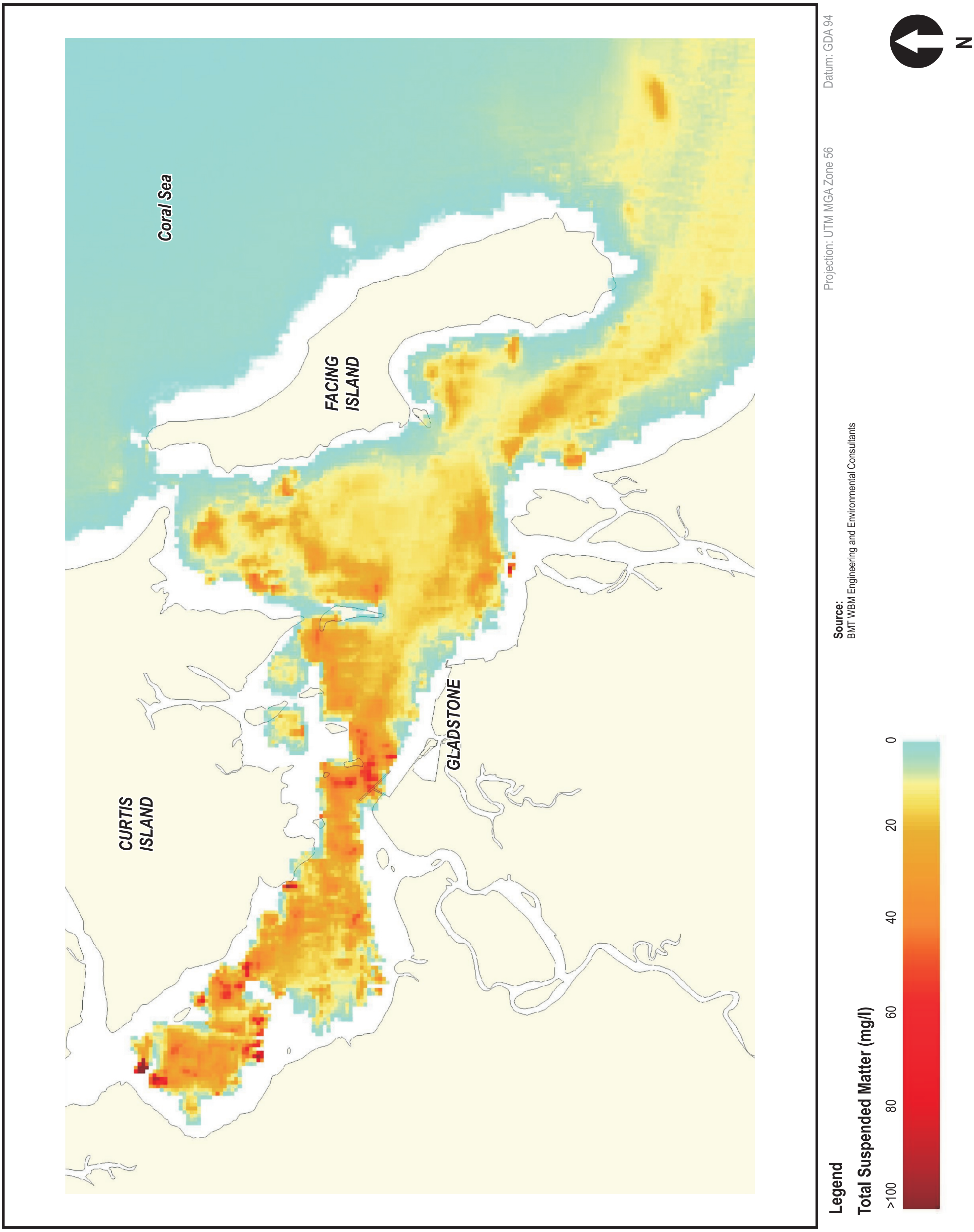
Project Element	Draft EIS element	Section of Draft EIS	Supplementary EIS Revision	Factors Affected by Change	Section Revised
Water quality	Water quality description of turbidity.	*Vol 5, Ch 8.3*	Further information is available from completed remote sensing analysis regarding long-term observations of the concentration of suspended solids in the water column.	• Marine ecology • Environmental assessment of dredging	*Volume 5, Chapter 8* *Volume 6*
Seagrass and algal communities	Description of seagrass and algal communities.	*Vol 5, Ch 8.6*	Further information is available from recently completed studies regarding the seagrass and algal communities in Port Curtis.	• Marine ecology • Environmental assessment of dredging	*Volume 5. Chapter 8* *Volume 6*
Reef habitats	Description of coral communities.	*Vol 5, Ch 8.7*	Further information is available from recently completed studies regarding the coral communities in Port Curtis.	• Marine ecology • Environmental assessment of dredging	*Volume 5, Chapter 8* *Volume 6*
Marine mammals	Description of marine mammal species, abundance and distribution.	*Vol 5, Ch 8.9*	Data presented has been revised based on further research regarding the marine mammals that may occur in Port Curtis.	• Marine ecology • Environmental assessment of dredging	*Volume 5, Chapter 8* *Volume 6*
Hydrodynamic regime	Hydrodynamic modelling presented for various development scenarios to examine effect of permanent infrastructure on hydrodynamics of Port Curtis.	*Vol 5, Ch 8.5.1*	Hydrodynamic modelling has been revised to update the existing bathymetry to incorporate recent dredging and to optimise the mesh for accurate representation of the developed scenario features for Queensland Curtis LNG (QCLNG) and the cumulative dredging projected by all Western Basin LNG proponents as an input to marine simulations.	• Marine ecology • Coastal environment • Environmental assessment of dredging	*Volume 5, Chapter 8* *Volume 5, Chapter 11* *Volume 6*

Project Element	Draft EIS element	Section of Draft EIS	Supplementary EIS Revision	Factors Affected by Change	Section Revised
Underwater noise	Predictions of underwater noise likely to occur, based on literature review, were presented and formed basis of impact assessment.	*Vol 5, Ch 8.4*	Underwater noise has recently been modelled for: • piling at the jetty • piling at the Materials Offloading Facility (MOF) • cutter suction dredge operation at the Swing Basin • LNG tanker at the Swing Basin • tugboat at the Swing Basin.	• Marine ecology • Environmental assessment of dredging	*Volume 5, Chapter 8* *Volume 6*
Sewage treatment	Sewage discharge to marine environment.	*Vol 5, Ch 8.5.2*	Further information presented to describe the near-field and far-field mixing of the discharge and the potential for overlapping plumes from adjacent proposed developments.	• Marine ecology	*Volume 5, Chapter 8*
Recreational boating	Vessel movements were estimated for larger commercial vessels only.	*Vol 5, Ch 8.5*	Further information is available from recently completed studies regarding recreational and commercial vessel movements in Port Curtis.	• Marine ecology	*Volume 5, Chapter 8*

8.3 REMOTELY SENSED WATER QUALITY INFORMATION

Historical data on total suspended solids (TSS) in surface waters was determined based on archived MODIS satellite data at a resolution of 250 m, for an area of interest situated in Port Curtis and offshore near Gladstone, Queensland[1]. Data was analysed and used to derive representative periodical TSS data for the region. In the case of this report, the relevant data was from February to April, as this was the period adopted for potential dredge impact assessments. The resultant data set is presented in *Figure 5.8.1.*

1 BMT WBM (2009). Baseline Sediment Data Provision and Interpretation Port Curtis



QUEENSLAND CURTIS LNG
A BG Group business

Project	Queensland Curtis LNG Project		
Client	QGC - A BG Group business		
Drawn	JB	sEIS Volume 5	Figure S5.8.1
Approved	RS	File No:	0086165b_SUP_CDR002_S5.8.1
Date	13/01/10	Revision	0

Title **Derived Mean Total Suspended Solid in Surface Waters February - April 2007-2009**

ERM
Environmental Resources Management Australia Pty Ltd

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8.4 *VESSEL MOVEMENTS IN PORT CURTIS*

The draft EIS identified approximate frequencies for the movement of larger commercial vessels within the Port of Gladstone. More recent studies[2] have shed light on the broader context of vessel movements, including breakdowns by types of vessel, vessel speed, navigation zones and daily patterns of use.

Key findings of relevance to assessing interactions between marine fauna and vessels include the following:

- There are approximately 150, 70 and 35 vessel movements per day for Auckland Point, the Calliope River and The Narrows, respectively.
- These numbers increase by about 30 per cent to 40 per cent on “fair weather” days.

Other findings specific to The Narrows include:

- For weekdays and weekends, respectively, 42 per cent and 70 per cent of the vessels transiting The Narrows do so while travelling at higher than planing speeds.
- Between 41 per cent and 54 per cent of these vessels run down the Curtis Island coastline, passing between the QCLNG site and the Passage Islands.
- There is no significant “within-day” pattern to boating levels – hourly activity levels are similar for all daylight hours.

Even if all vessels counted in The Narrows or Calliope zones had originated in the Auckland Point area, the implied annual number of vessel movements will be significantly greater than 55,000, for the following reasons:

- “Fair weather” days were excluded from the averages, while being recognised as having 30 to 40 per cent greater vessel movements.
- The results are only for 12 hours of daylight, and therefore exclude night-time and dawn/dusk operations.

On this basis it is reasonable to assume that vessel movements within the Port of Gladstone fall in the range of 70,000 to 80,000 movements per year. QCLNG vessel movements are therefore expected to produce an increase in movements of approximately 12 per cent at the peak construction period, and by less than 5 per cent.during LNG Facility operations.

The impact assessment of the risk of vessel collisions with marine fauna (*Vol 5, Ch 8.15, 8.16* and *8.17*) takes account of the many thousands of high-speed vessel movements occurring each year within the portions of Port Curtis that will be used by QCLNG Project vessel traffic.

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2 Alquezar, R. (2009). Maritime Harbor Movements of Port Curtis 2009. A report to BG-LNG. Centre for Environmental Management, CQUniversity Australia, Gladstone, Queensland.

8.5 UNDERWATER NOISE

An underwater noise model was developed to determine expected impacts on marine fauna from construction activities and LNG tanker operations.

Underwater noise models use bathymetric data, geoacoustic information and oceanographic parameters as inputs to produce estimates of the acoustic field at any depth and distance from the source.

The following section briefly summarises potential impacts of underwater noise on marine fauna based on noise modelling studies conducted for the EIS. The Underwater Noise Assessment Report is presented in *Appendix 5.3.*

Five noise sources were included in the assessment: an LNG tanker, tug boat, cutter suction dredge (CSD), and two pile-driving operations. The seabed parameters entered into the model were based on estimates obtained from core samples and seismic surveys.

Zones of interest for the underwater noise assessment include the following:

- *area of possible physical injury*: possibility that the animal may suffer physical injury and/or permanent hearing damage
- *area of possible avoidance*: possibility that the animal may experience masking and/or behavioural change and/or avoid the area.

Turtles

Little is known about the source levels and associated frequencies that cause physical injury to a turtle. For the purpose of this assessment, frequencies are based on empirically-based safety ranges from studies which have examined the effects of explosions on turtles. The estimated received levels at which there is a possibility of physical injury or behavioural effect for turtles is detailed in *Table 5.8.3* below.

In general, it is estimated that a pressure value of 222 dB re 1µPa should not be exceeded for adult turtles to avoid physical injury. Hatchlings were evaluated using the same auditory sensory (sound) values for fish, at 198 dB re 1µPa^{2}s.

Table 5.8.3 Estimated received levels at which there is a possibility of physical injury or behavioural effect for turtles.

Effect	Possible physical injury	Possible avoidance
Peak pressure	222 dB re 1µPa	175 dB re 1µPa
Sound level (SEL)	198 dB re 1µPa	No Data Available

Cetaceans and Dugongs

Values which were used to assess the possibility of physical injury or behavioural effect of underwater noise on cetaceans and dugongs are provided in *Table 5.8.4*. They are based on the criteria recommended by

Southall *et al*[3] and the *Environment Protection and Biodiversity Conservation (EPBC) Act* Policy Statement 2.1[4].

It is estimated that to avoid physical injury to dugongs and cetaceans a pressure value of 222 dB re 1μPa and sound level of 198 dB re 1μPa^2.s should not be exceeded.

Table 5.8.4 Estimated received levels at which there is a possibility of physical injury or behavioural effect for cetaceans and dugongs

Effect	Possible physical injury	Possible avoidance
Peak pressure	230 dB re 1μPa	224 dB re 1μPa
SEL	198 dB re 1μPa^2.s	160 dB re 1μPa^2.s

8.5.1 Noise Modelling Outcomes for Marine Fauna

A full list of figures and tables from the underwater assessment is provided in *Appendix 5.3*. Results were generated with octave band transmission loss characteristics between 250 Hz and 8 kHz. The modelled received depth is 2 m below the surface.

In general, results indicate that sound levels (SEL) from all sources will be below 198 dB re 1μPa2.s at 2 m below the surface. That is, below the level at which possible injury to dugongs, cetaceans, and turtles might occur. The largest sound levels will come from piling of the jetty and the MOF and these are highlighted in *Figures 5.8.2* and *5.8.3* below.

3 Southall BL, Bowles AE, Ellison WT, Finneran JT, Gentry RL, Greene Jr CR, Kastak D, Ketten DR, Miller JH, Nachtigall PE, Richardson WJ, Thomas JA and Tyack PL. (2007). Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations Aquatic Mammals, Volume 33, Number 4, 2007, ISSN 0167-5427

4 DEWHA (2008). EPBC Act Policy Statement- Interaction between offshore seismic exploration and whales. http://www.environment.gov.au/epbc/publications/pubs/seismic-whales.pdf accessed December 2009.

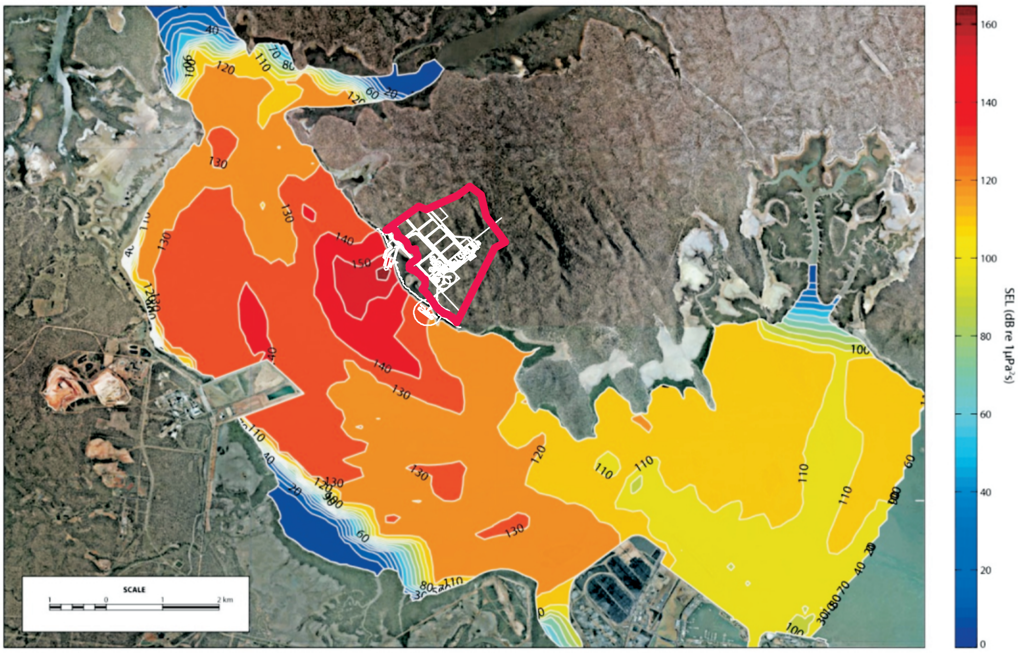


Figure 5.8.2 MOF Piling Operation SEL Noise Contours 2m below surface

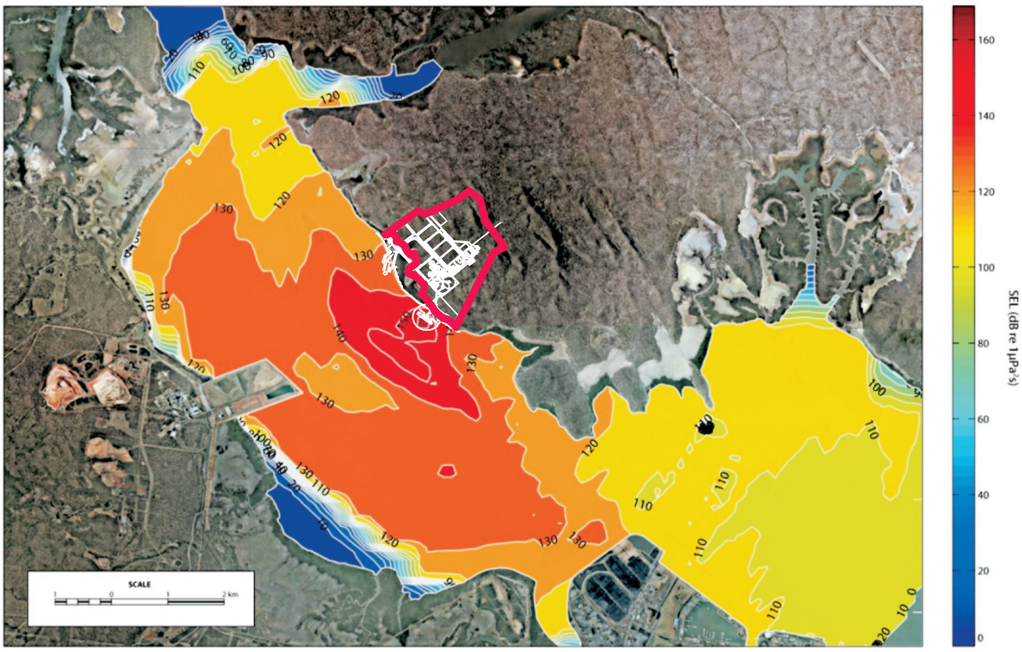


Figure 5.8.3 Jetty Piling Operation SEL Noise Contours 2m below surface

Legend

Proposed QCLNG Site Boundary

Source:
Bureau of Meteorology as referenced in Katestone Environmental (2009)
Air Quality Impact Assessment of the QCLNG Project, Gladstone, Queensland.
Unpublished report for BG International Limited, Report Reference KE0810645 Air, June 2009

QUEENSLAND CURTIS LNG A BG Group business	Project: **Queensland Curtis LNG Project**		Title: **MOF and Jetty Piling Operation SEL Noise Contours 2m below surface**
	Client: **QGC - A BG Group business**		
ERM Environmental Resources Management Australia Pty Ltd	Drawn: JB	**sEIS Volume 5 Figure S5.8.2 & S5.8.3**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved: RS	File No: 0086165b_SUP_CDR003_S5.8.2_S5.8.3	
	Date: 29/12/09	Revision: 0	

Table 5.8.5 summarises the maximum distances between noise sources and the zones of avoidance and possible physical injury for turtles, cetaceans and dugongs.

As shown, the furthest distance from piling of the jetty and MOF to the zone of possible physical injury is 55 m for turtles and 22 m for dugongs and cetaceans. The maximum distances between noise sources and the zone of avoidance for turtles range from 160 m to 1,500 m, while for cetaceans and dugongs, distances range of 5 m to 205 m.

The relatively short ranges can be attributed to the fact that the jetty and MOF pile-driving activities take place in very shallow water (approximately 5 m), which implies that only a small portion of the pile is in the water during the pile driving and that most of the acoustic energy is transferred into the seabed.

Table 5.8.5 Furthest distance to zones of avoidance and possible physical injury

Animal Class	Source(s)	Furthest distance from source to zone of avoidance	Furthest distance from source to zone of possible physical injury	Furthest distance from source to EPBC Act policy level (160 dB re 1μPa^2.s)
Turtles	Piling at jetty	1,500 m	55 m	N/A
	Piling at MOF	1,200 m	55 m	N/A
	Cutter suction dredge	55 m	-	N/A
	Tug boat	-	-	N/A
	LNG tanker and tug boat	160 m	-	N/A
Cetaceans and dugongs	Piling at jetty	205 m	22 m	205 m
	Piling at MOF	160 m	22 m	160 m
	Cutter suction dredge	5 m	-	5 m
	Tug	-	-	-
	LNG tanker and tug	-	-	-

8.5.2 Mitigation

8.5.2.1 Piling

The potential for exposure of marine mammals and turtles to harmful levels of underwater noise from piling activity is expected to be minor as the levels likely to cause harm are very localised and the species which may be impacted are likely to be transitory.

The proposed management measures to mitigate potential impacts, in line with best practice, are:

- Prior to commencement of activity carry out observation for marine mammals and turtles within exclusion zone of 250 m for turtles and marine mammals for 20 minutes.
- If no turtles or marine mammals are observed within the zone, commence a slow start to operations gradually building to full activity over a 15-minute period to allow any unseen turtles or marine mammals time to exit the zone.
- During operations maintain a watch for turtles and marine mammals; if they approach within 250 m operators are to be advised and to prepare to stop activities if animals continue to approach within 100 m.
- If a procedural stoppage is required then recommencement follows the steps from point 1 above.
- For night-time operations, if there have been no procedurally required stoppages during the preceding day, no observation requirements are imposed.

Any marine mammals and turtles observed will be recorded and reported.

8.5.2.2 Dredging and Vessel Operations

The potential for exposure of marine mammals and turtles to harmful levels of underwater noise from dredging activity or vessel activity is expected to be minor as the noise source will only cause a very localised avoidance zone. Other than the proposed management measures referred to above, no mitigation measures are considered to be required for dredging to further reduce the risk from noise to marine fauna.

8.6 HYDRODYNAMIC IMPACTS

Changes in bathymetry that will result from dredging and sea disposal of dredged material have the potential to alter the hydrodynamic regime in Port Curtis, including tidal circulation patterns and flushing characteristics. Detailed numerical modelling of Port Curtis hydrodynamics and coastal processes has been undertaken (BMT WBM, 2009; *Appendix 5.4*) to assess such potential impacts of the proposed dredging and reclamation works, in terms of both individual project impacts and cumulative impacts.

Tidal hydrodynamics and flushing were modelled with the existing TUFLOW-FV two-dimensional numerical model (BMT WBM, 2009), refined to reflect recent changes in bathymetry due to dredging, optimised for the identified scenarios being assessed, and extended to incorporate the GPC offshore spoil ground. The model has been calibrated and validated with extensive existing data. Five scenarios were modelled for the purpose of assessing hydrodynamic impacts, these being:

- **Scenario WQ1** - Existing environment, including bathymetry assumed at the end of the current program being undertaken by the CSD, *Wombat*.
- **Scenario WQ2a -** Scenario WQ1 plus bathymetric features which will exist when the temporary access works (coffer dams) associated with The Narrows pipeline crossing are in place
- **Scenario WQ2b** - Scenario WQ1 plus the "Project case", including all bathymetric features assumed to exist when the QCLNG Project is operational, including:
  - Construction dock embayment near the southern LNG boundary
  - Maintenance Offloading Facility (MOF)
  - QCLNG Swing Basin and approach channel
  - RG Tanna vehicle ramp structure
  - GPC offshore dredge spoil disposal
  - Clinton Bypass channel.
- **Scenario WQ3** – the "Project cumulative case", including Scenario WQ2b plus additional bathymetric features assuming completion of the Wiggins Island Coal Terminal Project, the Santos (GLNG) swing basin and approach channel, and the Targinie Extension Stage 1B
- **Scenario WQ4** – "Full cumulative", which in addition to all features in Scenario WQ3 assumes additional bathymetric features representing completion of the proposed Western Basin strategic dredging and disposal project.

Scenario WQ2b, WQ3 and WQ4 were repeated with a different configuration of the rock armouring for the pipeline at The Narrows, as follows:

- *Option 1:* assuming a 2.5 m high rock berm above the seabed for the entire length of the Pipeline between Laird Point and Friend Point
- *Option 2:* assuming a 2.5 m trench backfilled with rock in-situ material on the intertidal areas and with rock elsewhere
- *Option 3:* assuming a 2.5 m trench backfilled with in-situ material on the intertidal areas and a 2.5 m high rock berm above the seabed for the rest of the Pipeline length.

It is noted that Option 1 is likely to have the greatest impacts as the 2.5 m high rock armouring above the sea bed effectively reduces the cross-sectional area available to flow at the pipeline crossing.

The potential effects of the different development scenarios (i.e., Scenarios WQ2a through WQ4) on tidal hydraulics were assessed on the basis of modelled changes from the existing situation in:

- time series of tide levels at 11 locations in Port Curtis
- time series of current speeds at the same 11 locations
- instantaneous current velocity vectors throughout Port Curtis during peak

flood and peak ebb tides.

Model simulations were run for the equivalent of two months to assess potential changes to flushing times. This model started with an initial uniform concentration (100.0 units) of a notional conservative (inert) tracer over the full model domain in Port Curtis. Tracer concentrations were only reduced due to water flowing out of Port Curtis and being replaced by oceanic water (having an assumed tracer concentration of 0.0). The effects on tidal flushing for development Scenarios WQ2a through WQ3 were assessed on the basis of changes from the modelled existing case in:

- the spatial distribution of tracer concentrations in Port Curtis at the end of the two-month simulation period
- time series of tracer concentration at the 11 locations used to assess impacts on tidal hydraulics, which were used to calculate e-folding times in Port Curtis. E-folding time is the time required to reduce the tracer concentration by a factor of 1/e, e (or to about 37 per cent of its initial concentration), and thus is a measure of the exponential decay time of the tracer concentration.

8.6.1 *Tidal Hydraulics*

Dredging and reclamation for the proposed QCLNG dredging alone (Scenarios WQ2a and WQ2b) are predicted to result in changes of 2.1 cm or less on both high- and low-tide levels throughout the area. High-tide levels are also predicted to remain effectively unchanged under Scenarios WQ3, but some changes are predicted in low-tide levels under these scenarios, as detailed in *Table 5.8.6*. Predicted water levels are not affected by the pipeline options.

Table 5.8.6 Predicted Changes in Spring Low-Tide Level from Existing Situation

Location	Scenario WQ2b	Scenario WQ3
The Narrows	-1.4 cm	+0.3 cm
QCLNG Swing Basin	+1.0 cm	+2.1 cm
Santos swing basin	+0.4 cm	+1.4 cm
Auckland Point	+0.2 cm	+0.3 cm

These predicted changes in water levels in The Narrows from QCLNG dredging (Scenarios WQ2b and WQ3) are expected to have a negligible impact (1.4 cm or less for most locations, to a maximum of 2.1 cm at the Project site for Scenario WQ3) on both the high- and low-tide levels, as they are of a similar scale to natural fluctuation caused by barometric pressure and wind and wave conditions.

8.6.2 *Current Velocity and Flushing Rates*

For Scenario WQ2a, (with Pipeline Option 1, including the temporary coffer dams), the modelled changes in current velocity are generally localised to within 500 m upstream and 1 km downstream of the proposed pipeline crossing. The changes are greatest during ebb tide, when velocity decreases of up to 0.4 m/s downstream and increases of 0.1 m/s in the main channel between the dams are predicted.

Velocity change impacts all but disappear for Pipeline Crossing Option 2, where the pipeline is constructed within a trench in the seabed, thus resulting in no additional cover over the seabed.

Option 3 is a hybrid configuration with a buried pipeline on the inter-tidal areas and an armoured pipeline above the seabed across the channel. This configuration does not act to block flows on the shallow areas. However, increases in velocities are predicted within the main channel due to the 2.5 m pipeline cover. These effects extend about 250 m from the pipeline crossing and velocity changes are only 0.05 ms^{-1} to 0.1 ms^{-1}.

It is clear from this analysis that the most extreme changes in water velocities are usually 10 to 20 per cent of maximum flows. The most extensive effects occur as flow decreases on the margins of The Narrows, and extend to approximately 1 km north or 1.5 km to 2 km south of The Narrows. Mid-channel flow increases tend to be confined to a smaller area within about 500 m of The Narrows.

Given the armoured and course gravelly nature of the mid-channel seabed, mid-channel velocity increases are not expected to result in significant increases in bed erosion. Flow retardation on channel margins is expected to lead to additional deposition of sediments, at least for Option 1.

For Scenario WQ2b, the model predicts:

- decreases in peak ebb and flood current speeds of up to 0.4 m/s in the proposed Swing Basin and MOF pocket
- increases in peak flood speeds of up to 0.2 m/s west and north-west of the Swing Basin and MOF pocket, extending to The Narrows
- increases in peak ebb speeds of up to 0.3 m/s, extending upstream to approximately the location of the proposed MOF, and downstream of the Swing Basin to the south-east
- negligible changes of <0.05 m/s will result from disposal of dredged materials at the GPC offshore dredge spoil disposal area.

With regard to cumulative impacts, modelled changes to current velocities for Scenario WQ3 are very similar to those for Scenario WQ2b, with some additional effects on current speeds south of the approach channel and in Port Curtis beyond Auckland Point. Predicted changes are generally greater for WQ4, due to the loss of the tidal storage area from the proposed Western Basin reclamation extension.

Model predictions of tracer concentrations at the end of the two-month simulation period indicate that the temporary coffer dams (Scenario WQ2a) will have negligible effects on flushing and only in the vicinity of the temporary coffer dams. The QCLNG Project case (Scenario WQ2b) results in increases in final tracer concentration of up to four units over the existing situation in the vicinity of the proposed MOF, with lesser increases along the shoreline of Curtis Island between Laird Point and approximately Boatshed Point.

Modelling of cumulative impacts (Scenarios WQ3 and WQ4) predicts generally higher and more widespread effects on flushing, as indicated by the final modelled tracer concentrations. Modelled e-folding times under existing conditions are about 30 days in the proposed approach channel, about 38 days at the proposed MOF, and 45 days or more upstream in The Narrows and Grahams Creek. Modelled e-folding times indicate the same pattern of effects on flushing for the different development scenarios as predicted by the spatial distribution of tracer concentrations at the end of the simulation period. Effects of the temporary coffer dams (Scenario WQ2a) are highly localised. The QCLNG Project alone (Scenario WQ2b) is predicted to increase e-folding times by four or five days in the vicinity of the MOF, and to a lesser extent along the shoreline of Curtis Island. Modelling of cumulative effects (Scenarios WQ3 and WQ4) again indicates greater and more widespread increases in e-folding times, extending beyond Port Curtis.

These localised minor changes in flushing and e-folding, restricted to within the vicinity of the dredge footprint and Curtis Island, are not considered to have significant impacts on tidal flushing within Port Curtis.

8.7 EFFLUENT DISCHARGE

Appendix 5.9[5] of the draft EIS presented results of near- and far-field numerical modelling of the reverse osmosis concentrate (ROC) and wastewater (primarily treated sewage) discharges from the LNG Facility. Modelling was undertaken focusing on effluent discharges at the peak of construction, when rates of discharge would be anticipated to be at a maximum.

Modelling assumptions included:

- ROC discharged as a constant wastewater stream at the maximum anticipated flow rate of 16.7 L/s
- treated wastewater (sewage) effluent discharged as a constant wastewater stream at maximum flow rate of 4.0 L/s
- effluent streams will be pre-mixed and discharged via a common outfall, located at the end of the proposed QGC jetty structure
- the ROC will have a constant salinity of 63.5 g/L and the sewage effluent

5 BMT WBM Proposed QCLNG Project EIS – Marine Water Quality Assessments 2009

will have a constant salinity of 0.25 g/L

- ambient water will have a salinity of 35 g/L
- the combined waste stream temperature will be the same as that of the adjacent receiving waters. For the near field modelling, this temperature was assumed as 24° C
- Water quality parameters for the sewage effluent discharge were assumed as summarised in *Table 5.8.7* below.

Table 5.8.7 Assumed Sewage Effluent Discharge Parameters

Parameter	Indicative Discharge Range of Discharge Concentration	Discharge Concentration Assumed for Modelling
BOD5	10 to 20 mg/L	15 mg/L
Total nitrogen (TN)	30 to 40 mg/L as N	35 mg/L
Total phosphorus (TP)	5 to 10 mg/L	7.5 mg/L
Total dissolved solids (TDS)	250 mg/L	250 mg/L

8.7.1 Near Field

Specific considerations associated with the near-field modelling were as follows:

- Several outfall configurations were assessed, and the recommended configuration comprised a 10 m long diffuser with 50 mm diameter ports spaced at 1 m intervals (i.e. 11 ports in total). This configuration gave an exit velocity from each outfall port of the order of 1 m/s, to facilitate initial mixing and also reduce the likelihood of marine biofouling.
- It was assumed that the diffuser was oriented perpendicular to the prevailing current direction, that the minimum water depth at this site was 10 m and that the diffuser was at least 2 m below the water surface at all times.

The model results, as shown in *Figure 5.8.4* and *Figure 5.8.5*, indicated that:

- The discharge undergoes a greater than 20:1 dilution within 4 m of the mouth of the outfall, and more than 200:1 dilution within 40 m of the mouth of the outfall.
- By the time the discharge plume falls to the seabed, dilution rates exceed 200:1.

Figure 5.8.4 Near-Field Dilution with Distance Down-Current from Outfall[6]

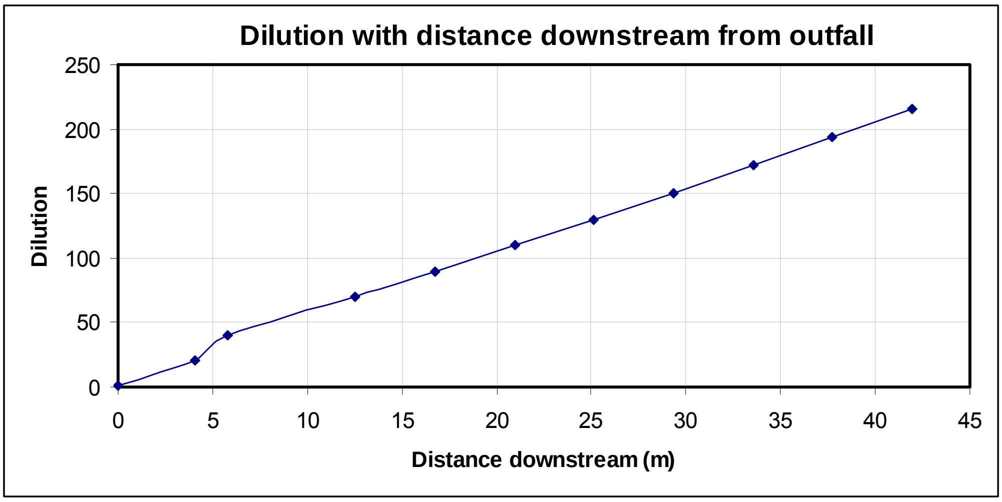
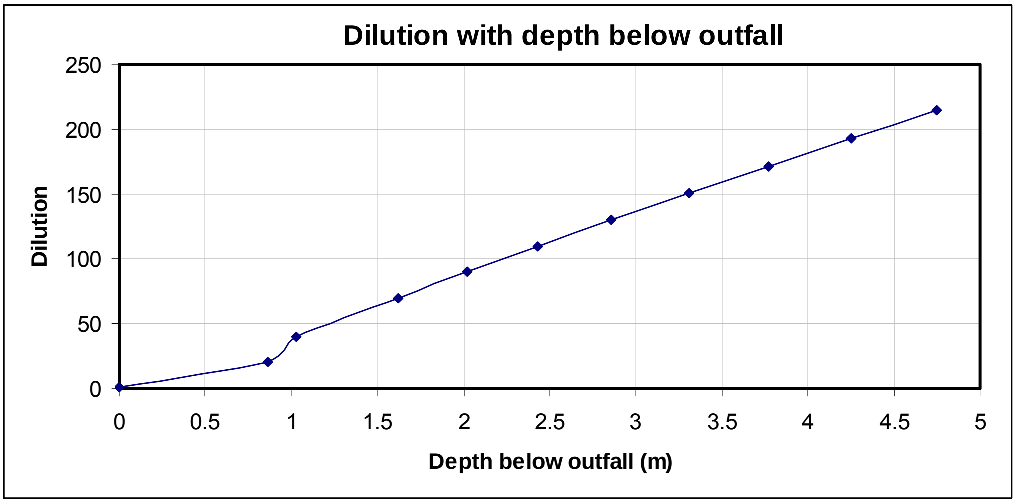


Figure 5.8.5 Near-Field Dilution With Depth Below Outfall[6]



8.7.2 Far Field

Far-field modelling of the combined wastewater effluent/ROC impact was undertaken by simulating three different conservative tracers to represent salt, TN and TP, with the following peak discharge loads (based on the peak discharge rates and discharge parameters as described above) at the outfall:

- 476 g/s of salt
- 140 mg/s of TN
- 30 mg/s of TP.

The model was run until quasi-steady state conditions resulted and results were extracted for several sites along the axis of tidal flows. These results

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show a maximum far-field salinity increase of the order of 0.28 g/L, which given background levels of more than 35 g/L and also natural variability in levels, will be negligible. Maximum concentrations (above ambient) of 80 µg/L of TN and 18 µg/L of TP are predicted at the discharge point.

Discharge concentrations are predicted to decrease by a factor of 50 to 80 within approximately 200 m of the discharge point. Increases in salinity, TN and TP were determined for a number of locations along the LNG Facility shoreline and Swing Basin (refer *Figure 5.8.6* for locations), and are shown graphically in *Figure 5.8.7* to *Figure 5.8.9.*

It can be seen that at the model result extraction locations selected in the vicinity of the LNG Facility and Swing Basin away from the outfall, total increases (above ambient) were less than:

- 25 mg/l for salinity
- 7 µg/l for total nitrogen
- 2 µg/l for total phosphorus.

Figure 5.8.6 Salinity Model Result Extraction Locations

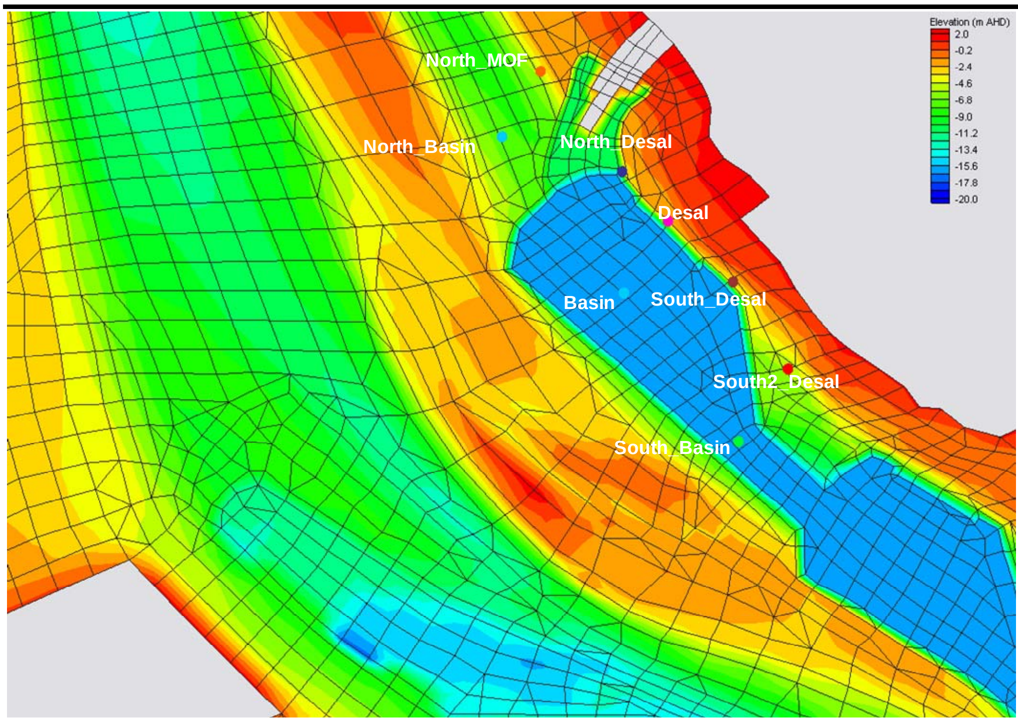


Figure 5.8.7 Far-Field Salinity Modelling Results

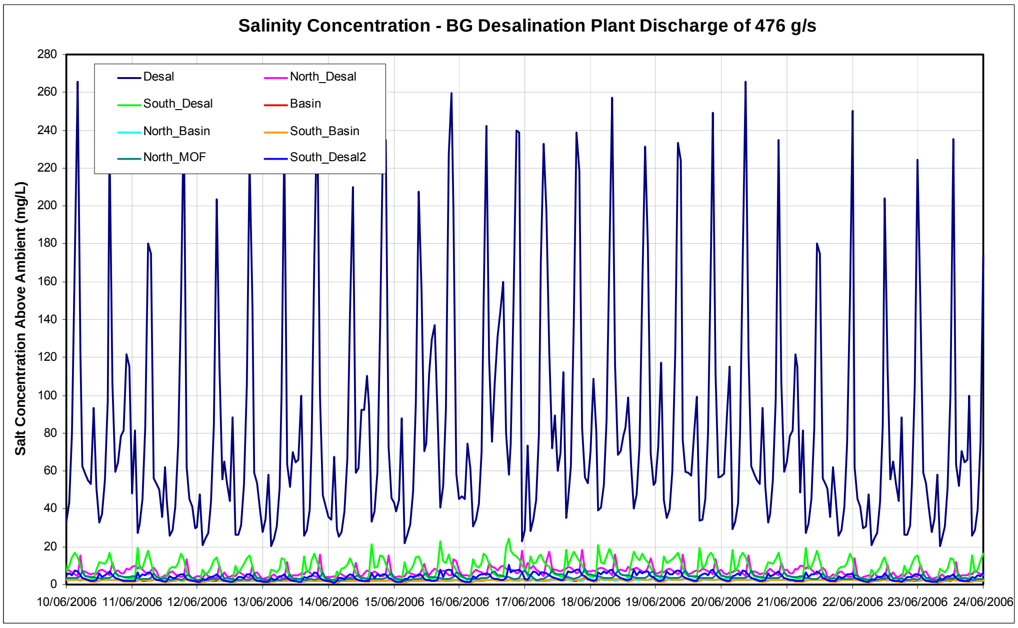


Figure 5.8.8 Far-Field Total Nitrogen Modelling Results

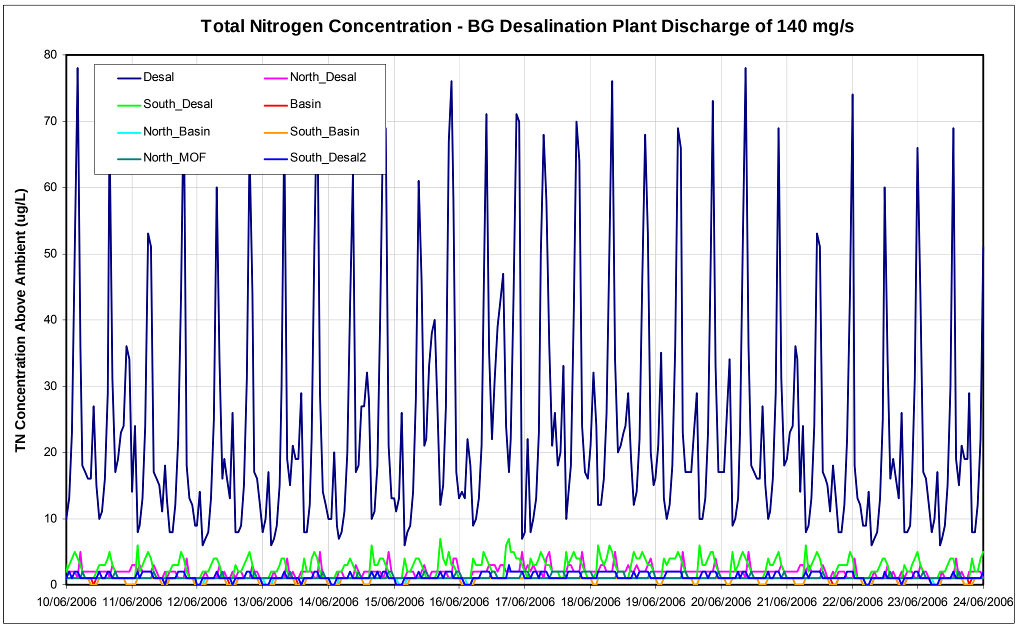
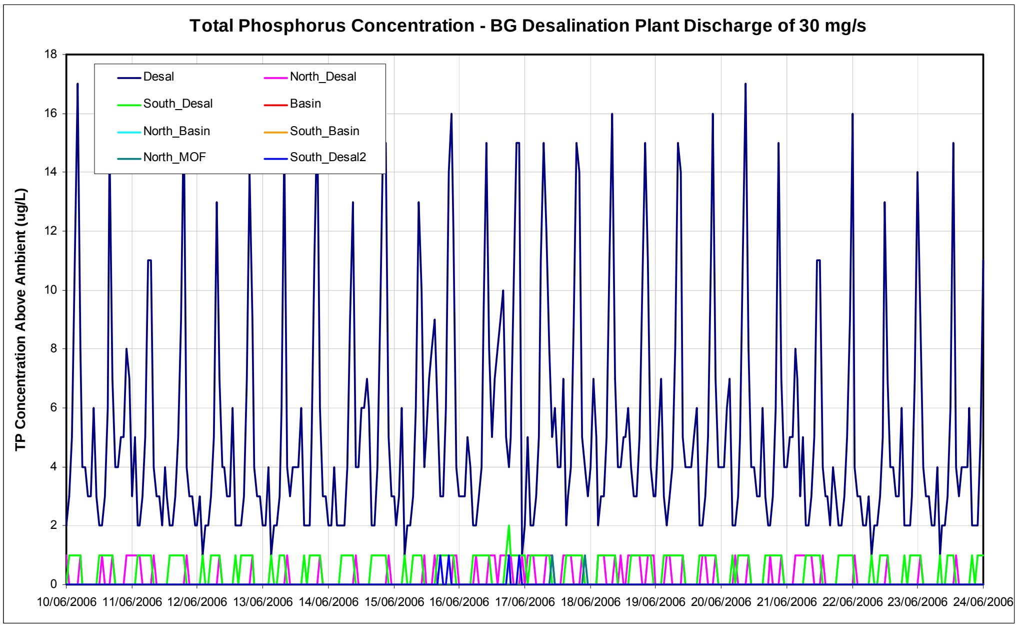


Figure 5.8.9 Far-Field Total Phosphorus Modelling Results



8.7.3 Receiving Waters and Discussion of Impact

A summary of water quality objectives for nutrients, as defined in the Queensland Water Quality Guidelines 2009[7] for south-east Queensland for slightly-to-moderately disturbed systems (as defined under the Queensland Environmental Protection (Water) Policy 2009[8]), are provided in *Table 5.8.8* below.

Table 5.8.8 Queensland Water Quality Guideline Values: Slightly to Moderately Disturbed Systems

Parameter	South East Region Water Type	
	Open Coastal	**Enclosed Coastal**
Total nitrogen (TN)	200 µg/l	140 µg/L
Total phosphorus (TP)	20 µg/L	20 µg/L

Water quality data for Port Curtis, including concentrations of total nitrogen and total phosphorus, were reported in detail in *Appendix 5.9*[9] of the draft EIS. This indicates that Port Curtis is the receiving environment for sewage and diffuse nitrogen sources from a number of settlements fringing Port Curtis as well as nitrogen discharges from industrial sources. Consequently, concentrations of nutrients vary significantly both temporally and spatially

7 http://www.derm.qld.gov.au/register/p03060aa.pdf

8 http://www.legislation.qld.gov.au/LEGISLTN/SLS/2009/09SL178.pdf

9 BMT WBM Proposed QCLNG Project EIS – Marine Water Quality Assessments 2009

across the port. Water quality sampling was undertaken in the vicinity of the LNG Facility site in 2008 and reported in the draft EIS (Appendix 5.9[10]), with samples collected and analysed from five sampling locations (refer *Figure 5.8.10*). Three water samples were taken at each site at low-, medium- and high-tidal states, during a medium-tidal range (in between spring and neap tides).

Results for physiochemical parameters and nutrients are summarised in *Table 5.8.9* below.

Table 5.8.9 Water Quality Sampling: Summary of Laboratory Results

Site	Tidal state[1]	Ammonia Nitrogen	Nitrogen Oxides	FRP[3]	Total P	Total N	TSS	TOC	Chlorophyll a
WQG[2]		**8**	**3**	**6**	**20**	**200**	**15**		**2**
Units		**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**mg/L**	**µg/L**
Site 1	L	< 2	< 2	< 2	11	200	3	1.4	1
	M	< 2	< 2	< 2	13	220	2	1.4	1
	H	4	3	< 2	13	270	6	1.3	2
Site 2	L	5	< 2	< 2	11	220	4	1.4	1
	M	< 2	< 2	< 2	13	230	6	1.4	2
	H	7	5	< 2	12	200	3	1.2	2
Site 3	L	< 2	< 2	< 2	10	200	3	1.3	1
	M	4	3	< 2	12	210	7	1.3	1
	H	4	2	< 2	22	210	5	1.1	2
Site 4	L	3	2	< 2	15	210	3	1.2	1
	M	4	2	< 2	12	210	5	1.2	2
	H	4	< 2	< 2	12	200	5	1.1	2
Site 5	L	< 2	< 2	< 2	12	220	5	1.3	2
	M	< 2	3	< 2	12	220	8	1.3	2
	H	4	3	< 2	11	220	7	1.7	1

1 L=Low tide, M=Mid tide, H= High tide
2 Queensland Water Quality Guidelines (QWQGs) for enclosed coastal waters of Central Queensland
3 Filterable Reactive Phosphorus
4 Highlighted cells indicate exceedance of the WQG

The implications of Project discharge into Port Curtis is a very localised increase in nutrient concentrations immediately adjacent to the discharge point of approximately 40 per cent for total nitrogen and 100 per cent for total phosphorus. Dilution and dispersion of the discharge is enhanced by virtue of the design of the outfall. The concentration of total nitrogen is reduced to approximately 0.5 per cent above background within 200 m of the discharge point and total phosphorus is reduced to approximately 1 to 2 per cent above background concentrations within 200 m of the discharge point. These concentrations are within the range of background variability and unlikely to cause significant effect to water quality.

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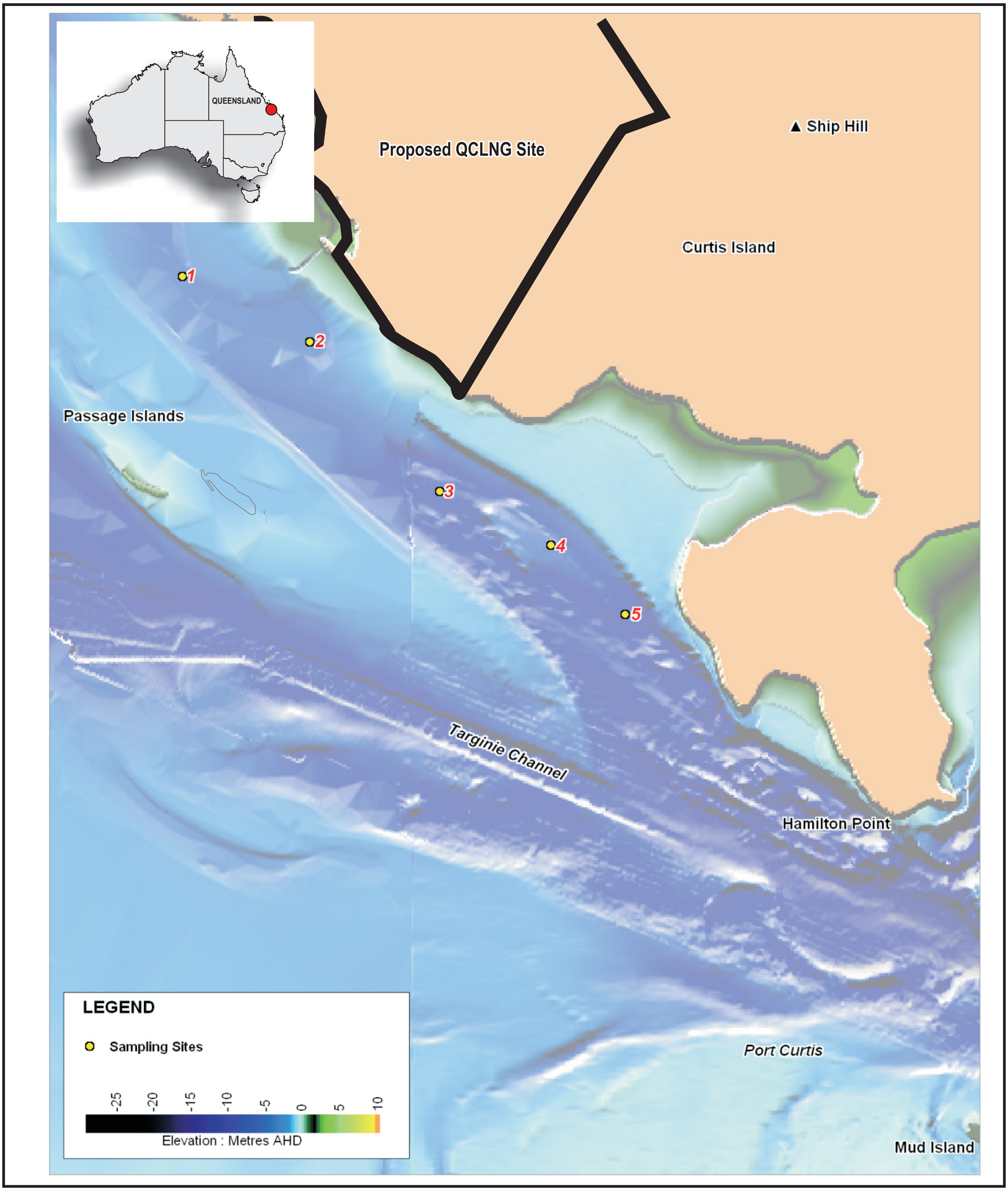


Source Note:
BMT WBM 2008
Ref. WQU_079_081115_WQSites.wor
Figure not to scale.

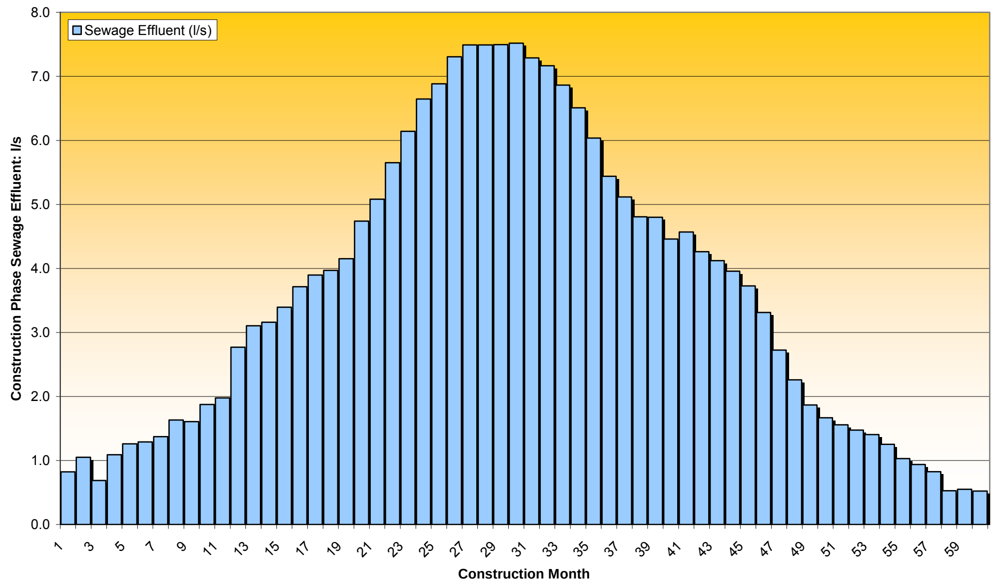
QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project		Title: WBM Water Quality Sampling Locations (November 2008)
	Client: QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	sEIS Volume 5 Figure S5.8.10	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved RS	File No: 0086165b_SUP_CDR005_S5.8.10	
	Date 06/01/10	Revision 0	

8.7.4 *Revised Discharge Impact Assessment for sEIS*

As a result of the increase in construction personnel from that described in the draft EIS, the peak rate of sewage effluent discharge may increase from the 4.0 l/s modelled for the draft EIS, to approximately 7.5 l/s. It should be noted that this peak rate of discharge will be for a limited period of approximately six months; indicative sewage effluent generation rates (based on 24 hour per day operation of the sewage treatment plant) for the construction period are shown in *Figure 5.8.11*.

As previously stated, QGC is currently investigating treatment of sewage effluent to a standard meeting the definition of tertiary treated sewage specified by sub regulation 135(3) of *The Great Barrier Reef Marine Park Regulations 1983* (Statutory Rules 1983 No. 262 as amended) prior to discharge from the LNG Facility site. However, this is subject to ongoing assessment of treatment technologies. On this basis, notwithstanding the increase in discharge rate from that modelled in the draft EIS, the peak nutrient flux (mg/s) is not expected to increase from that described in the draft EIS, and thus the outcomes of the near- and far-field modelling undertaken for the draft EIS and summarised above remain a valid representation of peak (worst case) loads.

Figure 5.8.11 Sewage Effluent (l/s) by Construction Month



8.7.5 *Potential plume overlap from other projects*

The separation distance between the QCLNG outfall and the nearest potential location for an outfall from a proposed project is in excess of 1 km. Given that the modelling results of levels of salinity, TN and TP at the Desal 2 location, (the closest to the potential future project location) gives levels above ambient of 5-10 µg/L salt, 2-3 µg/L TN, and below detection limits for TP, the QCLNG discharge is not expected to give rise to overlap effects and cumulative impacts on water quality.

8.8 *MANAGEMENT OF IMPACTS TO BENTHIC FLORA AND FAUNA FROM DREDGING*

Best practice management of the impacts of large-scale dredging programs is tending towards the definition of tiered impact zones, within which management and monitoring activities are pre-defined. Impact zones are defined in terms of direct and indirect effects, permanent and temporary effects, physical versus biological effects, and mortality versus sub-lethal effects[11, 12]. These approaches reflect, for benthic primary producers, the same concepts of impact and mixing zones as applied in Australia to the management of water quality from point source discharges[13]. They also reflect conventional approaches to statistical design of monitoring programs, where impact zones are stratified, and the changes are determined (both ‘‘impacts’’ and natural change) by comparison of the changes in each zone, over time[14]. Impact zones predicted to arise from the dredging activities for the QCLNG Project (described in *Volume 6*), mitigation strategies and management of impacts in each zone are summarised below, and illustrated schematically in *Figure 5.8.12* , adapted from Masini et al., 2008[15]).

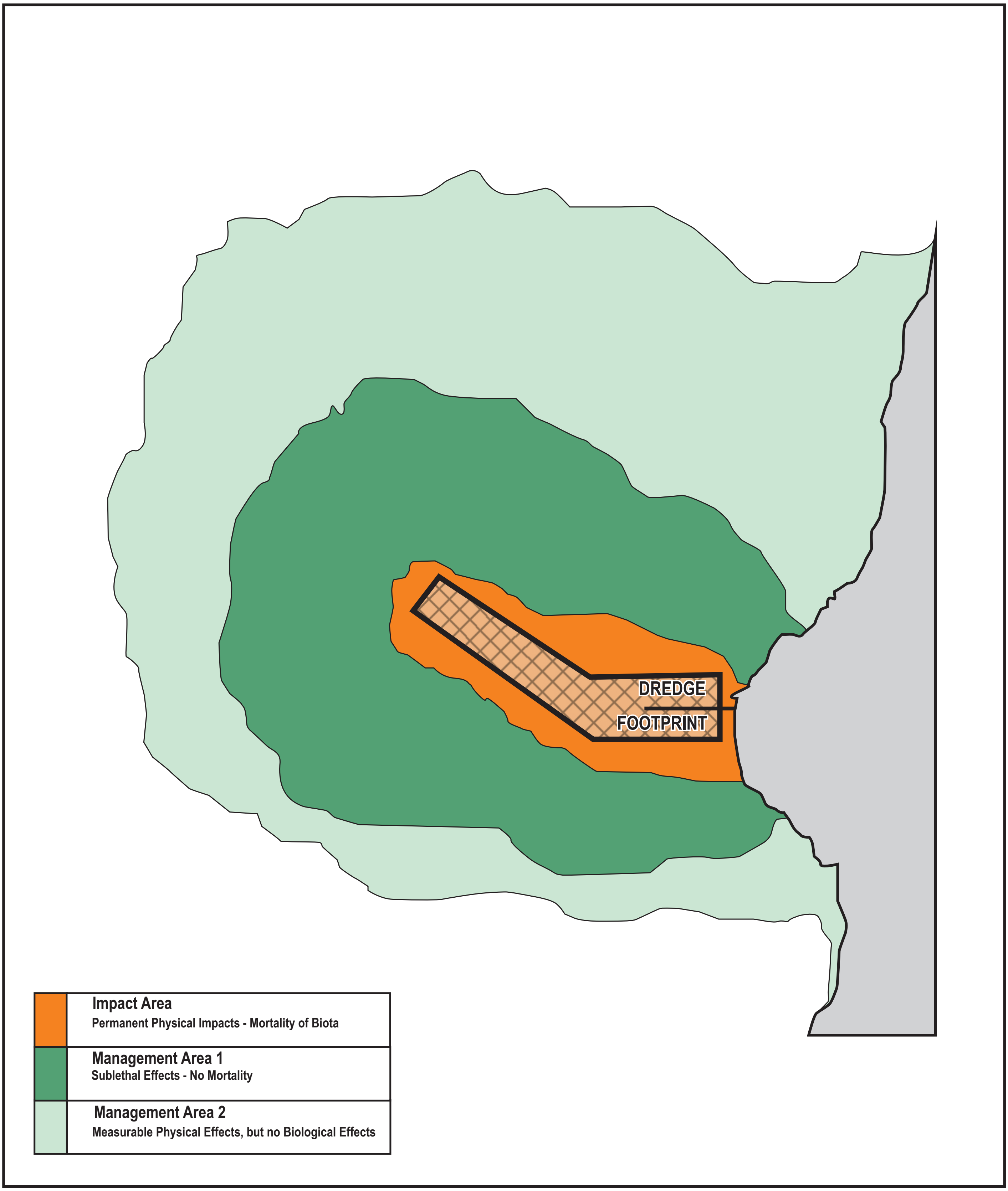
11 Masini, R., C. Sim and K. McAlpine, 2008. “Environmental Impact Assessment of Large-scale Dredging Projects”, Powerpoint presentation, IAIA08, Perth, WA.

12 SKM, 2008. “Pluto LNG Development: Dredging and spoil disposal management plan / Dredge Impact Management Plan, March 2008”, as approved by Department of Environment and Conservation (DEC) 16 November 2007..

13 Australian and New Zealand guidelines for fresh and marine water quality. Volume 1, The guidelines, October 2000. Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.

14 Underwood, AJ (1991). Beyond BACI: Experimental designs for detecting human environmental impacts on temporal variations in natural populations. Australian Journal of Marine and Freshwater Research 42, 569–587.

15 Ibid 11



Adapted from:

Masini, R., C. Sim and K. McAlpine, 2008. "Environmental Impact Assessment of Large-scale Dredging Projects", Powerpoint presentation, IAIA08, Perth, WA.

Not to scale

N

QUEENSLAND CURTIS LNG A BG Group business	Project: **Queensland Curtis LNG Project** Client: **QGC - A BG Group business**		Title: **Schematic of Impact Zones for Management for Dredging**
ERM Environmental Resources Management Australia Pty Ltd	Drawn: JB Approved: SL Date: 19/01/10	**sEIS Volume 5** **Figure S5.8.12** File No: 0086165b_SUP_CDR006_S5.8.12 Revision 1	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

8.8.1 Impact Area

This zone represents the area within which mitigation and management strategies have been applied in the Project design and planning phase, but within which there are still predicted to be mortality of biota . This may include direct impacts, such as those within the dredging footprint, which are usually permanent. It is also likely to include indirect impacts (such as those caused by loss of light and by sedimentation), which may be only temporary. In the cases of corals and seagrasses, regrowth is usually expected to occur within several years, assuming that the substrate is not damaged, and that water quality returns to normal after the impact period.

Impact areas are often treated as ‘‘mixing zones’’, as within the Australia and New Zealand Environment and Conservation Council (ANZECC) water quality guidelines. That is, management effort is applied in the design and operational phases to reduce the size and severity of impacts to the greatest extent reasonably practical. However, it is acknowledged (via the EIS and subsequent permitting processes) that – even after optimisation, mitigation and management – there will still be mortality of biota within this area. With project approvals premised on mortality within this zone, biota within this zone are not then monitored within the predictive/responsive monitoring and management plan which forms the core of the Draft Dredge Environmental Management Plan. Any monitoring within these areas is intended to confirm the predicted impacts, to confirm any predicted recovery, and to assist in refining current and future models of impact predictions.

The QCLNG Project, in adopting the zonal approach to dredging impact management, has likewise defined an Impact Area within which mortality is expected. Impact Area predictions have utilised an expert working group approach (as documented in *Volume 6, Section 2.4*). Separate criteria have been applied to seagrasses, which are primarily affected by ‘‘shading’’, and corals, which in turbid water are primarily affected by sedimentation.

Management and mitigation have been applied primarily in the design phase, and includes optimisation of locations, depths and layouts to reduce the amount of material to be dredged, as well as in the selection of equipment types and work methods. General controls will also be applied during dredging operations. These include measures such as maintenance of hopper door seals and management of reclamation decant weir levels. These controls will reduce the extent, intensity and duration of high-intensity plumes to the levels indicated in the plume plots in *Volume 6, Section 2*. However, within the predicted Impact Area, the residual impacts are expected to include mortality prior to recovery post-dredging, and in line with current trends in dredge impact management, it is proposed that these areas not be subject to the high-frequency monitoring and management dredge management plan (DMP) efforts which are intended to detect changes to the health status of sensitive receptors.

8.8.2 *Management Area 1*

This represents the zone where biological impacts are expected, but where appropriate management during dredging operations is expected to limit these to sub-lethal impacts only, and where rapid recovery is expected following cessation of the impact source. The same design, optimisation and mitigation which limited the extent of the Impact Area will also have served to reduce the extent, severity and duration of impacts in Management Area 1. However, the lower intensity of predicted impacts creates an opportunity for operational management to further reduce the severity of impacts.

QGC’s approach to environmental monitoring has included developing definitions for risk contours that represent areas where seagrass and coral mortality is not expected to occur. Management Area 1 therefore represents those portions of Port Curtis where a) sensitive receptors occur, and b) where risk contours overlap the distribution of the sensitive receptors.

It has become customary in large-scale dredging projects to implement a DMP which puts in place, before dredging begins, a series of surveillance measures which inform a pre-agreed set of management responses. This tiered set of management responses impose further constraints on dredging operations to ensure that the actual impacts are within the range of predicted impacts. A draft DMP (DDMP) has been prepared and is included in *Appendix 6.1*. This will form the basis of dredge permitting controls to be agreed between QGC and regulators in the lead-up to the commencement of dredging.

The draft DMP provides general, but does not yet include specific detail on the precise locations of monitoring sites, the frequency of observations, the biological indicators which will be used to assess health, or the experimental design which will be used to analyse monitoring results. Studies are currently under way, or will be commissioned between the conclusion of the EIS and the tabling of the completed DMP, which will provide pilot data upon which these details will be determined. These studies will also determine an experimental design to best discriminate between impacts of QCLNG Project dredging, and that of other dredging projects which may occur within the bay.

8.8.3 *Management Area 2*

Management Area 2 is the zone within which the EIS process has predicted that there may be measurable physical effects (such as turbid plumes), but where no biological effects are predicted; providing that the DMP adequately manages the effects of dredging within Management Area 1, it would be expected that no biological effects would be observed in Management Area 2.

Monitoring sites will be established within Management Area 2, but these are expected to serve as comparator sites for detecting impacts within Management Area 1. In the sense of ‘‘BACI’’ monitoring designs, this zone represents what would typically be termed ‘‘control’’ or ‘‘reference’’ areas.

8.8.4 Unimpacted Area

Zones beyond Management Area 2 are those zones where the EIS has predicted that no impacts will occur to physical conditions such as turbidity and sedimentation. There is no outer boundary to the Unimpacted Area, but for the purpose of monitoring, any survey sites within the Unimpacted Area (also used as ‘‘control’’ or ‘‘reference’’ sites) would be placed sufficiently close to Management Area 2 that there are no differences between naturally occurring changes inside and outside of these areas.

8.9 SEAGRASS AND ALGAL COMMUNITIES

8.9.1 Additional Baseline

8.9.1.1 Historical Information

Recent work has included the identification of early seagrass survey results to provide a greater historical perspective on changes within Rodds Bay and Port Curtis. In a 1989 Impact Assessment Study, WBM[16] reproduced survey maps of Rodds Bay and Port Curtis completed by Department of Primary Industries in 1988 (refer *Figure 5.8.13)*, as well as reporting results of their own surveys (refer *Figure 5.8.14*). While the coverage of these surveys was incomplete, it is possible to draw inferences on trends over three decades by examining those areas which were surveyed in the late 1980s and were resurveyed between 2002 and 2009. Analysis of these areas suggests:

- Several meadows varied in size between the 1988, 1989 and 2002 surveys, a pattern later seen in other annually monitored seagrass meadows in Port Curtis.
- WBM’s 1989 detailed survey of Port Curtis yielded an area of seagrasses (2,300 ha) 26 per cent larger than that estimated in 1988 by QDPI (1,700 ha). This difference in area may be a result of inter-annual changes, as has been observed in later seagrass surveys (see *Table 5.8.10*), but may also be partly a result of variance in the coverage of observations underpinning the 1988 data set.
- On a more local scale, several of the meadows which were observed in the 1988 or 1989 surveys are absent from the 2002 DPI surveys, while the 2002 data also reveals a number of meadows which were not detected in the 1988 and 1989 surveys; notwithstanding potential differences in the coverage of the data sets, there appears to be considerable variability in the distribution of seagrass meadows over time.

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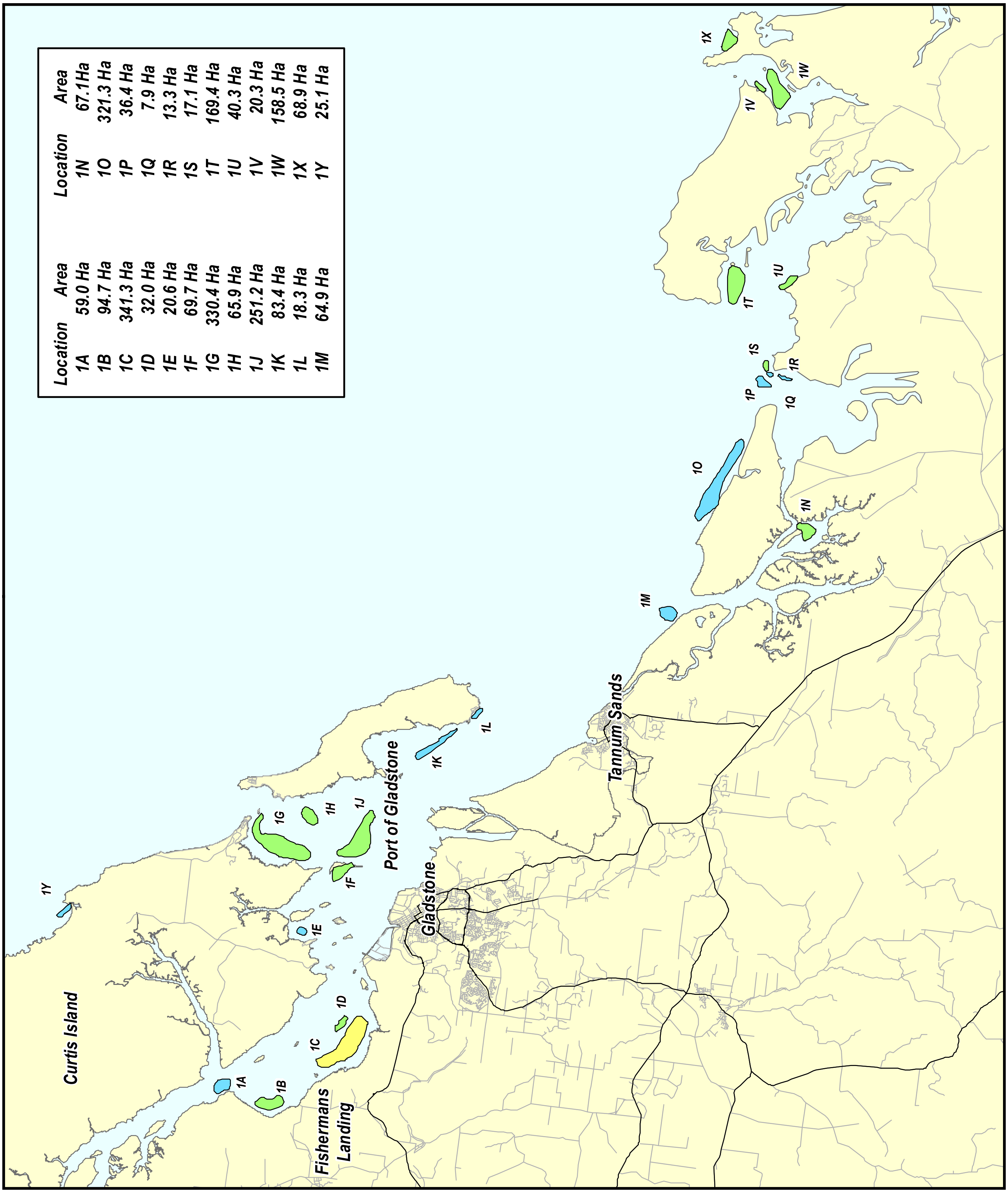
16 Winders, Barlow & Morrison, 1989. “Impact Assessment Study of Proposed reclamation of Land West of the Calliope River"



Legend

Seagrass Cover

- <10% Cover
- between 10% and 50% Cover
- > 50% Cover

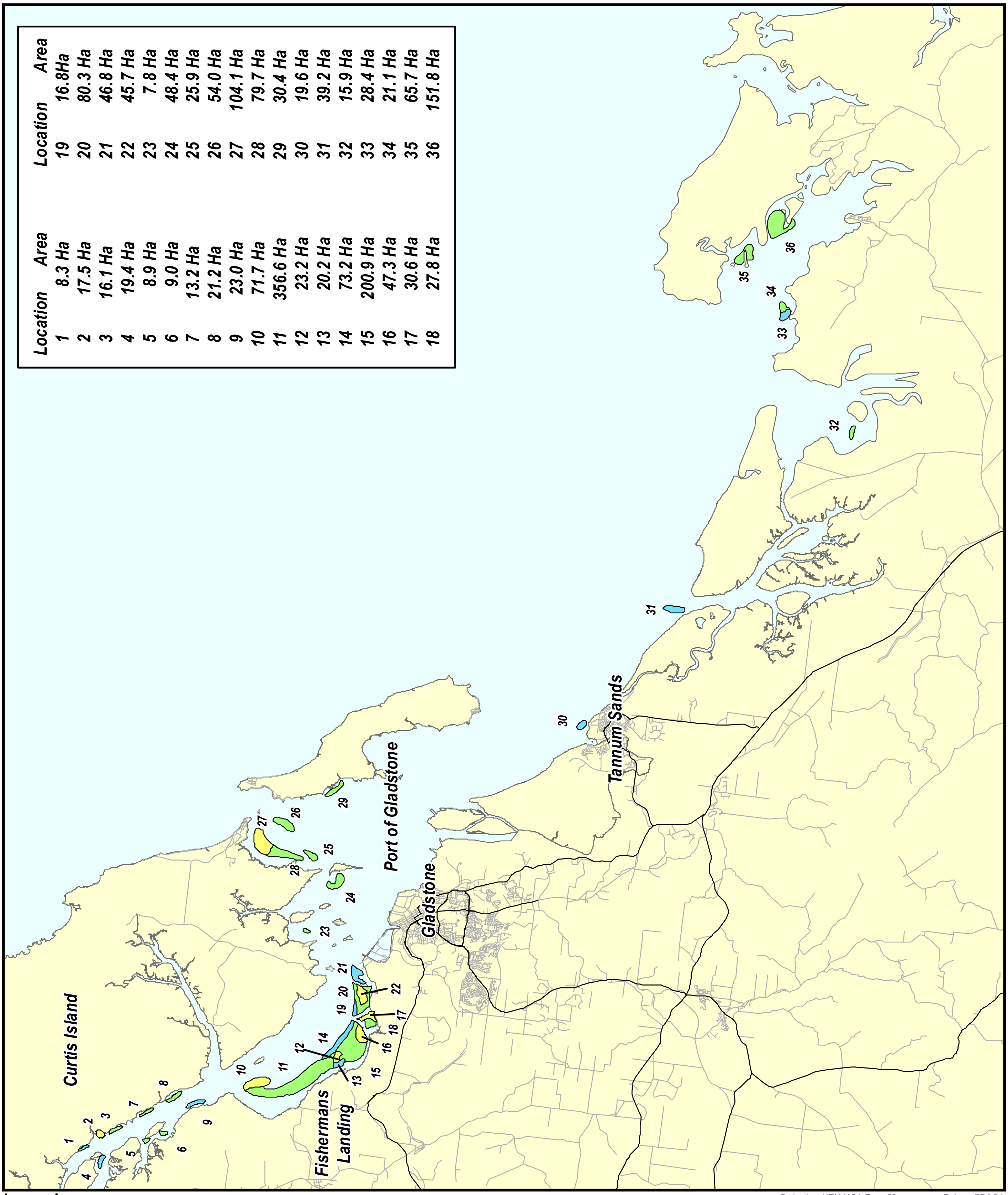
Source Note:
Intertidal Seagrass Cover; digitised from Figures 12.1.1 & 12.1.2 of WBM Report "Impact Assessment Study of Proposed Reclamation of Land West of the Calliope River". Original source: QDPI Limited Boat Based Surveys, 1988

Projection: UTM MGA Zone 56 Datum: GDA 94

0 2 4 8 km

N

QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project Client: QGC - A BG Group business	Title: Seagrass in the Port of Gladstone Region, 1988
ERM Environmental Resources Management Australia Pty Ltd	Drawn: KP — sEIS Volume 5 — Figure 5.8.13 Approved: BK — File No: 0086165b_SUP_GIS021_S5.8.13 Date: 19.01.10 — Revision: 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.



Location	Area	Location	Area
1	8.3 Ha	19	16.8Ha
2	17.5 Ha	20	80.3 Ha
3	16.1 Ha	21	46.8 Ha
4	19.4 Ha	22	45.7 Ha
5	8.9 Ha	23	7.8 Ha
6	9.0 Ha	24	48.4 Ha
7	13.2 Ha	25	25.9 Ha
8	21.2 Ha	26	54.0 Ha
9	23.0 Ha	27	104.1 Ha
10	71.7 Ha	28	79.7 Ha
11	356.6 Ha	29	30.4 Ha
12	23.2 Ha	30	19.6 Ha
13	20.2 Ha	31	39.2 Ha
14	73.2 Ha	32	15.9 Ha
15	200.9 Ha	33	28.4 Ha
16	47.3 Ha	34	21.1 Ha
17	30.6 Ha	35	65.7 Ha
18	27.8 Ha	36	151.8 Ha

Legend

Intertidal Seagrass Coverage

- <10% Cover
- between 10% and 50% Cover
- > 50% Cover

Source Note:
Intertidal Seagrass Cover; digitised from Figure 12.1.6 of WBM Report "Impact Assessment Study of Proposed Reclamation of Land West of the Calliope River", 1989

Projection: UTM MGA Zone 56 Datum: GDA 94

0 2 4 8 km

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Project	Queensland Curtis LNG Project	Title	Seagrass in the Port of Gladstone Region, 1989
Client	QGC - A BG Group business		
Drawn KP	sEIS Volume 5 Figure S5.8.14		
Approved BK	File No: 0086165b_SUP_GIS022_S5.8.14		
Date 19.01.10	Revision 0		

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8.9.1.2 *Interim Results of 2009 Survey*

Table 5.8.10 and *Table 5.8.11* summarise the most recent results from the Fisheries Queensland/Port Curtis Integrated Monitoring Program (PCIMP) seagrass monitoring program for the meadows immediately adjacent to the Fisherman's Landing area[17]. These results are a preliminary draft and may be subject to changes in the final report, however any changes are expected to be minor.

The preliminary results show that:

- In 2009 all four of the seagrass meadows in the Fisherman's Landing area were in a healthy state compared to previous monitoring events.
- All four meadows had expanded in area between 2008 and 2009, with the subtidal meadow to the north of Fisherman's Landing having the largest increase in area recorded in the eight years that annual monitoring has been conducted.
- Both of the northern Fisherman's Landing seagrass meadows had also increased in biomass over the period between 2008 and 2009.

17 Fisheries Queensland, in preparation, 2009

Table 5.8.10 Area (ha) for Fisherman's Landing meadows in Port Curtis November 2002, November 2004, October 2005, November 2006, October 2007, November 2008 and November 2009

Location	Meadow depth	Area ± R (ha)						
		2002	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
South Fisherman's Landing	Intertidal	464.0 ± 12.9	373.5 ± 11.9	406.4 ± 12.7	428.8 ± 13.0	470.1 ± 12.9	453.1 ± 13.2	456.9 ± 6.0
South Fisherman's Landing	Subtidal	72.6 ± 11.4	185.6 ± 8.7	112.1 ± 12.3	203.1 ± 8.2	20.6 ± 2.4	65.9 ± 5.1	77.4 ± 21.4
North Fisherman's Landing	Intertidal	269.1 ± 11.3	268.3 ± 12.5	231.1 ± 12.3	275.2 ± 12.0	309.9 ± 12.0	294.9 ± 12.6	315.0 ± 11.3
North Fisherman's Landing	Subtidal	268.3 ± 14.9	284.4 ± 7.1	7.0 ± 1.1	143.9 ± 8.0	153.0 ± 8.3	242.5 ± 8.2	288.2 ± 75.2
		1074 ± 50.5	**1111.8 ± 40.2**	**756.6 ± 38.4**	**1051 ± 41.2**	**953.6 ± 35.5**	**1056.4 ± 39.1**	**1137.5 ± 113.9**

Table 5.8.11 Mean above ground biomass (g DW m^{-2}) for Fisherman's Landing meadows in Port Curtis November 2002, November 2004, October 2005, November 2006, October 2007, November 2008 and November 2009.

Meadow ID	Location	Meadow depth	Mean biomass (g DW m^{-2})						
			2002	2004	2005	2006	2007	2008	2009
6	South Fisherman's Landing	intertidal	1.1 ± 0.1	0.24 ± 0.09	0.94 ± 0.61	2.65 ± 0.66	6.32 ± 0.86	1.42 ± 0.32	2.99 ± 0.89
7	South Fisherman's Landing	subtidal	0.9 ± 0.2	1.91 ± 0.36	0.03 ± 0.02	3.7 ± 0.95	4.16 ± 1.36	1.20 ± 0.53	0.66 ± 0.24
8	North Fisherman's Landing	intertidal	2.1 ± 0.3	0.14 ± 0.08	0.06 ± 0.04	1.28 ± 0.49	3.89 ± 0.77	0.69 ± 0.25	0.81 ± 0.23
9	North Fisherman's Landing	subtidal	0.9 ± 0.3	1.93 ± 0.27	0.001 ± 0.001	4.98 ± 0.72	4.64 ± 0.63	0.30 ± 0.09	3.02 ± 0.43

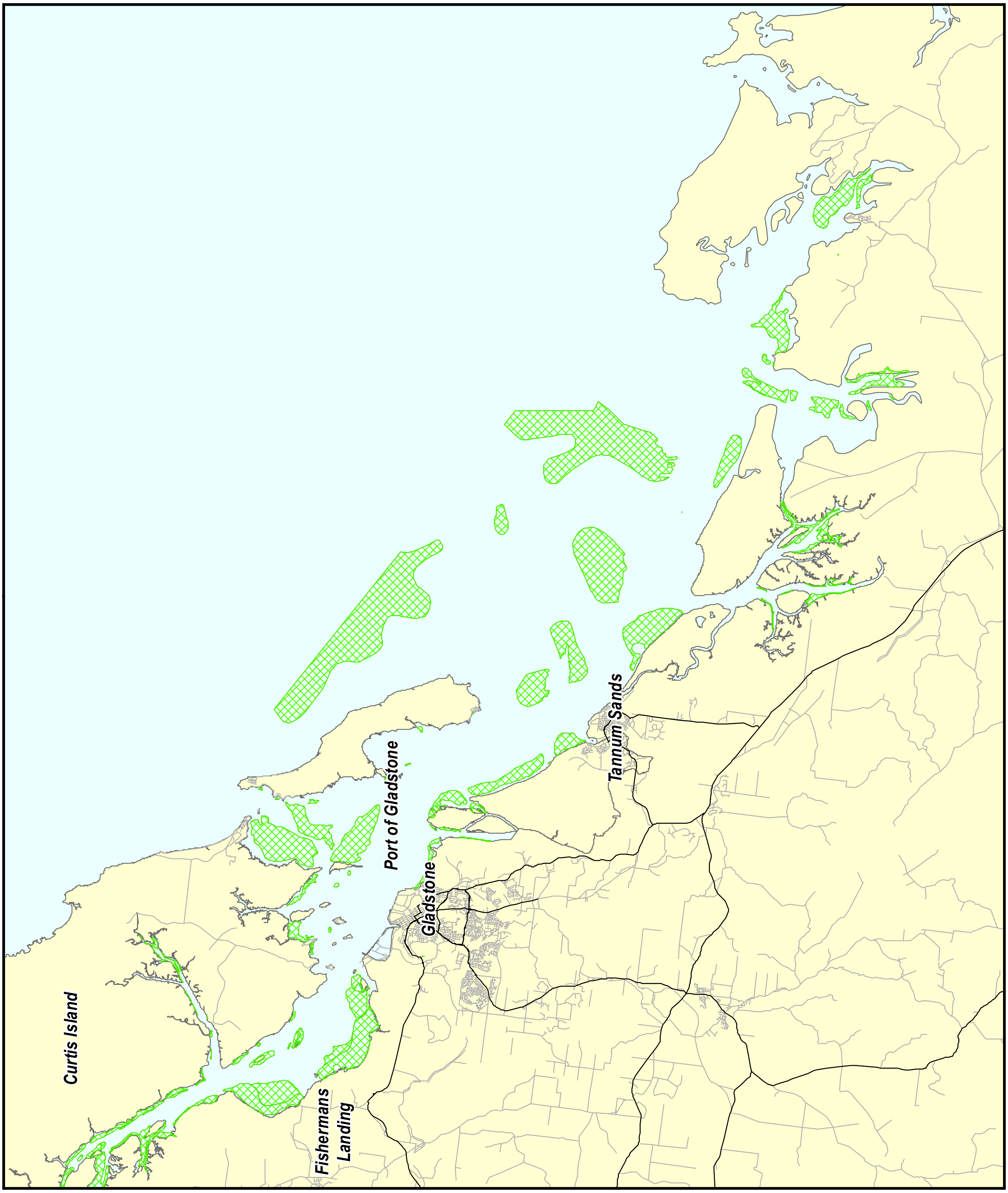
8.9.2 *Impact Assessment*

Seagrasses are an important environmental indicator within Port Curtis, due to their wide distribution and sensitivity to changes in conditions. It is recognised that future activities within Port Curtis have the potential to impact on these communities. The total area of seagrass meadows within the Port of Gladstone region has been estimated to be 6,118 ha[18], comprising 2,998 ha (49 per cent) in aggregated patches, 871 ha (14 per cent) in continuous seagrass cover and 132 ha (2 per cent) in isolated patches (refer to *Figure 5.8.15*).

Impacts to seagrasses within Port Curtis due to the proposed QCLNG activities may arise through the construction of the MOF and Construction Dock facilities (direct loss of habitat), The Narrows Pipeline crossing and through altered water quality conditions due to dredging and disposal (indirect loss of habitat). The direct loss of seagrasses associated with the construction of proposed infrastructure will be an irrecoverable loss of habitat; however, the potential indirect loss of seagrass due to altered water quality may be temporary with recovery of the seagrass following re-establishment of ambient water quality conditions post-completion of dredging.

Volume 6, Section 2.3.4 presents the results of modelling of suspended sediment levels arising from the dredging scenarios considered for the Project

18 Rasheed, M.A., Thomas, R, Roelofs, A.J., Neil,K.M and Kerville, S.P (2003). Port Curtis and Rodds Bay seagrass and benthic macro-invertebrate community baseline survey. November/December 2002. DPI Information Series QI03058 (DPI,Cairns), 47pp.)



Legend

Seagrass

Source Note:
Seagrass Distribution; Produced by Queensland Department of Primary Industries and Fisheries: 2002, Updated 2003

Projection: UTM MGA Zone 56

Datum: GDA 94

0 2 4 8 km

N

QUEENSLAND CURTIS LNG A BG Group business	Project Queensland Curtis LNG Project		Title **Seagrass in the Port of Gladstone Region, 2003**
	Client QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn KP	sEIS Volume 5 Figure 5.8.15	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved BK	File No: 0086165b_SUP_GIS025_S5.8.15	
	Date 19.01.10	Revision 0	

Table 5.8.12 provides a breakdown of the percentage and area cover of seagrasses likely to be directly impacted on by the proposed QCLNG dredging activities. No seagrass is estimated to be lost with the proposed MOF infrastructure, while approximately 0.004 ha of seagrass will be lost due to the Construction Dock. An area of 1 to 2 ha may be directly impacted on by the Pipeline crossing of The Narrows, predominantly at Friend Point. Relative to the total area of seagrass habitat present within the Port Curtis area, the direct loss of seagrasses due to the proposed infrastructure is considered minor.

Table 5.8.12 Direct loss estimates as a percentage and area cover (in ha) of seagrasses due to the proposed QCLNG infrastructure.

Factor	Loss estimate (in ha)	% Loss in Management Zone
MOF	0	0
Construction Dock	0.0036	<0.001
Pipeline Narrows crossing	1 to 2	≤0.03

* Areas based on 2002 habitat mapping.

Seagrasses rely on an optimal light climate for photosynthetic production. The level of optimal light may vary both within and between species, depending on the prevailing conditions at a particular location. Consequently, the sensitivity of seagrass to changes in light associated with deteriorating water quality (i.e. through increased turbidity and sedimentation due to dredging and material disposal), may differ within and between species depending on the prevailing conditions at a particular location. The impacts of deteriorating water quality on seagrass also show seasonal variance[19] .

The primary detrimental effect of increased turbidity on seagrass, is the increased attenuation of light, which affects the amount of light available for photosynthetic production[20]. Increased turbidity can reduce light to levels that cause sub-lethal stress or mortality. The severity of the impact is dependent on several factors including the duration of increased turbidity, the species of seagrass, and local hydrodynamic and oceanographic conditions[21].

Seagrasses can cope with temporary fluctuations in turbidity if the period of light reduction is limited. The threshold time length is species-specific and also

19 Erftemeijer PLA, Lewis RRR (2006) Environmental impacts of dredging on seagrasses: a review. Marine Pollution Bulletin, 52:1553–1572

20 Ralph PJ, Durako MJ, Enríquez S, Collier CJ, Doblin MA (2007) Impact of light limitation on seagrasses. Journal of Experimental Marine Biology and Ecology. 350: 176–193

21 Westphalen G, Collings G, Wear R, Fernandes M, Bryars S, Cheshire A (2004) A review of seagrass loss on the Adelaide metropolitan coastline. ACWS Technical Report No. 2 prepared for the Adelaide Coastal Waters Study Steering Committee. South Australian Research and Development Institute (Aquatic Sciences), Publication No. RD04/0073, Adelaide

depends on other environmental conditions[22]. Thresholds for light deprivation for seagrasses range from a few weeks to several months[23].

Increased turbidity due to dredging operations may be short-lived, but reworking and resuspension of unconsolidated deposited sediments in shallow areas may result in long-term impacts, which may cause a decline in seagrass habitat through prolonged light reduction[24]. Impacts to seagrasses exposed to pulsed turbidity events lasting a month or more are well documented[25].

Indicators of light stress in seagrass include both morphological and physiological responses. Morphological responses include changes in plant biomass and canopy height. Physiological responses include alterations to carbohydrate, tissue nutrient and chlorophyll-a concentrations, and adjustments in the efficiency with which light energy is captured and converted at the molecular level[26].

Maximum potential indirect losses have been calculated for seagrasses that will be exposed to depth averaged TSS concentrations greater than 25 mg/L (including forecast ambient TSS) for 50 per cent of the time (50th percentile), 20 per cent of the time (80th percentile) and 5 per cent of the time (95th percentile). Indirect losses have been estimated for each of the modelling scenarios 1 to 3 (*Table 5.8.13*), and for the percentile plots of the median, 50th, 80th and 95th for each of these scenarios. No indirect losses were predicted for the dredging associated with The Narrows Pipeline crossing. This is due to the relatively short duration of individual operations (trenching across The Narrows is expected to take three weeks), with periods between these operations during which there will be no discharges, which results in median increases in depth-averaged TSS concentrations within the range of natural background estimates when calculated over the full duration of the operation. During construction of The Narrows Pipeline crossing, TSS concentrations above 25 mg/L are only predicted to occur 5 per cent of the time (95th percentile).

Seagrass shading experiments commenced in November 2009 to characterise the light environment that seagrasses are accustomed to within the Port of Gladstone. Incorporation of the results of the field study shading experiments and light attenuation modelling will further refine predictive capacity.

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22 Ibid

23 *Op Cit. 29*

24 Onuf CP (1994) Seagrasses, Dredging and Light in Laguna Madre, Texas, U.S.A. Estuarine, Coastal and Self Science, 39:75-91

25 Moore KA, Wetzel RL, Orth RJ (1997) Seasonal pulses of turbidity and their relations to eelgrass (*Zostera marina*L.) survival in an estuary. Journal of Experimental Marine Biology and Ecology, 215: 115-134; Longstaff BJ, Dennison WC (1999) Seagrass survival during pulsed turbidity events: the effects of light deprivation on the seagrasses *Halodule pinifolia* and *Halophila ovalis*. Aquatic Botany, 65:105-121.

26 *Op Cit. 29*

Table 5.8.13 Indirect loss risk estimates as a percentage and area cover of seagrasses due to depth averaged TSS concentrations exceeding a threshold of 25 mg/L.

	Percentile	Equivalent No. of days exceeding TSS threshold	Area of seagrass (ha)	% of Port Curtis* seagrass
1: CSD dredge (~500 m^3/hr), spoil pumped to the reclamation, duration of ~53 days	50	26	244.3	4.0
	80	11	262.9	4.3
	95	3	363.2	5.9
2: BHD at MOF and Construction Dock, spoil barged to offshore, duration of ~ 90 days	50	45	304.5	5.0
	80	18	328.6	5.4
	95	4	429.9	7.0
3: Large CSD dredge (~1500 m^3/hr), spoil pumped to the reclamation, duration of ~64 days	50	32	248.8	4.1
	80	13	290.4	4.7
	95	3	381.3	6.2

* Areas based on 2002 habitat mapping, as illustrated by *Figure 5.8.15*

The demarcation of impact, monitoring and management zones has been based upon the areas encompassed by depth averaged TSS concentrations. Specifically, within the area encompassed by the 50th percentile of 25 mg/L TSS (the Seagrass Impact Area or SIA) impacts are expected and therefore monitoring will only be undertaken for the purposes of validating outcomes and refining predictive capacity. *Table 5.8.13* identifies this area as being 244 ha for dredging Scenario One, 305 ha for dredging Scenario Two and 250 ha for dredging Scenario Three. No management criteria are specified for this zone in the DDMP. It is expected that the seagrasses within the SIA will regrow or recolonise within one to three years of cessation of dredging.

Within the area that the 80th and 95th percentiles encompass (Seagrass Management Area 1, SMA 1), impacts are possible but unlikely, and so monitoring for reactive management purposes will be implemented in this zone. This represents a further 119 ha to 133 ha, depending upon the dredging scenario (*Table 5.8.13*). Reactive management criteria for this zone are outlined in the DDMP.

For areas outside the 95th percentile (Seagrass Management Area 2, SMA 2), no impacts are predicted. Therefore, monitoring will be undertaken to confirm this, and to serve as a comparison zone for interpreting any changes within SMA 1. If necessary, management criteria for SMA 1 will be used for SMA 2, and additional reference sites further afield would be used for comparative purposes.

The percentile plots presenting contours of depth-averaged TSS, from which the data in *Table 5.8.13* are derived, are based on the maximum depth averaged TSS occurring in each cell over the duration of the dredging operation. It is therefore considered that the estimated impact areas are conservative and that the actual area affected may be less than those predicted.

To better understand the period of exposure it is necessary to examine the cumulative TSS concentration at sites of concern presented in *Volume 6, Section 2.3.4* and summarised in *Table 5.8.14*.

Table 5.8.14 Summary of predicted TSS concentrations received at sites for different dredge scenarios

<table>
<tr><th>Site</th><th>Location of meadow</th><th>Scenario 1</th><th>Scenario 2</th><th>Scenario 3</th></tr>
<tr><td>1</td><td>Adjacent to Laird Point.</td><td>Does not at any time receive TSS exceeding ~22 mg/L.</td><td rowspan="3">Characterised by elevated concentrations on near-daily basis with peaks in TSS concentrations associated with neap tide events of about 30 mg/L (Site 1) and 40 mg/L (Sites 2 and 3).</td><td>Increase in background concentrations typically occurred within the second half of the dredge operations. Within this time two peak periods are identified and levels exceeding 18 mg/L (6 mg/L above ambient).</td></tr>
<tr><td>2</td><td>Adjacent to the decant water outlet in northern part of Western Basin.</td><td>Predicted to consistently receive TSS exceeding 25 mg/L with spikes of up to ~40 mg/L.</td><td>Concentrations of 70mg/L or greater are predicted to occur at least five times on tidally-influenced cycle.</td></tr>
<tr><td>3</td><td>Adjacent to the Construction Dock.</td><td>Predicted to receive periods of extended increases in TSS with concentrations > 18 mg/L occurring frequently and a maximum of ~ 26 mg/L.</td><td>Predicted a near-daily occurrence of elevated TSS concentrations with a maximum concentration of 80 mg/L (70 mg/L above ambient).</td></tr>
<tr><td>4</td><td>South of Passage Island.</td><td rowspan="2">Increased concentrations with clusters of events either side of the neap tide resulting in ~ 8 to 10 days exposure to greater than ~ 36mg/L (Site 4) and 19 mg/L (Site 5).</td><td rowspan="2">Predicted to receive with near-daily increases of background TSS concentrations. Maximum concentrations also follow cyclic patterns as a result of the tidal regime of the Port. Peaks at Site 4 typically exceed 42 mg/L while at Site 5 TSS was above 26 mg/L (background level 17 mg/L) on numerous occasions.</td><td>Intermittent peaks > 42 mg/L (5 mg/L above background).</td></tr>
<tr><td>5</td><td>South of the Fisherman's Landing</td><td>Cyclic pulses above the background and TSS levels typically exceeded 20 mg/L with maximum concentration nearing 28 mg/L (10 mg/L above ambient).</td></tr>
<tr><td>6</td><td>North of Wiggins Island.</td><td colspan="3">No increases of background TSS concentrations are predicted.</td></tr>
</table>

Sedimentation may also impact on seagrasses causing stress, mortality or changes in habitat distributions. The settlement of suspended material on seagrass leaves may interfere with photosynthesis by restricting light capture[27]. If sedimentation rates are high, this can ultimately result in burial and, often, rapid mortality[28]. These impacts may be exacerbated where epiphytes are abundant on seagrass blades, as greater amounts of sediment will be accumulated[29].

The impact of sedimentation on seagrass depends on several factors, such as the depth of burial, the properties of the sediment, and the species of seagrass[30]. If seagrasses are only lightly covered and the rhizome system is not damaged, re-growth through the sediment may be possible[31]. However, if plant elongation and growth rates are too slow to surpass sediment accretion rates, direct mortality may result. Data presented in *Table 5.8.15 is* based upon experimental burial rates of 2 cm to 16 cm over a period of 60 days to 300 days. These rates (over the 300-day experimental period) are equivalent to net sedimentation rates (i.e. the balance of sedimentation over resuspension) of 65 $g/m^2/day$ to 524 $g/m^2/day$.

Shoot mortality is a common response in seagrasses exposed to burial from sedimentation[32]. In some species, mortality following burial can be extremely rapid (e.g. *Cymodocea serrulata*, *Halodule uninervis*, *Syringodium isoetifolium*), while other species can survive burial for prolonged periods (e.g. *Enhalus acoroides*)[33]. Seagrass species with vertical shoots (e.g. *Cymodocea*, *Thalassia*, *Thalassodendron*, *Syringodium*, *Halodule*) can respond to increased sedimentation by relocating the leaf-producing meristems (growth centres) closer to the new sediment level. This mechanism for enhanced vertical growth is triggered by a light-sensitive mechanism located in the shoot meristem[34].

The capacity of seagrass species to withstand sediment burial may be size dependent[35]. Data presented in *Table 5.8.15* indicates that small species of seagrass, such as *Cymodocea serrulata* and *Halophila ovalis*, characterised by low shoot mass, low above-ground biomass, thin rhizomes, high horizontal

27 Tamaki H, Tokuoka M, Nishijima W, Terawaki T, Okada M (2002) Deterioration of eelgrass, Zostera marina L., meadows by water pollution in Seto Inland Sea, Japan. Marine Pollution Bulletin 44:1253-1258.

28 Mills KE, Fonseca MS (2003) Mortality and productivity of eelgrass Zostera marina under conditions of experimental burial with two sediment types. Marine Ecology Progress Series 255:127-134.

29 Erftemeijer PLA, Lewis RRR (2006) Environmental impacts of dredging on seagrasses: a review. Marine Pollution Bulletin, 52:1553–1572

30 Duarte CM, Terrados J, Agawin NSR, Bach S, Kenworthy WJ (1997) Response of a mixed Philippine seagrass meadow to experimental burial. Marine Ecology Progress Series, 147:285–294

31 Wilber DH, Brostoff W, Clarke DG, Ray GL (2005) Sedimentation: Potential Biological Effects of Dredging Operations in Estuarine and Marine Environments. Engineering Research and Development Centre, Vicksburg MS, Technical note, 15 pp

32 Cabaço S, Santos R, Duarte CM (2008) The impact of sediment burial and erosion on seagrasses: A review. Estuarine, Coastal and Shelf Science, 79: 354-366

33 Duarte CM, Terrados J, Agawin NSR, Bach S, Kenworthy WJ (1997) Response of a mixed Philippine seagrass meadow to experimental burial. Marine Ecology Progress Series, 147:285–294.

34 Ibid

35 Cabaco et al.(2008) Op Cit No. 32, and Duarte et al (1997) Op Cit No. 33

rhizome elongation and small leaves, are more sensitive to burial[36]. Conversely, larger species appear more robust[37].

Similarly, seagrass sensitivity to increased turbidity and sedimentation is greater in species with lower carbohydrate stores (e.g. *Halophila ovalis*) than those with high carbohydrate stores (e.g. *Thalassia testudinum*; *Posidonea sinuosa*). However, although larger, slow-growing species with substantial carbohydrate reserves show greater resilience to turbidity and sedimentation than smaller species, the latter display much faster post-dredging recovery when water quality conditions improve[38].

Table 5.8.15 Response of seagrass species to experimental burial[39]

Species	Burial levels (cm)	Experiment-al period (days)	Burial Level (cm)		Comment
			50% Mort.	100% Mort.	
C. serrulata	2, 4, 8, 16	60, 120, 300	2	–	Initial shoot density decline in high burial levels (8 and 16 cm) followed by shoot density recovery.
E. acoroides	2, 4, 8, 16	60, 120, 300	4	–	Shoot density decline only by the end of the experiment (300 days).
H. uninervis	2, 4, 8, 16	60, 120, 300	4	–	Initial shoot density decline in high burial levels (8 and 16 cm) followed by shoot density recovery.
H. ovalis	2, 4, 8, 16	60, 120, 300	2	2	Early increase of shoot density at intermediate burial levels (4 and 8 cm of burial).
S. isoetifolium	2, 4, 8, 16	60, 120, 300	8	–	Initial shoot density decline in high burial levels (8 and 16 cm) followed by shoot density recovery.
T. hemprichii	2, 4, 8, 16	60, 120, 300	4	–	Shoot density decline.

Seagrass recovery from sediment burial and erosion following natural disturbances is relatively independent of their specific burial thresholds, dependent strongly on their longer-term colonisation capacity and patch dynamics[40]. These characteristics represent different strategies for survival in the face of stress or disturbance. Smaller fast-growing (short-lived) species such as *Halophila ovalis* or *Halodule wrightii* generally do not survive long

36 Cabaco et al.(2008) Op Cit No. 32

37 Duarte et al (1997) Op Cit No. 33

38 Erftemeijer PLA, Lewis RRR (2006) Environmental impacts of dredging on seagrasses: a review. Marine Pollution Bulletin, 52:1553–1572

39 Op Cit No. 32

40 Ibid

once their environmental thresholds have been breached. However, these species tend to recolonise more rapidly following disturbance. Rasheed (1999)[41] found that experimentally cleared plots in meadows dominated by the relatively slow-colonising species *Z. capricorni* recovered to the level of the uncleared controls after 12 months.

The predicted levels of sedimentation for the areas of risk for Scenario 1 are low. The 95th percentile map for sedimentation rate shows two distinct areas; along the western shoreline of Curtis Island from the MOF site to areas surrounding Hamilton Point and adjacent the tail-water discharge site, predicted to be influenced by sedimentation rates in the order of 2 and 5 g/m^2/day, (net sedimentation of approximately 0.06 mm to 0.16 mm/month of continuous exposure), respectively. This order of sedimentation rate is unlikely to cause mortalities or preclude recolonisation by seagrass once water turbidity has recovered to normal conditions.

In Scenario 2 the 95th percentile map for sedimentation rate shows extended areas of increased sedimentation rates resulting from the BHD operations, ranging between 2 and 100 g/m^2/day (3.1 mm/month). Sedimentation rates surrounding Hamilton Point and the small group of adjacent islands are predicted to be > 5 g/m^2/day with rates as high as 100 g/m^2/day, adjacent to the MOF. Again this sedimentation rate is unlikely to cause mortalities or preclude recolonisation by seagrass once water turbidity has recovered to normal conditions.

Modelling of Scenario 3 predicted, for the 95th percentile (worst case), sedimentation rates ranging between 2 and 100 g/m^2/day. Predicted sedimentation rates of 2 g/m^2/day occur in a predominantly continuous contour from waters between Barney Point and South Trees Island, to Friend Point and Laird Point in the north of the estuary. Sedimentation rates of 5 g/m^2/day or greater were scattered among Laird Point, waters near the tail-water discharge site on the western side of Port Curtis. Regions between the MOF and Picnic Island on the eastern side of the port were characterised by typically more continuous areas. Predicted zones of sedimentation rates 25 g/m^2/day (0.78 mm/month) or greater were concentrated at the entrance of Grahams Creek, North Passage Island and immediately adjacent to the proposed land reclamation site in the northern region of the port and surrounding Hamilton Point and Picnic Island with the central port region. As with other cases modelled, the predicted rates of sedimentation are unlikely to cause mortalities or preclude recolonisation by seagrass once water turbidity has recovered to normal conditions.

Similarly, the accumulation of sediments associated with The Narrows pipeline crossing is minimal. Fine sediments are predicted to be spread widely but thinly throughout Targinie Creek and the adjacent estuary, with a downstream bias. The highest sedimentation rates area indicated to equate to an average thickness of a approximately 5 mm, while the lowest concentrations equate to

41 Rasheed MA (1999) Recovery of experimentally created gaps within a tropical Zostera capricorni (Aschers.) seagrass meadow, Queensland Australia. Journal of Experimental Marine Biology and Ecology, 235 (1999) 183–200

an average thickness of 6 µm. Again this sedimentation rate is unlikely to cause mortalities or preclude recolonisation by seagrass once water turbidity has recovered to normal conditions.

8.10 PORT CURTIS REEF HABITATS

8.10.1 Additional Baseline

A study was commissioned by QCLNG to provide further information on characterisation of spatial patterns in intertidal reef habitats and benthic communities in intertidal and sub-littoral reef environments.

8.10.1.1 Intertidal Rocky Shores

Port Curtis is a depositional environment and consequently intertidal rocky shores are generally restricted to areas that experience relatively strong tidal currents and wave action (i.e. the lower intertidal zone). Overall, exposed intertidal rocky shores within Port Curtis cover 297 ha, which represents ~1.4% of the total intertidal wetland area of the Port Curtis region.

Unvegetated mud and sand banks (24 per cent), mangroves (~25 per cent), saltpan (18 per cent) and seagrass meadows (~21 per cent) form the largest intertidal habitat areas in the Port Curtis area.

Most of the smaller islands in Port Curtis (Tide, Witt, Picnic, Diamantina, Turtle, Quoin, Compigne, Chinaman and Rat islands) are located to the south of Curtis Island. These islands appear to be an extension of the elevated ridge lines on Curtis Island as they intersect the waters of Port Curtis. The smaller islands are generally characterised by steeply sloping rocky shorelines consisting of boulders and ridges of the underlying parent rock material. In places, the rocky shores have been covered by littoral drift deposits of sand, shell and fine mud materials. Examples of this occur at Quoin and between Witt and Diamantina Islands. The Passage Islands west of Curtis Island also appear to have resulted from the littoral deposition of muddy sediments over a submerged former ridge line.

By contrast, the intertidal foreshores of the barrier islands (Curtis and Facing islands) within Port Curtis are often gently sloping with broad expanses of sandy or muddy intertidal flats backed by mangroves and separated by pronounced rocky headlands or points consistent with the major topographic ridgelines of each island. These are structurally complex intertidal habitats that contain a mosaic of habitat for marine flora and fauna communities. Gatcombe Head, located on the southern tip of Facing Island, differs from all other intertidal rocky shores in the study area in that it is steeply sloping and has limited mud/sand deposits. This headland is exposed to strong tidal currents and oceanic swells from the south and east.

8.10.1.2 *Sub-Littoral Reefs*

The water quality of Port Curtis is characterised by high suspended sediment loads at most times of the year with a noticeable gradient in water clarity, which improves towards the sea (South Channel and North Entrance) and diminishes further into the harbour towards The Narrows.

The benthic reef fauna and flora assemblages of Port Curtis exist within the constraints imposed by variable water (and air) temperature range, large tidal range, strong tidal currents and low light levels and associated high suspended solid concentrations. Most light-dependent reef-building corals, seagrass and seaweed (macroalgae) species therefore occur from the lower intertidal area to a depth not usually exceeding 2 m below low-water datum.

Many of the rocky shores extend into subtidal waters to form rocky reefs/rubble banks. Baseline deepwater benthic habitat assessments in Port Curtis[42] recorded nine reef habitat classes on the basis of density, diversity and types of epifauna. The dominant habitat classes found were:

- medium-density benthic community on rubble substrate, dominated by bryozoans, hard coral, hydroids, echinoids (1984 ± 1612 ha). This habitat class was recorded south of East Banks and Facing Island
- high-density benthic community – scallop/rubble substrate dominated by a bivalves with a mix of reef biota (1456 ± 832 ha). This habitat class was recorded in deepwater areas (coincident with navigation channels between Fisherman's Landing and west Facing Island, as well as a patch south of Gatcombe Head (south of Facing Island)
- high-density benthic community on rubble substrate dominated by sponges, soft coral, hard coral, hydroids, bryozoans, gorgonians and a mix of other benthic taxa (915 ± 352 ha)
- high-density benthic community on rubble substrate dominated by bryozoans, sponges, low numbers of other taxa (944 ± 337 ha). This habitat class occurred east of Boyne Island.

Reefs located in North Passage and along the western side of Facing Island typically had high hard coral cover, with a maximum value of >47 per cent cover (average = 39 per cent). However, at the two turbid fringing reef sites, hard coral was low (average = 4 per cent), and observations indicated that coral colony size was typically low (<15 cm diameter). This suggests that reefs in these areas may be subject to major disturbances on a relatively regular basis, which could include flooding and physical disturbance due to storms and cyclones. It is also possible that the low cover and colony size is a consequence of low growth and/or recruitment rates, possibly in response to high sedimentation levels, low light levels and/or low water temperatures.

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42 Rasheed, M.A., Thomas, R, Roelofs, A.J. Neil, K.M. and Kerville, S.P. (2003). Port Curtis and Rodds Bay seagrass and benthic macro-invertebrate community baseline survey, November/December 2002. DPI Information Series QI03058 (DPI, Cairns), 47 pp.

Hard corals comprised >30 per cent of total benthic cover at five sites: Oaks North, Rat Reef North and South (North Passage), Manning Reef, and Rocky Point South (West and South Facing Island). The hard coral assemblages at these sites were dominated by different taxa, as summarised below:

- Manning Reef, which had the highest recorded coral cover within the study area, was numerically dominated by *Acropora robusta*, a large branching species. Hard coral species together represented <10 per cent cover at this site. A large proportion of dead coral with turfing algae (13 per cent) was recorded in association with these colonies.
- Rat Reef North and Rat Reef South had moderate cover of Acroporid corals, with *A. robusta* dominant at Rat Reef North, and *A. millepora* and tabulate *Acropora* co-dominant at Rat Reef South. These two sites also had a wide variety of other non-Acroporid corals, with *Turbinaria* species co-dominant.
- Rocky Point South and Oaks North had moderately high cover of *Turbinaria* (24 per cent and 15 per cent cover, respectively), ~10 per cent cover of Acroporid corals, and a variety of other hard coral taxa.
- Farmers Reef and Bushy Islet had hard coral assemblages comprised of a variety of non-Acroporid corals (14 per cent and 13 per cent, respectively), with *Pocillopora/Turbinaria* species most abundant at Farmers Reef, and *Porites* species most abundant at Bushy Islet.

In a more recent survey of deeper sub-littoral reefs in the vicinity of Hamilton Points, URS[43] found soft coral cover comprised between 0 per cent and 11 per cent of surveyed transects. This is consistent with trends within Port Curtis whereby sediment-tolerant species dominate to the north and west of the bay.

8.10.1.3 Macroalgae

Macroalgae cover, which is also regulated by ambient light levels, varied greatly among sites from 24 per cent to 63 per cent (mean = 43 per cent ± 12 per cent s.d.). Macroalgae numerically dominated the reef benthos at most sites, with the highest macroalgae cover recorded at the two most turbid sites. However, incidental observations indicated that the macroalgae zone at these sites was restricted to the upper few metres of the water column.

Assemblages were comprised of a range of brown (predominantly *Padina*), green (*Caulerpa, Halimeda*) and red (commonly *Asparagopsis*, as well as foliose and encrusting coralline species) macroalgae species. *Asparagopsis taxiformis* was recorded at all sites and numerically dominated or co-dominated at eight of the 10 sampled sites. This is a relatively common species in near-shore turbid environments in Queensland[44]. One site (Oaks North) was numerically dominated by the brown alga *Padina* (16 per cent cover), together with a wide variety of other macroalgae taxa. Small ''turf''

43 GLNG ProjectSupplementary EIS. December 2009

44 Cribb, A. B. (1996) ''Seaweeds of Queensland: a naturalist's guide.'' (The Queensland Naturalists' Club: Brisbane) ; Huisman, J. M. (2000) ''Marine Plants of Australia.'' (University of Western Australia Press: Perth)

algae was moderately abundant at most sites, most notably Rocky Point North and Rocky Point South (28 per cent to 30 per cent cover).

8.10.1.4 *Other Taxa*

A range of other soft corals and other epifauna species typical of reef environments in the broader region were recorded in Port Curtis. Most of these taxa were heterotrophic filter-feeders, and are not entirely reliant on light (as are the autotrophs) to meet their energy requirements. The periodic low light levels associated with resuspended particles, together with periodic freshwater inflows, is likely to prevent extensive development of reef-building corals and other autotrophic species. By contrast, the high phytoplankton biomass would provide a plentiful food resource for heterotrophic particle feeders.

8.11 POTENTIAL IMPACTS TO CORAL REEFS

Sedimentation, suspended solids (SS) and turbidity are natural agents of coral disturbance. The water quality of Port Curtis is characterised by high suspended sediment loads at most times of the year. This is due to the typically large tidal range (mean tidal range of 3.3 m), with strong tidal (ebb and flood) currents in all channels in the harbour, which resuspend bed sediments. There are also typically turbid and low-salinity outflows from the surrounding catchment (via Boyne and Calliope rivers) during the summer months. There is a noticeable gradient in water clarity, which improves towards the sea and reduces further into the harbour towards The Narrows.

These environmental conditions have a strong influence on spatial patterns in reef community structure within Port Curtis. In a recent survey, reefs located in North Passage and along the western side of Facing Island typically had high hard coral cover, with a maximum value of >47 per cent cover (mean of 39 per cent). However, at the turbid fringing reef sites near Curtis Island hard coral cover was found to be low (average of 4 per cent)[45]. Further west and north, and in closer proximity to the QCLNG site, URS[46] recently identified soft-coral dominated sub-littoral reefs, with a maximum of approximately 11 per cent cover. In these areas live corals comprised as much as 30 per cent of live benthic cover.

Dredging can increase sedimentation, SS and turbidity levels above background for moderately large time scales (e.g. months). However, as indicated by modelling presented in *Volume 6* and previous monitoring, these impacts occur at a relatively small spatial scale (e.g. 1 km to 12 km from source). The following sections discuss the impacts of dredging on corals and the impacts that may occur as a result of dredging activities associated with the proposed QCLNG Project.

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45 BMT WBM (2009) Port Curtis Reef Assessment Report

46 GLNG Project Supplementary EIS. December 2009

8.11.1 Effects of Suspended Solids

Elevated SS can have positive and negative effects on corals, depending on their stage of development. Whereas SS, in the form of particulate organic matter, can be consumed by adult corals[47], excessive SS can have detrimental effects on coral gametes and larvae. Gilmour (1999)[48] assessed the effects of SS on fertilisation and planulae larval survival in the coral *Acropora digitifera*. He found that high (100 mg/L) and low (50 mg/L) SS concentrations significantly decreased fertilisation, but post-fertilisation embryonic development was not inhibited. It was suggested that the presence of sediment particles may increase egg aggregation to the extent of inhibiting fertilisation success or, alternatively, adherence of sediment particles to the surface of an egg might have the same effect.

Conversely, increased SS may be beneficial to adult corals, particularly when stressed from increased turbidity[49]. Particulate organic matter can provide substantial energy and growth benefits for some coral species[50]. This might compensate for a reduction of photosynthetic activity due to increased turbidity.

8.11.2 Effects of Turbidity

In naturally turbid environments, such as the western parts of Port Curtis, coral communities can remain healthy by three mechanisms[51]:

- rapid replenishment of energy reserves during periods between sublethal turbidity events
- shifts between phototropic and heterotrophic dependence
- rapid rates of photoacclimation, a process where corals can adjust to lower light by increasing the size and amount of chloroplasts in zooxanthellae.

Recent monitoring results[52] have concluded that moderate turbidity and short phases of high turbidity seem less detrimental than sedimentation. This was confirmed by Stoddart *et al*. (2005)[53] who assessed the effects of a dredge plume on corals at Dampier, Western Australia. They reported that coral

47 Anthony, KRN (2000). Enhanced particle-feeding capacity of corals on turbid reefs (Great Barrier Reef, Australia). Coral Reefs 19, 59-67.

48 Gilmour, J (1999). Experimental investigation into the effects of suspended sediment on fertilisation, larval survival and settlement in Scleractinian coral. Marine Biology 135, 451-462.

49 Anthony, KRN (2000). Op cit 47

50 Anthony, KRN and Fabricius, K. 2000. Shifting roles of heterotrophy. Journal of Experimental Marine Biology and Ecology 252, 221-253.

51 Anthony, KRN & Larcombe, P 2002. Coral reefs in turbid waters: sediment-induced stresses in corals and likely mechanisms of adaptation. pp. 239-244. In: Proceedings of the 9th International Coral Reef Symposium, Bali. Ed. Kasim Moosa. Bali, Indonesia.

52 Sanders, D and Baron-Szabo, R (2005). Scleractinian communities under sediment input: their characteristics and relation to the nutrient input concept. Palaeo 216: 139-181.

53 Stoddart, JA, Blakeway, DR, Grey, KA and Stoddart, SE (2005). Rapid high-precision monitoring of coral communities to support reactive management of dredging in Mermaid Sound, Dampier, Western Australia. In: Corals of the Dampier Harbour: Their Survival and Reproduction During the Dredging Programs of 2004. Soddart, JA & Stoddart, SE (Eds.). Published by Mscience.

communities at monitoring sites 500 m and 1 km from dredging and disposal sites did not respond to turbidity levels significantly above background for several weeks, or in very intense events of a few days. Fabricus (2005)[54] surmised that the effects of shading from turbidity are minimal in shallow water and progressively increase with depth.

8.11.3 Effects of Sedimentation

Coral larvae settling from the plankton to the seabed require a hard surface on which to settle. Larvae will not successfully settle on loose sediment, therefore sedimentation affects recruitment by both decreasing the amount of substrate available for settlement and decreasing survivability of settling larvae[55].

Juvenile corals (those that have successfully settled onto hard substratum) are highly susceptible to sedimentation because of their small size[56]. Sedimentation events that may rapidly smother and kill juvenile corals may be inconsequential to adult coral colonies. Therefore, a sedimentation event may alter the age-structure of a coral population by killing the smaller members of the population. In addition, sedimentation can result in partial colony mortality, which will reduce the mean size of coral colonies in a population.

Coral communities are often highly diverse, supporting many species of scleractinian coral and different coral growth forms. Different species will have different sedimentation tolerance thresholds to sedimentation in terms of amount of, and duration of (exposure), sedimentation that a coral can withstand before resulting in negative physiological response, including both sublethal and lethal affects (*Table 5.8.16)*. The structure of coral communities in Port Curtis has been found to be consistent with the general rule of declining coral species diversity and coral cover along natural gradients of increasing turbidity.

Table 5.8.16 Sedimentation rates and duration before negative physiological response, or mortality was observed.

Genius species	Accumulation rate ($g/m^2/day$)	Duration (Days)	Reference[57]
Acropora millepora	1.0	2	Babcock & Davies (1991)
Acropora palmata	<20.0	<1	Rogers (1983)
Acropora cervicornis	20.0	38	Rogers (1983)

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54 Fabricius, KE (2005). Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis. Marine Pollution Bulletin 50, 125-146.

55 Babcock, R and Davies, P (1991). Effects of sedimentation on settlement of Acropora millepora. Coral Reefs. 9, 205-208; Gilmour, J (1999). Experimental investigation into the effects of suspended sediment on fertilisation, larval survival and settlement in Scleractinian coral. Marine Biology 135, 451-462.

56 Wittenburg, M and Hunte, W (1992). Effects of eutrophication and sedimentation on juvenile corals. I. Abundance, mortality and community structure. Marine Biology 116, 131-138.

57 Babcock, R dan Davies, P (1991). Effects of sedimentation on settlement of Acropora millepora. Coral Reefs. 9, 205-208: Rogers, CS (1983). Sublethal and lethal effects of sediments applied to common Caribbean reef corals in the field. Marine Pollution Bulletin 14, 378-382; Stafford-Smith, MG (1992). Mortality of the hard coral Leptoria phrygia under persistent sediment influx. Proceedings of the Seventh International Coral Reef Symposium, Guam. 1: pp. 289-299: Hodgson, D (1990). Tetracycline reduces sedimentation damage to corals. Marine Biology 104, 493-496.

Genius species	Accumulation rate ($g/m^2/day$)	Duration (Days)	Reference[57]
Diploria strigosa	20.0	38	Rogers (1983)
Diploria clivosa	<20.0	38	Rogers (1983
Montastrea annularis	20.0	38	Rogers (1983)
Leptoria phrygia	>2.5	21	Stafford-Smith (1992)
Montipora verrucosa	>1.0	10	Hodgson (1990)
Oxypora glabra	2.0	98	Hodgson (1990)
Pocillopora mendrina	>1.0	10	Hodgson (1990)
Porites lobata	>1.0	10	Hodgson (1990)

With the exception of Babcock & Davies (1991), all experiments were undertaken in relatively clear water environments (e.g. normally experience low levels of sedimentation). The former was undertaken in aquaria.

A number of field studies have confirmed that sedimentation can have coral community-wide effects, typically by killing the least tolerant species. *Table 5.8.17* provides a list of sediment accumulation rates measured over reefs experiencing some impact. It differs from the studies listed in *Table 5.8.16* because it focuses on community-wide effects rather than on individual species.

Table 5.8.17 **Sediment accumulation rates measured over reefs experiencing some impact (modified after Thomas and Ridd, 2005[58]).**

Accumulation rate ($g/m^2/day$)	Location	Additional information	Reference
Environments with naturally low levels of sedimentation			
20 40 80	Caribbean, Puerto Rico	Death of dominant species. *Acropora palmate.* *Acropora cervicornis.* *Montastraea annularis.*	Roger (1979)
1.3 to >50, median 6.5, average 15.2	Puerto Rico	Impact from river runoff in timber-cleared area; stress if rate maintained >3.0.	Cortes & Risk (1985)
Environments with naturally high levels of sedimentation			
8.6 near old road, 12.9 near new road	GBR, Cape Tribulation	Sedimentation increase caused by higher sand erosion in new road area.	Hoyal (1986)
0.9-1.2	Malindi	Site influenced by soil erosion but no impact detected. *Porites* and *Galaxea* dominating.	McClanahan & Obura (1997)

These studies have been classified into those conducted in environments characterised by those with naturally low levels of sedimentation and low turbidity waters, and those with naturally high levels.

8.11.4 *Potential Impacts to Coral Associated with Proposed Dredging Activities*

Results of modelling carried out to predict the extent and rate of sedimentation as a result of dredge operations for the three dredge operation scenarios considered is presented in *Volume 6, Section 2.3.6*

58 Thomas, S and Ridd, P (2005). Field assessment of innovative sensor for monitoring of sediment accumulation at inshore coral reefs. Marine Pollution Bulletin 51, 470–480

For Scenario 1 and Scenario 3 the 95th percentile plots indicate maximum predicted sedimentation rates of 25 g/m^2/day [59] in localised areas near to the north-east tip of Tide Island. The reefs of Tide Island, as with other small islands and the fringing western shoreline of Curtis Island, typically have high macroalgae cover and low coral cover. Nearby Turtle Island was found to have 4.3 per cent hard coral cover, which was comprised almost exclusively of *Favites* while Diamantina Island was found to have 1.5 per cent cover of *Turbinaria*, (no other hard coral taxa was recorded). The predicted 95th percentile sedimentation rate at more distant reefs is less than 2 g/m^2/day.

None of the reported literature values for critical sedimentation rates were determined for soft corals. As these frequently occur in higher turbidity environments (and do so within Port Curtis), it can be expected that critical sediment thresholds will be higher for soft corals than for hard corals. However, in the absence of alternative supporting data, the hard coral threshold of 2 g/m$^{/day}$ has been used for the assessment of impacts to soft coral.

Soft coral reefs occurring on Hamilton Point and having live coral cover exceeding 10 per cent lie within the critical 95th percentile sedimentation rate for Scenarios 2 and 3, but fall outside of the critical median (50th percentile) sedimentation rate. Predicted plumes from Scenario 1 do not impinge upon these communities at levels that pose a threat.

It is unlikely that the predicted rate of sedimentation associated with Scenarios 1 and 3 would cause significant mortality to corals. This is because the most severe rates of sedimentation are localised in areas of low coral abundance and the species that are present are those naturally adapted to high rates of sedimentation and SS.

For Scenario 2 the 95th percentile map shows extended areas of increased sedimentation rates resulting from the BHD operations, ranging between 2 and 100 g/m^2/day. Predicted areas characterised by rates of 2 g/m^2/day occur along the length of the estuary from The Narrows and Grahams Creek in the north to the deep channel waters at the entrance of the port. Closely banded with these areas are zones predicted to incur rates of 5 g/m^2/day. Turtle Island and Diamantina Island reefs are predicted to receive daily cycles of SS concentrations greater than 40 mg/L with a number of peaks occurring > 60 mg/L above background turbidity.

The predicted rate of sedimentation associated with Scenario 2 may cause some hard-coral mortality at the low percentage cover reefs of Diamantina Island and Turtle Island. Portions of the Hamilton Point soft-coral dominated sub-littoral reefs lie within the 95th percentile contour, and are therefore expected to have a low risk of impact. Additionally, the incidence of hard-coral mortality is likely to be low due to the frequent washing of sediment and input

59 These plots provide a time-summary for each location to identify locations that may be at higher risk. It should be noted that the statistics are calculated independently for each cell, i.e. concentrations would occur at different points in time for each location, and these figures do not show a plume that may occur at any one point in time.

of clearer water caused by daily tidal cycles. Furthermore, most of the reefs are dominated by macroalgae with relatively low coral cover. Consequently the significance of the impact is considered to be minor and the potential for recovery following cessation of dredging is considered to be high.

From the above discussion, it is not considered necessary or practical to monitor low percentage cover hard-coral reefs near Turtle and Diamantina islands, but the soft-coral dominated reefs of Hamilton Point will be included in monitoring and dredge management initiatives in the DDMP.

Dredging operations for The Narrows pipeline crossing are unlikely to impact on corals due to the relatively short duration of individual operations (trenching is expected to proceed across The Narrows in approximately three weeks), which result in minimal increases in sedimentation and TSS, as discussed in *Volume 6.*

8.12 POTENTIAL IMPACTS TO MANGROVES

Impacts to mangroves within Port Curtis due to the proposed activities may arise through the construction of the MOF and Construction Dock facilities (direct removal of habitat). The direct loss of mangroves associated with the construction of proposed infrastructure will be an irrecoverable loss of habitat.

Impacts or indirect loss of mangrove due to increased sedimentation is unlikely occur. However, if impacts or indirect loss do occur due to increased sedimentation, mangroves may recover with re-establishment of ambient sedimentation loads post-completion of dredging. As such, potential direct and indirect impacts to mangroves have been distinguished here, as the subsequent ecological significance of indirect versus direct impacts will differ.

A revised estimate of direct impacts on mangroves in Port Curtis as a result of the Project has been made, based on the amendments to the Project description as described in *Volume 2* of this sEIS. Direct impacts have been calculated addressing the following:

- Pipeline crossing across Humpy Creek and Targinie Creek, and The Narrows. It should be noted that mangroves along the Pipeline route will be cleared across a construction corridor approximately 40 m wide, but at the completion of construction will be allowed to re-establish across most of the construction corridor. Only a narrow corridor (indicatively 5 m wide) would be prevented from re-establishing directly above the Pipeline (potentially by rock armouring or other trench backfill material above the Pipeline). However, the purposes of estimating direct impacts, the full 40 m wide construction corridor has been assumed
- construction of the MOF for the LNG Facility, including clearing of mangroves required for dredging access
- construction of the LNG jetty, including a 10 m wide buffer on either side of the jetty approach structure and trestles. The jetty approach structure is approximately 15 m wide, resulting in removal of mangroves and

vegetation in a corridor approximately 35 m wide where mangroves will not be allowed to re-establish through the period of operations, in order to prevent any encroachment on jetty infrastructure

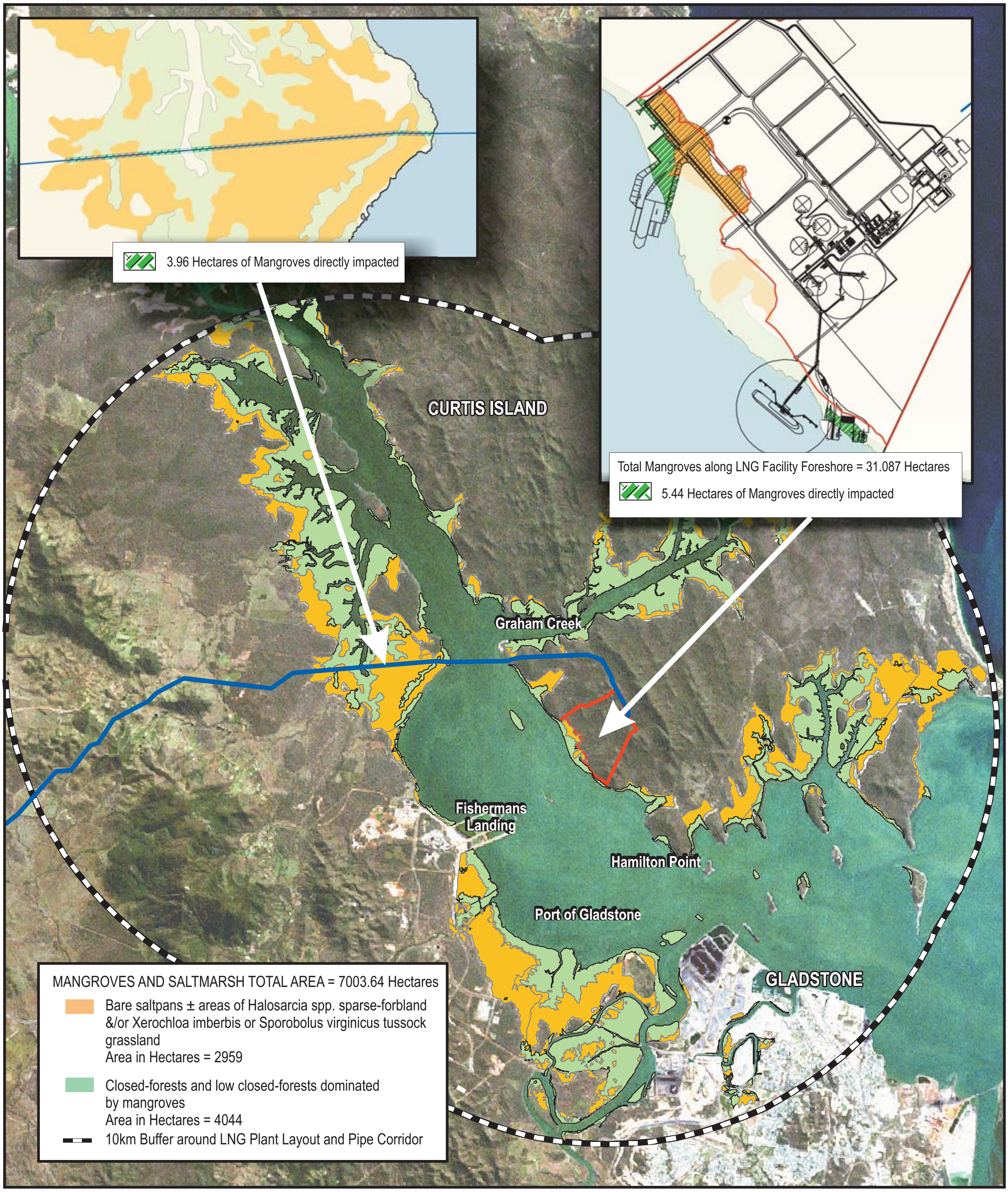
- the LNG Facility construction dock, including clearing of mangroves required for dredging access.

Figure 5.8.16 shows these items in relation to mangroves mapped in Port Curtis, and *Table 5.8.18* summarises the areas impacted on. It should be noted that detailed construction methodology of the Pipeline crossing of Humpy Creek, Targinie Creek, and The Narrows is still being determined, and that the configuration of both the MOF and Construction Dock continue to be revised through the detailed design phase of the Project. As a result, actual as-constructed direct impacts on mangroves may vary from those presented in *Figure 5.8.16* and *Table 5.8.18*, however, QGC will ensure that any changes to the direct impacts on mangroves as a result of Project evolution are understood and agreed by appropriate regulators prior to commencement of construction.

Table 5.8.18 Direct Mangrove Impacts

	Direct Mangrove Impacts (ha)
Pipeline construction corridor (Humpy & Targinie creeks, Friend Point[1])	4 ha
LNG Facility foreshore (MOF, construction dock, LNG jetty, and all associated dredging)	5.4 ha
Total area mangroves directly impacted on	***9.4 ha***
Total area of mangroves within 10 km of pipeline corridor/LNG Facility[2]	***4044 ha***
Direct mangrove impacts as % of total within 10 km	***0.23%***

1 Minor area of mangroves within the Pipeline corridor at landfall on Laird Point near Graham Creek.
2 The 10 km buffer used to calculate the total area within 10 km of the Pipeline and LNG Facility is shown in *Figure 5.8.16*.
3 Design of the MOF and Construction Dock continues to be refined. Alternative configurations of these facilities currently under consideration may result in an increase in direct mangrove impacts of up to approximately 1.5 ha.



Legend

- Proposed QCLNG Site Boundary
- 10km Buffer around LNG Plant Layout and Pipe Corridor
- Proposed Export Pipeline

Source Note:

Vegetation data: Regional Ecosystem v5.0 QLD Herbarium

Projection: UTM MGA Zone 56   Datum: GDA 94

0 1 2 4 km

N

QUEENSLAND CURTIS LNG — A BG Group business	Project: Queensland Curtis LNG Project Client: QGC - A BG Group business		Title: **Mangroves and Saltmarsh - Direct Project Impacts**
ERM — Environmental Resources Management Australia Pty Ltd	Drawn: JB Approved: DS Date: 08.01.10	sEIS Volume 5 — Figure S5.8.16 File No: 0086165b_SUP_CDR001_S5.8.16 Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

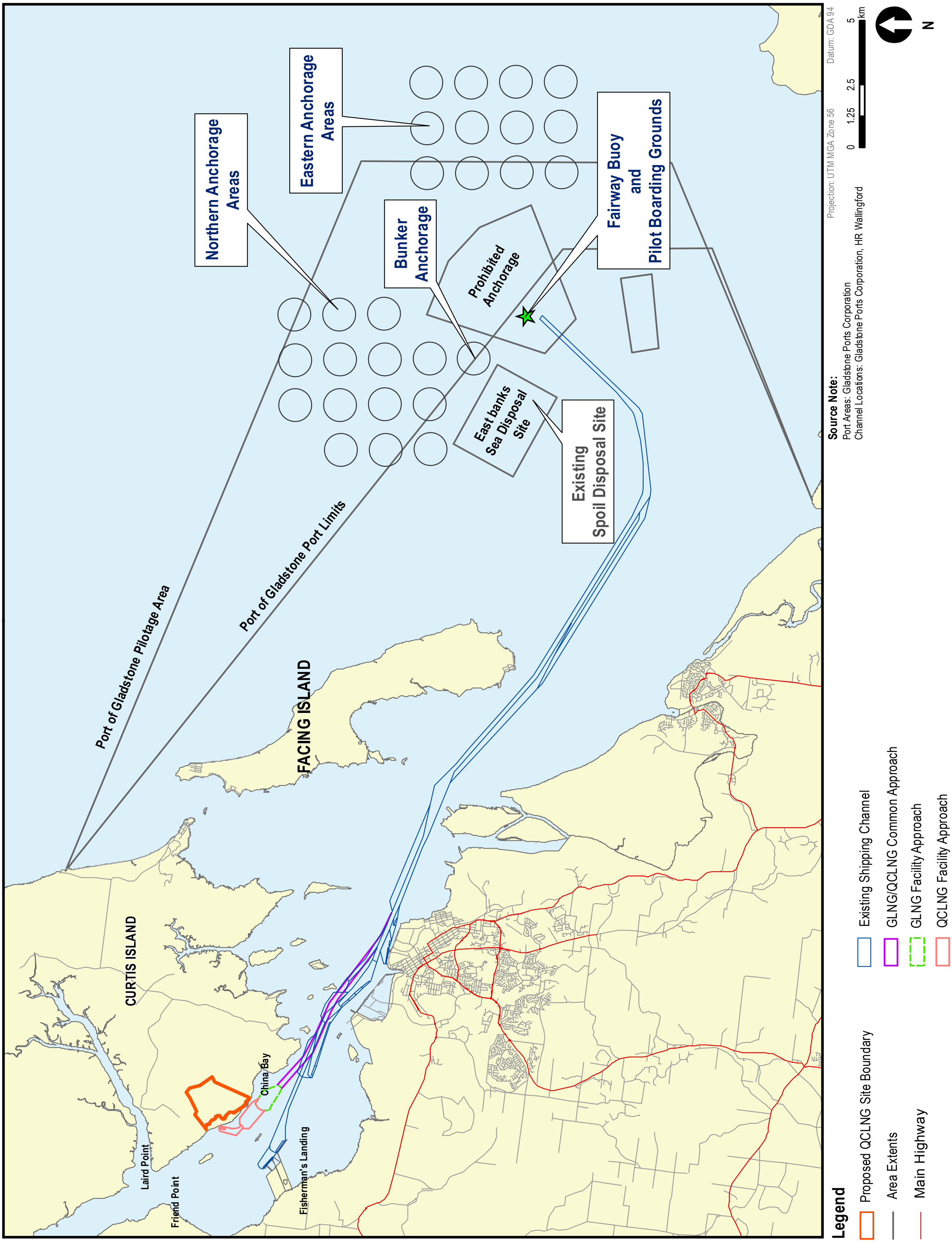
8.13 BENTHIC COMMUNITIES OF THE EAST BANKS SPOIL GROUND

The offshore spoil ground site was established in 1980. During the period 1980 to 1982 12,000,000 m^3 of capital dredging material was placed in this offshore spoil disposal ground. Maintenance dredging material has been disposed of in the offshore spoil disposal ground since the early 1990s.

An investigation was undertaken to assess the characteristics and potential environmental values of the existing offshore spoil disposal ground. A combination of methods was used to assess seabed habitats within the spoil ground:

- identification and mapping of seabed habitat classes using a single beam, dual frequency sounder
- underwater video and grab sampling to validate sediment types within derived acoustic habitat classes.

The location of the offshore spoil disposal ground is illustrated in *Figure 5.8.17.*



QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project Client: QGC - A BG Group business	Title: **Location of Offshore Dredged Spoil Disposal Ground**
ERM Environmental Resources Management Australia Pty Ltd	Drawn: KP — sEIS Volume 5 — Figure S5.8.17 Approved: BK — File No: 0086165b_SUP_GIS016_S5.8.17 Date: 19.01.10 — Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

There are two key benthic fauna habitats within the spoil ground; soft sediment habitats; and isolated patches of hard substrate.

Soft sediment associated epifauna was found to be very sparse with the substrate comprised largely of bare substrate. This finding is consistent with previous surveys[60] that have mapped the south-eastern and north-western corners of the spoil ground as open substrate with low-density benthic fauna. Rasheed *et al.* (2003) mapped a meadow of seagrass (*Halophila decipiens*) with very sparse coverage (0.5 per cent) in the south-western corner of the spoil ground. However, no areas of seagrass were identified with the acoustic mapping (which is capable of identifying moderately dense vegetation), or from underwater video footage taken during the validation exercise.

Areas of soft sediment would provide habitat for marine invertebrate communities such as macroinvertebrates (i.e. worms, molluscs etc). Most of the spoil ground appeared to have limited levels of bio-turbation (holes, burrows etc.), whereas numerous burrows were observed at the siltier sites sampled immediately outside the spoil ground. The exception to this was one site in the south-eastern corner of the spoil ground, which had high levels of bio-turbation as well as extensive micro-topographical variation due to ripple formation. These invertebrate communities would provide ecological functions that are important to the maintenance of local ecosystem processes, such as nutrient cycling processes and provision of food resources for larger animals including fish and crustacean species.

The isolated rocky substrate encountered during the validation typically supported a sparse cover of hard substrate associated sessile fauna including sponges, soft coral, gorgonians, hydroids, and crinoids. Across the spoil ground, it is estimated that rocky substrate accounted for <10 per cent of the area. Similar observations made by Rasheed *et al.* (2003) found a moderate cover (15 per cent) of rubble substrate within the spoil ground dominated by bryozoans and hydroids with low numbers of other taxa.

As discussed in *Volume 6, Section 2.3.3.5*, disposal of material at the spoil ground is predicted to result in an average increase in the depth of the seabed by at least 1 cm over 8.8km^2 , with a burial thickness in excess of 20 cm over an area of 0.125 km^2 (1,250 ha) of the disposal ground. Regular use of the disposal site over time is likely to have retarded the establishment of a stable benthic community. As such, disposal of spoil to the offshore spoil ground, in continuation of previous practice, is considered unlikely to lead to significant adverse environmental impacts.

60 Rasheed, M.A., Thomas, R., Roelofs, A.J. Neil, K.M. and Kerville, S.P. (2003). Port Curtis and Rodds Bay seagrass and benthic macro-invertebrate community baseline survey, November/December 2002. DPI Information Series QI03058 (DPI, Cairns), 47 pp.

8.14 POTENTIAL IMPACTS ON AUSTRALIAN SNUBFIN DOLPHIN AND INDO-PACIFIC HUMPBACK DOLPHIN

The Australian Snubfin dolphin (*Orcaella heinsohni)* (previously listed as Irrawaddy dolphin, *Orcaella brevirostris)* and the Indo–Pacific Humpback dolphin *(Sousa chinensis)* together with the Bottlenose dolphin (*Tursiops aduncus*), are the only strictly coastal dolphin species found in northern Australia. Australian Snubfin dolphin and the Indo–Pacific Humpback dolphin are listed as rare under the *Nature Conservation Act 1992* (Qld), and are classified as near-threatened by the IUCN. They are both listed as cetacean and migratory species under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

Dolphins of the genera *Sousa* and *Orcaella* genera share a similar shallow coastal-water distribution in northern Australian and South-east Asia, with both occurring mainly in waters less than 15 m deep and within 10 km of the coast and 20 km from the nearest river mouth. The Australian Snubfin dolphin was only recently described as a new species[61.] Recent genetic studies on Indo-Pacific Humpback dolphins indicate Australian populations may also represent a different species only found in Australia[62]. *Figure 5.8.18* and *Figure 5.8.19* illustrate the known distributions of the Indo-Pacific Humpback dolphin and Australian Snubfin dolphin*.*

61 Beasley I, Robertson KM. and Arnold P. 2005. Description of a new dolphin, the Australian Snubfin Dolphin Orcaella heinsohni sp. n. (Cetacea, Delphinidae). Marine Mammal Science 21: 365-400

62 Frère CH. Hale PT, Porter ., Cockcroft VG and Dalebout ML. 2008. Phylogenetic analysis of mtDNA sequences suggests of Humpback dolphin (Sousa spp.) taxonomy is needed. Marine and Freshwater Research, 59: 259–268

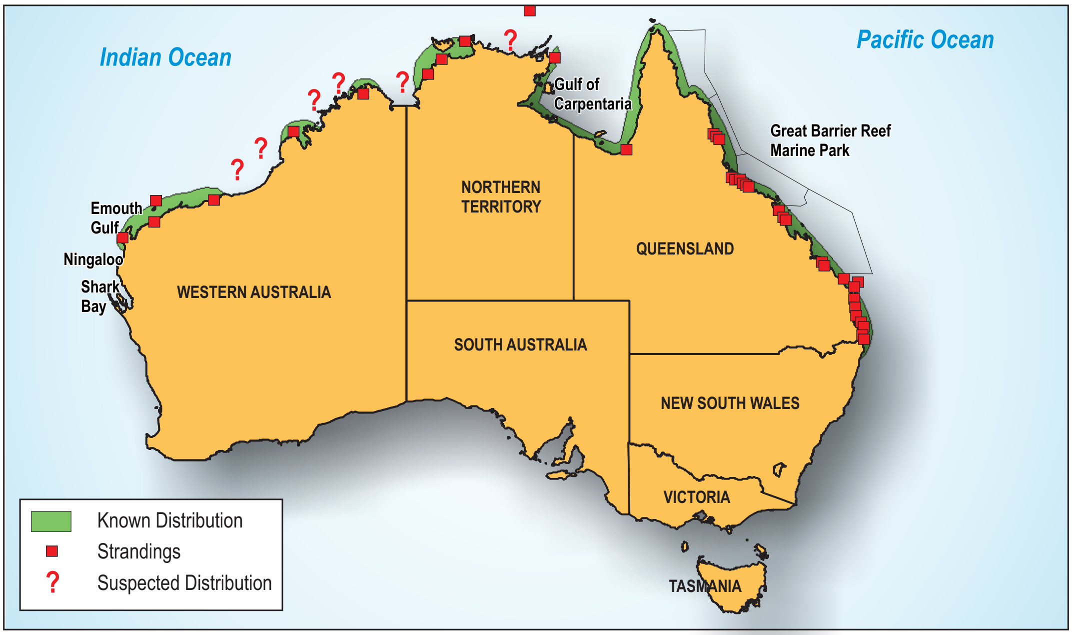


Figure 5.8.18 - Known and Suspected distribution of *Sousa chinensis* in Australian waters

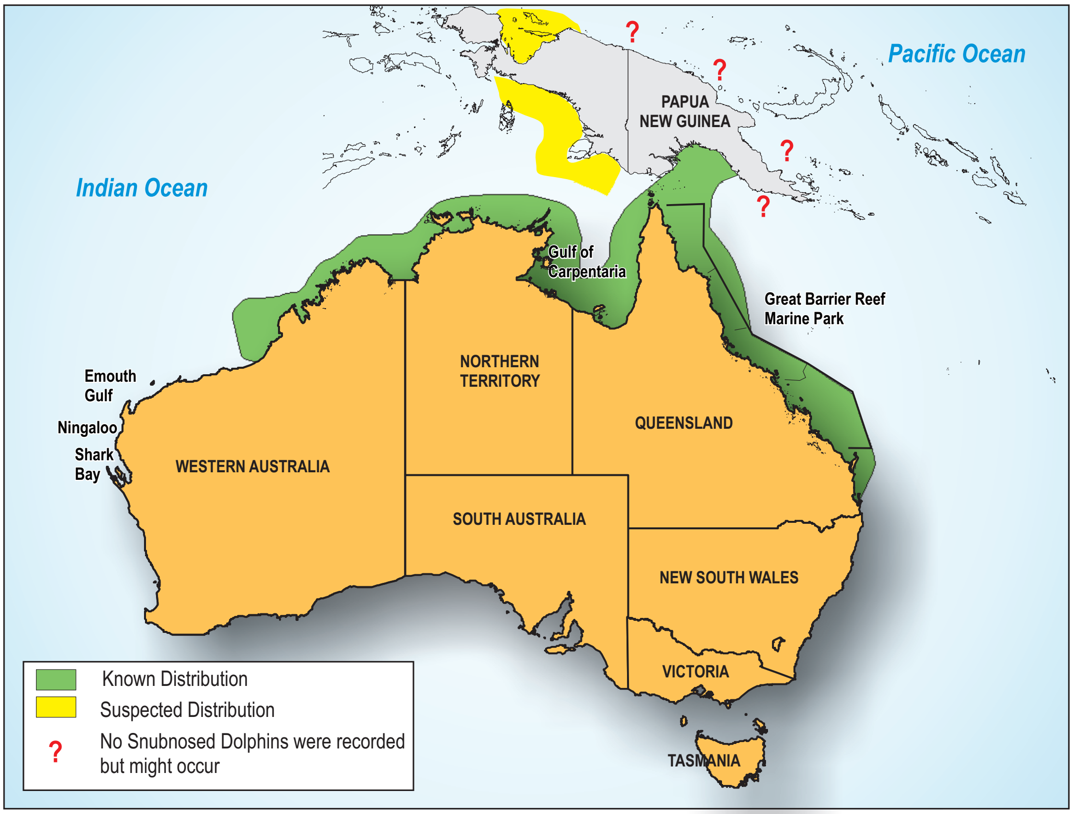


Figure 5.8.19 - Known and suspected distribution of *Orcaella heinsohni* in Australian waters

Source:
Parra GJ, Corkeron PJ and Marsh H. 2004.
The Indo-Pacific Humpback Dolphin, Sousa chinensis (Osbeck, 1765), in Australian Waters: A Summary of Current Knowledge.
Aquatic Mammals, 30(1), 197-206
Beasley I, Robertson, KM and Arnold P. 2005.

0 500 1000 km

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ERM
Environmental Resources Management Australia Pty Ltd

Project	Queensland Curtis LNG Project	Title	Known and Suspected Distribution of Dolphin in Australian Waters
Client	QGC - A BG Group business		
Drawn JB	sEIS Volume 5	Figure S5.8.18 & S5.8.19	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
Approved RS	File No: 0086165b_SUP_CDR004_S5.8.18_S5.8.19		
Date 30/12/09	Revision 0		

8.14.1 Habitat and Distribution

Both the Indo-Pacific Humpback and Australian Snubfin dolphins inhabit coastal, estuarine, and occasionally riverine areas, in tropical and subtropical regions. The species occurs mostly in waters less than 15 m deep and within 10 km of the coast and 20 km from the nearest river mouth[63].

Site fidelity and residence time in an area is an important component in assessing potential risk from activities. Studies from Cleveland Bay (Townsville) have indicated that both species are not permanent residents. Rather, they both used the area regularly from year to year following a model of emigration and re-immigration. Individuals of both species spend periods of days to a month or more in coastal waters of Cleveland Bay before leaving, and periods of over a month outside the study area before entering the bay again[64]. Recent work by Cagnazzi *et al.* (2009)[65] at Tin Can Inlet found separate groups of Humpback dolphin; a northern group that appear to be permanent residents within a relatively small geographical area and a southern group that ranged over a much wider area, the full extent of which was not determined but considered to be about 20 km.

Little is known about the local distribution and abundance of Humpback dolphin or Snubfin dolphin in the Port Curtis region apart from isolated records of mortalities and sightings. These records are:

- Humpback dolphin: a single specimen found dead in 2003, two in 2004 and two in 2005.
- Snubfin dolphin: a single juvenile specimen found dead in 2007.

The results of GPC's aerial and boat-based surveys[66], which covered an area from north of Curtis Island to south of Rodds Bay, are consistent with current literature that acknowledges the importance of Rodds Bay as a key habitat area for significant marine megafauna species. A total of 163 Indo-Pacific Humpback dolphins and 81 dugongs were observed. The surveys identified a range of age classes using the region, suggesting that it is not only an important foraging area but an area important for calving of these marine mammals.

No records were made of the Australian Snubfin dolphin. The low numbers of Snubfin dolphins observed suggest that they are irregular visitors to the port rather than resident in the port area.

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63 Jefferson, T. A. and Karczmarski, L. 2001. Sousa chinensis. Mammal Species 655: 1-9.; Parra, G J. 2005. Behavioural ecology of Irrawaddy, Orcaella brevirostris (Owen in Gray, 1866), and Indo-Pacific Humpback dolphins, Sousa chinensis (Osbeck, 1765), in northeast Queensland, Australia: a comparative study. Ph.D. thesis, School of Tropical Environment Studies and Geography, James Cook Univ., Townsville; Corkeron PJ, . Morissette NM, . Porter LJ, and Marsh H. 1997. Distribution and status of Humpbacked dolphins, Sousa chinensis, in Australian waters. Asian Marine Biology 14: 49-59;

64 Parra GJ, Corkeron PJ and Marsh H. 2006. Population sizes, site fidelity and residence patterns of Australian Snubfin and Indo-Pacific Humpback dolphins: Implications for conservation. Biological Conservation, 129, 167–180

65 Cagnazzi DB, Harrison PL and Ross GJB. 2009.Abundance and site fidelity of Indo-Pacific Humpback dolphins in the Great Sandy Strait, Queensland, Australia. Marine Mammal Science unpublished.

66 GPC Wester Basin Dredging Project Draft EIS

8.14.2 Feeding Ecology

Little information exists on the feeding habits of the Humpback dolphin and Snubfin dolphin. The following text is taken directly from Parra *et al.* (2009), which is the only known study of their feeding habitats[67]. *Snubfin and Humpback dolphins appear to be opportunistic-generalist feeders, eating a wide variety of fish and cephalopods associated with coastal-estuarine waters. Bottom-dwelling and pelagic fishes were consumed by both species, indicating Snubfin and Humpback dolphins capture fish throughout the water column. Humpback dolphins appear to feed primarily on fish, while Snubfin dolphins also included cephalopods in their diet. The most important prey in numerical terms for Snubfin dolphins was the Cardinal fish, Cuttlefish and the Tooth pony fish. Grunts, Cardinal fishes and Smelt-whitings were found to be the most important fish prey for Humpback dolphins. Several fish prey, including the most important, was common in the diet of both dolphin species indicating some partial dietary overlap. Differences in diet likely reflect some of the morphological and ecological differences between both species. The diet of Snubfin and Humpback dolphins included taxa that are targeted by net and trawling fisheries in Queensland. Interactions with these fisheries are expected, particularly in areas where fishing operations overlap with dolphins' high-use areas.*

8.14.3 Population Size

There are no current estimates of population sizes for either the Indo-Pacific Humpback dolphin or Australian Snubfin dolphin in Australian waters. The few available estimates of abundance for both species throughout their range indicate that populations of both species tend to be small. Riverine populations of Snubfin dolphin are all below 100 individuals with the total species population number likely to be in the 1,000s rather than 10,000s[68].

The sparse data available for selected areas indicates that Humpback dolphins occur in discrete, geographically localised populations. Key localities include Moreton Bay, Queensland and the lower reaches of the Brisbane River and adjacent offshore waters, where a resident population occurs in water less than 10 m in depth, and offshore to 6 km. Tin Can Inlet features a group estimated to number approximately 150 individuals[69].

The Indo-Pacific Humpback dolphin has been found by recent surveys[70] to be the most common coastal dolphin in the Port Curtis area with observed distribution from north of Curtis Island to south of Rodds Bay. In contrast no Snubfin dolphin was observed and the only record of the species in the region

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67 Parra, G. J. and Jedensjö, M. (2009) Feeding habits of Australian Snubfin (Orcaella heinsohni) and Indo-Pacific Humpback dolphins (Sousa chinensis). Project Report to the Great Barrier Reef Marine Park Authority, Townvsille and Reef & Rainforest Research Centre Limited, Cairns (22pp.).

68 Op Cit.64

69 Cagnazzi et al 2009. Op cit. 65

70 GPC Wester Basin Dredging Project Draft EIS

is a single juvenile specimen found dead in 2007. It is unlikely that the Snubfin dolphin occurs in the port other than as a transitory or irregular visitor.

8.14.4 *Impact Assessment*

Habitat

The QCLNG Project will cause direct loss of up to 0.02 per cent of seagrass meadows with indirect and temporary disturbance to approximately 4 to 7 per cent of seagrass meadows (depending on the dredging scenario) which form a part of the feeding area of the dolphins as well as habitat for their prey species. The loss of habitat is not considered to represent a significant impact for either the Indo-Pacific Humpback dolphin or the Australian Snubfin dolphin.

Underwater Noise

The predicted levels of underwater noise are discussed *Section 8.5*. This indicates that sound levels from all sources will be below the level at which possible injury might occur to either the Indo-Pacific Humpback dolphin or the Snubfin dolphin.

The frequencies of communications produced by the Indo-Pacific Humpback dolphins include whistles (1.2-16 kHz)[71] and broad band clicks (2-22 kHz)[72] (no data is available for the Snubfin dolphin and it is assumed that their hearing range is similar to the Humpback dolphin). This overlaps the upper range of frequencies emanating from piling and approximately coincides with frequencies emanating from boat traffic.

Würsig *et al*. (2000)[73] recorded the impact of pile driving (6 m to 8 m water depth) on Humpback dolphin behaviour. No overt behavioural changes were observed in response to the pile-driving activities, but the animals' speed of travel increased and some dolphins remained within the vicinity while others temporarily abandoned the area. The noise levels for piling associated with the QCLNG Project are predicted to have a behavioural effect on dolphins out to about 200 m from the source. The predicted outcome is that Humpback dolphins and any Snubfin dolphins may avoid approaching within about 200 m of piling activity, the significance of this temporary displacement from a small portion of habitat is considered to be minor.

The source levels of noise emanating from vessels are below the threshold for avoidance and it is predicted that although there may be some occasions of behavioural avoidance, the significance of this will be minor.

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71 Schultz, K.W. and Corkeron, P.J. (1994). Interspecific differences in whistles produced by inshore dolphins in Moreton Bay, Queensland, Australia. Canadian Journal of Zoology 72: 1061-1068, cited in Ross GB (2006) Review of the Conservation Status of Australia's smaller Whales and Dolphins

72 Van Parijs, S. and Corkeron, P.J. (2001). Boat traffic affects the acoustic behaviour of Pacific Humpbacked dolphins Sousa chinensis. Journal of the Marine Biological Association of the United Kingdom 81: 533-538, cited in Ross GB (2006) Review of the Conservation Status of Australia' smaller Whales and Dolphins

73 Würsig, B., Greene, C.R. and Jefferson, T.A. (2000) Development of an Air Bubble Curtain to Reduce Underwater Noise of Percussive Piling. Marine Environ. Res., 49, 79–93

Vessel Interactions

Collisions between dolphins and vessels are relatively rare, due to the speed and mobility of dolphins, but have been recorded. Small inshore dolphins are most vulnerable to high-speed vessels,[74] however, they are not considered to be at risk from collision with larger slower-moving ships.

In a recent study of vessel movements in Port Curtis, Alquezar[75] identified total traffic in the vicinity of Auckland Point, the Calliope River and The Narrows as averaging 128-183, 37-98, and 20-37 movements during daylight hours, for weekdays and weekends, respectively. Numbers were observed to rise significantly higher than this during fair weather, and the daylight-only survey frame clearly underestimated total port movements. On this basis it is reasonable to assume that vessel movements within the Port of Gladstone may fall in the range of 70,000 to 80,000 movements per year.

Alquezar also noted that 42 per cent to 81 per cent of all vessel movements (across all parts of the port) were at planing speed or greater. Very few of the vessel movements arising from QCLNG Project maritime traffic will travel faster than displacement speed, and therefore QCLNG traffic is unlikely to lead to an appreciable increase in risk of collisions with marine fauna.

Ferries will be used during construction and operation phases of the QCLNG Project. These will travel between Auckland Point or RG Tanna and the Curtis Island site, a distance of about 5 to 7 km. Although the likelihood of collision is low, the protocols illustrated in *Figure 5.8.20* will be implemented to further reduce the potential for collisions with dolphins.

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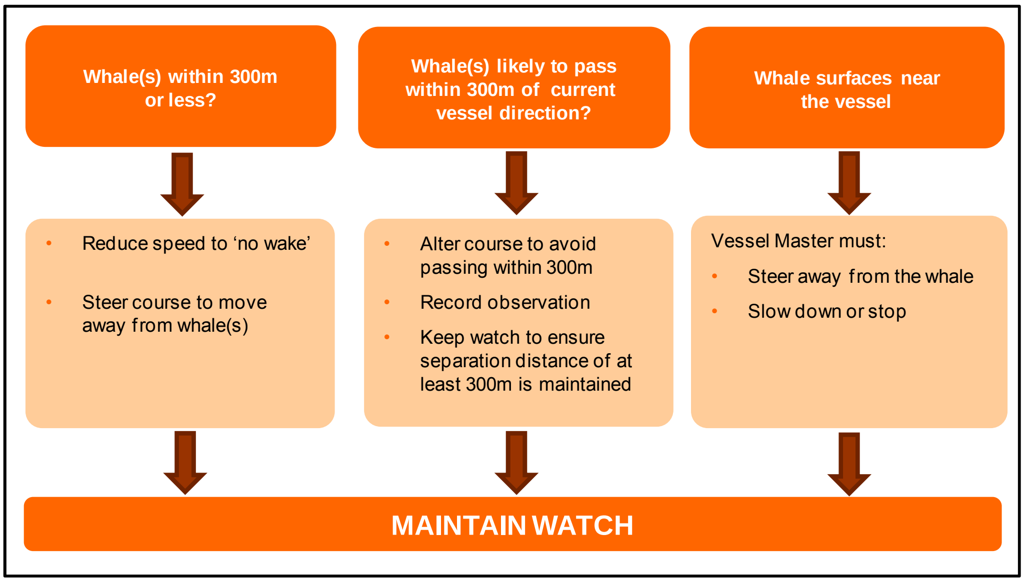
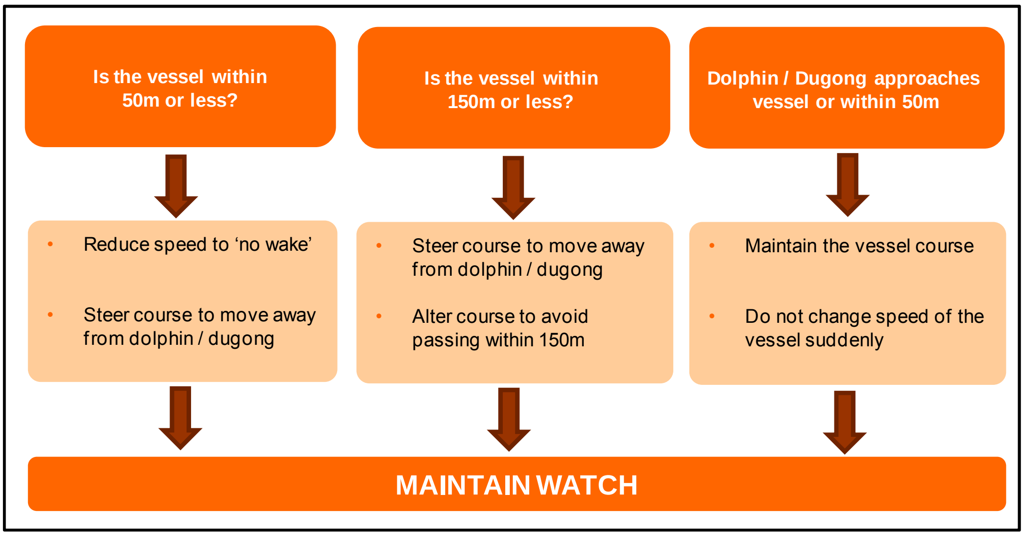
74 Ross GB (2006) Review of the Conservation Status of Australia's smaller Whales and Dolphins

75 Alquezar, R (2009). Maritime Harbour Movements of Port Curtis 2009. A report to BG-LNG. Centre for Environmental Management, CQUniversity, Gladstone, Australia.

Figure 5.8.20 Protocol for avoiding vessel – whale/dolphin/dugong collisions



Whale sighting



Dolphin / Dugong sighting

8.14.5 Conclusion

Based on predicted levels of habitat disturbance, vessel activity and underwater noise, it is considered unlikely that the cetacean populations in the Port of Gladstone will be significantly impacted on by dredging and material disposal activities for the QCLNG Project.

Specifically, the scale of loss of seagrass habitat is not considered to represent a significant impact upon either the Indo-Pacific Humpback dolphin or the Australian Snubfin dolphin. Underwater noise from all sources is predicted to be below the level at which possible injury might occur to the either the Indo-Pacific Humpback dolphin or the Australian Snubfin dolphin. Similarly, underwater noise from all sources is predicted to be below the thresholds for avoidance in these dolphin species, and although occasional behavioural avoidance may occur, the significance of this is considered to be minor. The likelihood of collisions between dolphins and vessels used in QCLNG operations is considered very low, given the vessel numbers and their low speeds compared to existing traffic, however, protocols to further reduce potential collisions will be implemented.

8.15 POTENTIAL IMPACTS ON DUGONG

8.15.1 Habitat

Dugongs are known to utilise seagrasses within Port Curtis. In particular, seagrasses in this area have been declared locally significant on the basis of dugong feeding behaviour. Loss of about 0.02 per cent of seagrass meadow habitat is predicted to occur through direct impacts of dredging. A further 4 to 7 per cent of seagrass meadows (depending on the dredging scenario) will be indirectly affected with a predicted temporary loss or reduction in seagrass biomass due to dredging activities. There is strong potential for areas of seagrass meadow that have been indirectly affected by dredging to recover within 12 months.

8.15.2 Population size

As discussed in the draft EIS (*Volume 5, Chapter 8, section 8.3.2.7*) a survey conducted in November 2005 estimated there were 183 (± 66) dugongs in the Port of Gladstone area[76]; dugong feeding activity was observed on the majority of intertidal seagrass meadows surveyed during a study of benthic habitats in the port[77].

8.15.3 Underwater Noise

There have been very few studies into the hearing ability of dugongs. Initial research results into their auditory physiology have highlighted some significant anatomical differences between manatees and dugongs[78], but because of the absence of studies on the dugong it is often assumed that hearing range and sensitivities are approximately equal to the manatee. The manatee has peak frequency sensitivity at 16 and 18 kHz with a lower limit of 400 Hz and an upper limit of functional hearing at about 46 kHz[79]. From this it can be inferred that dugongs are unlikely to be disturbed by noise from piling, dredging or shipping activities. The limited low-frequency hearing sensitivity

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76 Marsh H and Lawler I R (206) Dugong distribution and abundance on the urban coast of Queensland: a basis for management. Marine and Tropical Science Research Facility Interim Projects 2005-06 FINAL Report Project 2.

77 Rasheed M A, McKenna S A, Taylor H A and Sankey T L (2008) Long term seagrass monitoring in Port Curtis and Rodds Bay, Gladstone – October 2007. DPI&F Publication PRO7-3271 (DPI&F, Cairns), 32 pp.

78 Patton GW, Gerstein ER, Domming DP, Sutherland M and Perinetti R (1992) An Annotated Bibliography of Sirenian Hearing, Mote Marine Laboratory Report No. 272. https://dspace.mote.org:8443/dspace/bitstream/2075/51/1/272.pdf, accessed December 2009

79 Gerstein ER, Gerstein L, Forsythe SE and Blue JE (1999). The underwater audiogram of the manatee (Trichechus manatus), Journal of the Acoustical Society of America 150(6): 3575-3583.

may be responsible for the observed low level of response to boating traffic[80] discussed below.

8.15.4 Vessel Interactions

At present, few dugongs are killed by boats, however, increasing vessel traffic in dugong habitat increases their risk[81]. A recent study of the short-term behavioural responses of dugongs to boats[82] found that the majority of observed dugongs did not visibly react to experimental boat passes unless the boat was within approximately 50 m. Most observations of responses to boats were limited to shallow water (<2 m). This result is consistent with the results of a Florida trial[83] carried out using a powerboat to make multiple runs through a group of manatees, which found that the manatees began reacting to the approaching boat at about the same distance (50 m to 60 m) irrespective of boat speed.

Shipping and ferry activity will be conducted in deeper waters that do not support seagrass meadows, therefore the likelihood of both disturbance to dugongs and vessel collision with dugongs is reduced to encounters with transitory animals. The discussion in *Chapter 8.15.4* regarding patterns of vessel movements within Port Curtis is also relevant for assessing potential impacts to dugong populations. As such, the likelihood of Project vessel interactions with the Port Curtis dugong population is considered to be low. Although the likelihood of collision is low, the protocols illustrated in *Figure 5.8.20* will be implemented to further reduce the potential for collisions with dugongs.

8.15.5 Conclusions

It is considered unlikely that the QCLNG Project would lead to a significant impact on dugong populations found in Port Curtis. This is primarily because of the low level of disturbance likely to be caused by the Project and secondarily because the population size is considered to be large enough, and wide-ranging enough, that they would be buffered from the localised impacts.

80 Hodgeon AJ and Marsh H (2007). Response of dugongs to boat traffic: The risk of disturbance and displacement, Journal of Experimental Marine Biology and Ecology 340 (1): 50–61.

81 DEWHA (2009) Dugong Fact Sheet http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?showprofile=Y&taxon_id=28 accessed December 2009.

82 Hodgson AJ and Marsh H (2007). Response of dugongs to boat traffic: The risk of disturbance and displacement, Journal of Experimental Marine Biology and Ecology 340 (1): 50–61.

83 Weigle, B.L., Wright, I.E. & Huff, J.A. 1994, ‘‘Responses of manatees to an approaching boat: a pilot study’’, in Proceedings of the First International Manatee and Dugong Research Conference, held at Gainesville Florida, 11–13 Marsh 1994 cited in Preen T. Dugongs, Boats, Dolphins and Turtles in the Townsville-Cardwell Region and Recommendations for a Boat Traffic Management Plan for the Hinchinbrook Dugong Protection Area, Report to the Great Barrier Reef Marine Park Authority, http://www.gbrmpa.gov.au/__data/assets/pdf_file/0004/2938/preen.pdf accessed December 2009.

8.16 POTENTIAL IMPACTS ON TURTLES

8.16.1 Habitat

The Green turtle (*Chelonia mydas*); Loggerhead turtle (*Caretta caretta*); and Flatback turtle (*Natator depressus*) are known to occur in Port Curtis, nesting occasionally on the beaches of Curtis Island and Facing Island. However, there are no known turtle-nesting beaches within close proximity (within 5 km) to the proposed QCLNG Project and therefore there are no direct impacts predicted to nesting habitat.

Green turtles have been regularly observed within local seagrass meadows, particularly those on Pelican Banks (eastern side of Curtis Island) (Taylor *et al.* 2007).

Leatherback turtles (*Dermochelys coriacea*), Hawksbill turtles (*Eretmochelys imbricata*) and Olive Ridley turtles (*Lepidochelys olivacea*) are not known to nest in the Port Curtis area. Individuals may migrate through the area, but significant numbers of them are unlikely in the Project area.

8.16.2 Underwater Noise

The sea turtle's auditory canal consists of cutaneous plates underlain by fatty material at the side of the head which serves the same function as the tympanic membrane in the human ear. From previous research it is evident that sea turtles can detect sound, and that their hearing is confined to lower frequencies, mainly below 1,000 Hz[84]. Studies using auditory brainstem responses of juvenile Green and Ridley's turtles and subadult Green turtles showed that juvenile turtles have a 100 to 800 Hz bandwidth, with best sensitivity between 600 and 700 Hz, while adults have a bandwidth of 100 to 500 Hz, with the greatest sensitivity between 200 and 400 Hz[85]. This band of hearing sensitivity approximately coincides with the frequencies emanating from pile-driving operations and overlaps the lower frequencies emanating from vessel activities.

Little is known about the source levels and associated frequencies that will cause physical injury to turtles. Studies by Keevin and Hempen (1997)[86] on the effects of explosions on turtles recommend that an empirically based safety range developed by Young (1991)[87] be used for guidance. Using Young's safety range formula and converting back to sound pressure levels, a conservative value of 222 dB re 1μPa @1 m is obtained for adult turtles and

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84 Bartol, S.M., Musick, J.A. and Lenhardt, M.L. 1999. Auditory evoked potentials of the Loggerhead sea turtle (Caretta caretta). Copeia 3: 836–840.

85 Bartol, S.M. 2006. Turtle and Tuna Hearing, Woods Hole Oceanographic Institute, NOAA Technical Memorandum NMFS PIFSC 7, MA, USA; Ketten, D.R. and Bartol, S.M. 2005. Functional Measures of Sea Turtle Hearing. Woods Hole Oceanographic Institute, MA, USA

86 Keevin, T.M. and Hempen, G.L. 1997. The environmental effects of underwater explosions with methods to mitigate impacts. US Army Corps of Engineers, St. Louis District.

87 Young, G.A. 1991. Concise methods for predicting the effects of underwater explosions on marine life. NAVSWC No. 91-22. Naval Surface Warfare Centre, Silverspring, Maryland, USA. Cited in Keevin and Hempen (1997).

198 dB re 1µPa^{2}s for hatchlings. Based on these assumed thresholds adult turtles are likely to be unaffected however it is possible that hatchlings within about 55 m of the piling operations may suffer physiological harm. The locations of piling operations are some 5 to 10 km distant from turtle nesting beaches and in opposite direction from the likely pathway of hatchlings as they move to sea from the nesting beaches. Therefore, although hatchlings may be theoretically susceptible the probability of them being in the zone of potential impact is low.

The only known data addressing threshold shift (hearing deterioration) in turtles are from a study conducted by Eckert et al. (2006)[88] on Leatherback turtles. This study demonstrated that when exposed to repetitive high-level acoustic energy impulses greater than 185 dB re 1 µPa the tested turtles suffered temporary threshold shift and eventually permanent threshold shift[89]. The likelihood of turtles approaching to within such a close range of piling operations and remaining there for several hours is considered to be very low and consequently the potential for threshold shift is also considered to be low.

Sea turtles have been recorded as demonstrating a startle response to sudden noises[90]. However, no information is available regarding the threshold level necessary for behavioural effects. In the case of pulsed low frequency sound effects on turtle nesting behaviour, nest numbers were monitored on beaches near the Port of Hay Point (Queensland) before, during and after a pile-driving program lasting several months in 1996-97. Results showed no significant trend in nest numbers, indicating that the female turtles had not been particularly sensitive to this pulsed source[91], but nest numbers were too few to provide a conclusive result. McCauley *et al*. (2000)[92] conducted controlled exposure experiments on a Loggerhead turtle and a Green turtle to monitor behavioural response to approach by an airgun, which generates similar sound characteristics to that of piling. They found two types of response:

- Above a received noise intensity of approximately 155 dB re 1 µPa^2/s the turtles began to noticeably increase their swimming speed.
- Above a received noise intensity of approximately 164 dB re 1 µPa^2/s the turtles began to show more erratic swimming pattern, possibly indicative of them being in a distressed state.

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88 Eckert S., Levenson D.H. and Crognale M.A. 2006. The sensory biology of sea turtles:what can they see, and how can this help them avoid fishing gear?.pp in Swimmer Y. and Brill R. (eds) Sea Turtle and Pelagic Fish Sensory Biology: Developing Techniques to Reduce Sea Turtle Bycatch in Longline Fisheries

89 It should be noted that the study was based on a small sample of Leatherback turtles, the results are based on airborne noise (not underwater noise), and it is unlikely that a turtle would (in an uncontrolled situation) be exposed to multiple high intensity noise impulses from piling operations

90 Lenhardt, M.L., Bellmund, S., Byles, R.A., Harkins, S.W. and Musick, J.A. 1983. Marine Turtle reception of bone conducted sound. Journal of Auditory Research 23: 119–1125.

91 URS LeProvost Dames and Moore, in association with WBM Oceanics Australia 2001, Port of Weipa, Long Term Dredge Material Management Plan, Report on Phase Three (Stage 2) Monitoring Program, URS, Brisbane.

92 McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M-N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J. and McCabe, K. 2000. Marine Seismic Surveys – A Study of Environmental Implications. Australian Petroleum Production and Exploration Association Journal 2000: 692–708

Based on these assumed thresholds for avoidance, turtles within 160 m to 1,500 m of the piling operations may be expected to demonstrate a level of behavioural avoidance during piling. During shipping operations the area within which behavioural avoidance may occur is predicted to be in the order of 160 m and during dredging about 55 m from the dredge. The area affected is not considered to represent important habitat for turtles and the significance of potential avoidance over a relatively short period of construction is considered to be minor.

8.16.3 Loss of Habitat

The total area of seagrass that would be directly affected is approximately 2 ha. Relative to the approximately 6,200 ha of seagrass meadows present within the Port Curtis area, the direct loss of seagrasses and the subsequent indirect effects on turtles from the QCLNG Project is considered negligible.

Conservative dredged sediment dispersion modelling indicates that the indirect effects of dredging (increased levels of suspended solids in the water column) on seagrass habitat may potentially extend over an area of between 360 ha to 430 ha, depending upon the dredging methodology, but the loss of habitat within these areas will be temporary, and it is expected that seagrasses will regrow in these areas within one to three years of the cessation of dredging. The effect on any turtles in the area is therefore considered minor.

8.16.4 Light

Potential light impacts to turtles from construction activities are mainly associated with the operation of support and construction vessels in the near-shore areas of Curtis Island. The consequences of potential light impacts to turtles associated with the operation of support and construction vessels in the near-shore areas is predicted to be negligible given the low levels of light, the transitory nature of the disturbance and the distance from nesting beaches.

Lighting associated with the operation of the onshore facilities and marine facilities represents a source for potential impacts to turtles. However, there is no line of sight between the QCLNG Project and nesting beaches therefore the impact would only accrue to feeding or transitory animals. Potential light impacts to the local turtle population are considered to be negligible, given the disruption to a small portion of the population.

8.16.5 Vessel Interactions

The interaction between turtles and Project vessels has the potential to cause injury or mortality to individual animals via direct striking or entrapment/entrainment. The discussion in *Chapter 8.4* regarding patterns of vessel movements within Port Curtis is also relevant for assessing potential impacts to turtle populations. Likelihood of vessel-turtle interactions is considered to be low, however, in line with current best practice a range of mitigation measures are proposed to further reduce the risk of impact to turtles: These include the collision avoidance protocol presented in

Figure 5.8.19 and measures described in the Draft Dredge Management Plan (*Appendix 6.1*) which include

- Vessel speed limits will be applied to vessels operating within the construction area to reduce the risk of vessel strikes on marine mammals.
- During barge transport of dredged material, a lookout for marine turtles will be maintained by dredge crew. In the event that a marine turtle is sighted, the vessel speed and direction will be altered as necessary to avoid impact with the marine turtle (within safety constraints).
- Where practicable, barges will use consistent routes during offshore disposal.
- Adopt ''slow start'' procedure for dredges to alert turtles and potentially deter them before the cutter head is started.
- At times where the cutter head of the CSD is raised while the dredge pumps are still running (for example, during the line flushing as part of normal operations), the cutter head will remain operational (that is, this continue to rotate) to act as a deterrent to any marine turtles in the vicinity of the dredge and reduce the risk of entrainment within the dredging equipment.
- In the event that the dredging or spoil disposal activities result in injury or mortality to two or more marine turtles, a review of the current management measures will be undertaken in consultation with a marine turtle specialist to identify potential additional management measures.

8.16.6 Conclusions

It is considered unlikely that the QCLNG Project would lead to a significant impact on the turtle populations found in Port Curtis. This is because of the low level of disturbance likely to be caused by the Project and the separation distance to sensitive nesting beaches.

8.16.6.1 Ray-Finned Fish

A total of 33 species of syngnathid (seahorse and pipefish) were identified in the *EPBC Act* Protected Matters Report (see *Annex 5.3* of the draft EIS) and have the potential to inhabit the inshore environment of the Port of Gladstone. Syngnathids are occasionally associated with marine structures and potentially inhabit the seagrass communities within the Port of Gladstone.

Potential Impacts on Syngnathids

Underwater Noise

The capacity for hearing in syngnathids, is not well understood and there are no known audiograms of syngnathids. Many syngnathids have been documented to produce sound (loud clicks), suggesting that sound is important for communication in the aquatic environment[93] (The function of clicks may be associated with mating, to co-ordinate spawning or to advertise prey availability. Among these contexts, feeding clicks are the most widely noted. For two species of seahorse studied, peak frequency measurements were highest between 2,650 to 3,430 Hz for Dwarf seahorse (*Hippocampus zosterae*), and 1,960 to 2,370 Hz for Lined seahorse (*Hippocampus erectus*)[94]. The frequency of noise making suggest that hearing sensitivity is the greatest in the higher frequency ranges and, by extension that the least sensitivity is in the lower frequency range.

Syngnathids possess a swim bladder that is used for both communication and buoyancy. It is the swim bladder of the fish, which is a gas-containing organ, that will expand and contract with a rapidly changing acoustic field and as a result may cause physical injury. The important metric when determining syngnathid susceptibility to physical injury is its body mass, and hence the juveniles are most susceptible to physical injury from a pressure wave.

Using Young's[95] safety range formula and converting back to sound pressure levels, and a conservative value for a nominal body mass of 7 g, it can be expected that a SEL of between 198 and 203 dB re 1µPa^2.s will result in a 50 per cent risk of physical injury to seahorses and pipefish. By comparing this theoretical sensitivity to the results of the underwater noise modelling under taken for the QCLNG Project, it can be inferred that dredging and marine operations will not cause physical harm to syngnathids. Seahorse and pipefish within about 50 m of the piling operations may be at risk of physical injury. However the likelihood of syngnathidae species being in such close proximity to the piling operations is very low due to the unsuitable habitat in the areas to be piled.

Loss of Habitat

The distribution of the listed syngnathidae species has been determined based on occurrence within IMCRA bioregions as an indicator of whether suitable habitat is likely to occur in the Port Curtis area. The majority of listed pipefish are recorded to occur in reef areas, the exceptions being the Tiger pipefish, Short-bodied pipefish and Girdled pipefish, and hence are unlikely to be affected by Project-related impacts. Several of the listed seahorse species inhabit shallow seagrass ecosystems and consequently these species, and those pipefish that also inhabit seagrass areas, may be adversely affected by the direct or temporary loss of seagrass habitat.

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93 Bergert, B. and. Wainwright WC. (1997). Morphology and kinematics of prey capture in the syngnathid fishes Hippocampus erectus and Syngnathus floridae. Mar. Biol. 127: 563–570; Colson, D., Sheila P., Brainerd E. and Lewis S. (1998). Sound production during feeding in Hippocampus seahorses (Syngnathidae). Environmental Biology of Fishes, 51: 221-229; Ripley JL. and Foran CM. (2006). Differential parental nutrient allocation in two congeneric pipefish species (Syngnathidae: Syngnathus spp.) J. Exp. Biol; 209(6): 1112 - 1121.

94 Colson, D., Sheila P., Brainerd E. and Lewis S. (1998). Sound production during feeding in Hippocampus seahorses (Syngnathidae). Environmental Biology of Fishes, 51: 221-229

95 Young, G.A. 1991. Concise methods for predicting the effects of underwater explosions on marine life. NAVSWC No. 91-22. Naval Surface Warfare Centre, Silverspring, Maryland, USA. Cited in Keevin and Hempen (1997).

The total area of seagrass that would be directly affected is approximately 2 ha. Relative to the approximately 6,200 ha of seagrass meadows present within the Port Curtis area, the direct loss of seagrasses and the subsequent indirect effect on the populations of listed syngnathidae species in the area from the QCLNG Project is considered negligible.

Conservative dredged sediment dispersion modelling indicates that the indirect effects of dredging (increased levels of suspended solids in the water column) on seagrass habitat may potentially extend over an area of between 360 ha to 430 ha, depending upon the dredging methodology, but the loss of habitat within these areas will be temporary, and it is expected that seagrasses will regrow in these areas within one to three years of the cessation of dredging. The effect on any listed syngnathidae species is therefore considered minor.

Conclusions

The QCLNG Project is not expected to cause a significant impact on populations of EPBC-listed syngnathidae species that may be present in Port Curtis. This is because of the limited area of disturbance likely to be caused by the Project and because of the temporary nature of the disturbance.